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Advance in the applications of konjac glucomannan and its derivatives

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Abstract

Konjac glucomannan is a kind of neutral polysaccharides with excellent biocompatibility and biodegradable activities. The recent studies on the applications of konjac glucomannan and its derivatives in pharmaceutical, bio-technical, fine chemical fields etc. were reviewed.
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1. Introduction

Amorphophallus konjac K. Koch is a perennial herbaceous herb. It grows in mountain or hilly areas in subtropical regions mainly in the South East of Asia. It has been used as food and food additives in China and Japan for more than 1000 years. Konjac glucomannan is a component derived from the konjac tuber. Katsuraya et al. (2003) reported the recent study on the constitution of konjac glucomannan. The results of methylation analysis showed that the branching point is C-6 carbon of glucosyl units. ^{13}C NMR spectroscopy (1D and DEPT) of konjac glucomannan supported the presence of β-C-1-linked C-6 carbon of glucosyl units as the branching units. The ^{13}C NMR spectra indicated that the ratio of terminal glucosyl units to terminal mannosyl units is ca. 2 and branching frequency is ca. 8%.

Konjac glucomannan has the ability to lower blood cholesterol and sugar level, help with weight loss, promote intestinal activity and immune function etc. At the same time, this polysaccharide can be prepared into various derivatives easily because of its good biocompatibility and biodegradable activity. The deep development and exploits of konjac glucomannan and its derivatives have been paid great attention recent year. The Food Chemicals Codex only lists the current uses of konjac flour in the United States as a gelling agent, thickener, film former and emulsifier. However, the studies on the applications of konjac glucomannan and its derivatives have been extended greatly from food and food additives to various fields, such as pharmaceutical, bio-technical and fine chemical industry etc. The review summarizes the recent studies on the applications of this polysaccharide.

2. Applications in the pharmaceutical area

2.1. Drug delivery

Due to its biogradablility and gel-forming ability, konjac glucomannan can be widely used in drug delivery.

Wu and Shen (2001) invented a kind of konjac glucomannan capsule for chronic stomach disease. One gastric-soluble capsule for patient with chronic stomach diseases was prepared from konjac glucomannan, 0.4% vitamin B6 and 5% silicophosphate buffer.

Wang and He (2002) reported that a kind of alginate–konjac glucomannan–chitosan beads could be used as controlled release matrix. It was observed that KGM could be contained within beads, and faintness hydrogen binding and electrostatic interaction existed between ALG and KGM by infrared spectra. Clear dents were found on

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the surface of beads using KGM by scanning electron microscopy.

Hermelin and Grimshaw (2003) invented compositions and methods for the enhancement of iron uptake or the treatment of iron deficiency by enhancing the rate and extent of dissolution in a subject in need thereof. The composition contained at least two iron-providing materials in a single dosage form wherein at least one of the iron-providing materials contained a modified release mechanism, matrix, or coating. Konjac glucomannan was used as a matrix. The iron-providing materials included within the composition have different rates of release. Following administration to the animal, the iron-providing materials were released in the gastrointestinal tract over a period of up to 24 h.

Pathak et al. (2003) invented gel-forming macromers including at least four polymeric blocks, at least two of which were hydrophobic and at least one of which was hydrophilic, and including a crosslinkable group. Konjac glucomannan was used as a hydrophilic block. The macromers can be covalently crosslinked to form a gel on a tissue surface in vivo. The gels formed from the macromers have a combination of properties including thermosensitivity and lipophilicity, and are useful in a variety of medical applications including drug delivery and tissue coating.

2.2. Bio-adhesive properties improvement

Dettmar, Dickson, Hampson, and Jolliffe (2000) invented a kind of pharmaceutical composition having improved bio-adhesive properties, which was produced by combining an alginate, xanthan gum and/or a carrageenan gum and a glucomannan and/or a galactomannan. The composition can provide both a protecting and a healing effect on mucosal surface for treatment of disorders of the esophagus.

2.3. Cellular therapy

Slepian and Stephen (2001) invented a method for providing a synthetic barrier made of biocompatible polymeric materials in vivo that involved application of a material to a tissue or cellular surface such as the interior surface of a blood vessel, tissue lumen or other hollow space. The material may also be applied to tissue contacting surfaces of implantable medical devices. The polymeric materials composed of konjac glucomannan are characterized by a fluent state which allows application to and, preferably adhesion to, tissue lumen surfaces, which can be increased or altered to a second less fluent state in situ; controlled permeability and degradability; and, in the preferred embodiments, incorporation of bioactive materials for release in vivo, either to the tissue lumen surface or to the interior of the lumen, which alter cell to cell interactions.

2.4. Gel filler materials for prosthetic implants

A prosthetic device for implantation into a mammalian body comprised of a non-absorbable biocompatible flexible material shell or sac filled with various biocompatible gel filler materials. Ita and Clarke (2003) invented a gel filler materials that were comprised of biocompatible glucomannan obtained from konjac hydrocolloid flour and other biocompatible hydrocolloids, producing a natural look and feel for the prosthetic implants, especially reconstructive prostheses such as breast implants.

3. Applications in the biotechnology area

3.1. Materials for immoblization

Chen and Zhang (2000) provided a method for immobilization of cells using carrageenan and glucomannan. The composite for immobilizing cells was composed of 40–90% carageenan and 60–10% konjac glucomannan. The cell was immobilized by dissolving the composite in water at >80 °C, cooling, adding cells, and dropping into 2–3% KCl solution. The recombinant *Escherichia coli*, yeast, and *Bifidus bacillus* were immobilized using this method.

3.2. Materials for fixation support

Takezaki (2000) provided a patent about a fixation support agent with improved qualities so that a biopsy sample embeded in the agent was nicely thin-sliced with a microtome without destroying the cells on the cutting section due to the damage on the blade caused by the impurities such as husks or ashes of mannan contained in the conventional agent. The novel agent exhibited the improved agglutination force and transparency, and it was less stained with many kinds of staining dyes. The fixation support agent for biopsy sample consisted of a different type of modified derivative of glucomannan obtained from the refined flour of konjac (*Amorphophallus rivieri*).

3.3. Materials for encapsulation

Nussinovitch (2004) invented a temperature-stable droplet containing a temperature-stable hydrocolloid membrane. The membrane encapsulated a liquid that contained at least one enzyme, a cell, a biological agent, a pharmaceutical agent, an immunological agent, or mixtures thereof. Konjac glucomannan was used as one of the hydrocolloid materials. The hydrocolloid membrane encapsulating the liquid was a thickness capable of holding the liquid without bursting through a temperature range of about -20 °C to about 90 °C.

4. Applications in the fine chemical area

4.1. Films and membranes

Konjac glucomannan has very good film-forming ability. Several kinds of transparent blend films of konjac glucomannan with polyacylamide, gelatin, sodium carboxymethylcellulose, polyvinylpyrrolidone, chitosan, sodium aginate and cellulose, were invented, respectively (Xiao, Gao, Wang, & Zhang, 2000; Xiao, Gao, & Zhang, 2000; Xiao, Liu, Lu, & Zhang, 2001; Xiao, Lu, Gao, & Zhang, 2001; Xiao, Lu, Liu, & Zhang, 2001; Xiao, Lu, & Zhang, 2001; Yang, Xiong, & Zhang, 2002). The results indicated that the occurrence of intra and intermolecular interaction of the pure components, as well as the intermolecular interactions between KGM and these substance through hydrogen bond formation. The thermal stability and mechanic properties of both tensile strength and elongation at the break of the films were improved by blending konjac glucomannan with these substances. Some semi-interpenetrating polymer networks (semi-IPNs) from konjac glucomannan derivatives were also reported (Gao & Zhang, 2001a,b; Gao, Zhang, & Cao, 2003; Lu & Zhang, 2002; Xiao, Weng, & Zhang, 2002; Yang, Huang, Zhang, Zhou, & Gao, 2004).

Chen et al. (2003) prepared biodegradable plastics based on soy dreg (SD). For enhanced water resistivity of the SD plastics, thermoplastic benzyl konjac glucomannan (B-KGM) films were covered on SD sheets in a lamination compression process, and SD/B-KGM (SB) composite sheets were obtained.

Tang, Du, Zheng, and Fan (2003) reported soy protein isolate-carboxymethylated konjac glucomannan blend films. The thermostability and mechanical and water vapor barrier properties of blend films were greatly enhanced due to the strong intermolecular hydrogen bonding between SPI and CMKGM.

Li and Xie (2000) also reported a kind of edible membrane material made from the mixture of konjac glucomannan and xanthan, which showed better strength and water-resistance than konjac glucomannan itself.

4.2. Coating materials

In the patent of Yang, Yang, Petcavich, and Mao (2001), coating materials containing konjac glucomannan were invented for preserving fresh produce (e.g. cantaloupes, apples and the like). The coating composition was effective to control respiratory exchange, i.e. the passage of gases, particularly oxygen, ethylene, carbon dioxide and water vapor, into and out of the produce, thereby controlling maturation and ripening of the produce.

In the patent of Kawano (2001), rice grains were coated with a gel of glucomannan hydrate, and treated with heat to obtain grains coated with dietary fibers or irreversible gel. The product might be used in a variety of ways. For example, it could be cooked in conventional ways, manufactured as retort or pressurized food. The cooked rice grains were not readily disintegrated and made into gruel.

Yasuda and Kawamura (2000) invented steam-supplying food packaging materials for microwave cooking and cooking of food. The packaging materials, which release steam toward the inside upon microwave heating to steam food such as shao-mai, mantou (steamed buns), etc. had a steam-supplying material which comprised a shape retention material and a steam generator containing H_2O and a water retention agent such as konjac glucomannan, agar, carrageenan, gelatins, caseins, acrylic polymers, etc. contained therein or supported thereon.

4.3. Cosmetics

This field has been well studied in Japan. Omura, Shida, and Nanba (2001a) invented a hair composition containing glucomannan and/or keratose quaternary ammonium derivatives which provide excellent conditioning effect and moisture-retaining effect without causing stickiness, and some kinds of hair-styling preparations containing glucomannan with less stickness and giving natural gloss and smoothness to hair (Omura & Nanba, 2001a; Omura, Shida, & Nanba, 2001b–d). Some kinds of cosmetic oil-in-water emulsions containing konjac glucomannan were also invented (Omura, Abe, & Nanba, 2001; Omura & Nanba, 2001b; Omura, Shida, & Nanba, 2001e).

Takada (2000) invented a kind of water-insoluble glucomannan gel particles as mild scrubbing agents for cosmetics. The dried gel particles did not damage the skin and tooth surface. Therefore, they were effective as scrubbing agents.

Saito (2000) also invented a kind of cosmetics containing pigments coated with water-soluble glucomannan that showed good skin-moisturizing effect, give long makeup effect, and had no sticky skin feel.

The quick-drying disinfecting gels for hand were invented by Shimizu and Ohshiba (2000). The gels were obtained by mixing EtOH solutions with gel-forming polymers and glucomannan as a thickener. The gels were uniformly applied to hands and were removed by rubbing without rinsing with water.

Arminas and Calello (2003) invented an organic solvent based cosmetic remover composition which gelled to a viscosity of 25–500,000 centipoise with a synthetic metal silicate gelling agent. Konjac glucomannan could be used as the suitable gelling agents.

4.4. Emulsifiers and surfactants

Gan (1999) invented a new surfactant from refined konjac powder. Konjac glucomannan was hydrolyzed, oxidized, and esterified with stearic acid, then neutralized with NaOH. The final product can be used widely in pharmaceutical, food and chemical industry etc.

Four series of konjac glucomannan esters (KGME) of long fatty acid were also prepared by heterogeneous method (Tian, Dong, Luo, & Yao, 1999). Results showed that in the proper range of degree of substitution (DS), KGME had good emulsifying ability in O/W emulsion, even in high salt concentration and acidic pH. Clove oil–water (O/W) emulsion had good stability within four weeks at room temperature, and the breakage of emulsion was not brought about.

Ma, Wang, and Xu (1999) studied the emulsifying properties of isolated soy protein–konjac glucomannan conjugate. By comparing the emulsifying properties of the samples prepared with different buffers at various pH with that of the sample made in water, phosphate and acetate in the buffers were assumed to have catalytic function to the conjugation. The reaction was carried out with isolated soy protein to konjac in weight ratio of 1:1 presented the best emulsifying ability. The research suggested that the conjugate could be used as an effective emulsifier for O/W emulsions.

5. Applications in other areas

Besides the applications mentioned above, konjac glucomannan and its derivatives were also used in many other areas.

They can be used as biodegradable resin compositions (Tokiwa and Tsuchiya 2003), soil modifier (Wakisaka, Uda, Katayama, & Shimizu, 2000), soil amendment (Takada-Oikawa et al., 2000), and a surface size composition for the surface sizing of paper, board or other suchlike (Kimpimaki, Lindstrom, & Nurmi, 2001). Konjac glucomannan also can be used as fish lure (Igarashi, Saiki, & Yamada, 2001). In addition, konjac glucomannan powder can be mixed with powdery or granular charcoal and water and press-molded to charcoal shaped products having excellent properties in dehumidification, deodorization, sound absorption, and electromagnetic shielding and are suitable for building materials, water treatment, pet care products, health products, etc. (Morita, Niimura, Matsunaga, & Uhara, 2001).

6. Conclusion

Konjac glucomannan is a kind of polysaccharide with wide uses. Although they have been utilized and investigated for so many years, konjac glucomannan and its derivatives still need to be well investigated compared with other polysaccharides such as cellulose and starch etc. There are still lots of work to be done for understanding of this interesting polysaccharide and more promising products are waiting to be developed from it.

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