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Review of Food Nanotechnology in China

Nanotechnology, a multidisciplinary science, is a high-tech means of understanding, controlling, and operating materials at atomic, molecular, or supermolecular levels (1–100 nm). A development outline of nanotechnology from 2001 to 2010 has been formulated in China, and half of the provinces in China listed nanotechnology development in each of their eleventh "five-year plans." The consultancy firm Helmut Kaiser has estimated that the nanofood global market will reach $20.4 billion in 2010, and China will then become the biggest nanofood market in the world (1). In this column, I will provide a brief introduction to Chinese food nanotechnology.

Nanotechnology and Food Processing

Ultrafine powder, especially nanoparticles, is currently the hottest research area in high-tech fields. The surface area of a material can increase dramatically after it is treated by an ultrafine-powder process; the most common of which is ultrafine-powder milling. One food nanomilling machine, manufactured in Taiwain, can make a particle size of 100 nm through dry milling.

Zongcai et al. (8) described a highly pure, dietary cereal fiber nanoproduction method. They removed protein through extraction with dilute alkali and hydrolysis with α-amylase, then wet crashed the product into an ultrafine powder and homogenized it dynamically by hyperpressure at the nanometer scale. In the end, the final products were obtained by spray drying. The advantages of this invention were that a) nano dietary fiber was ready for dispersion, which was beneficial for absorption and bioavailability by the human body; b) the high-temperature treatment could not only inactivate enzymes but also eliminate bad odors, which made the product more apt to be accepted by consumers; c) the amount of dietary fiber with a particle size of under 150 nm could be more than 97%, which made the product feel smoother to consumers; and d) the production technology was simple and ready to be industrialized.

Yuan et al. (6) invented a new ball mill technology with multidimensional oscillating and multilevel grading capabilities that could produce powder with an average particle size of approximately 100 nm. They studied the temperature, moisture level, toughness, pollution, particle coacervation, particle size, and evenness of plant nanopowder during its production. They successfully developed a bioenrichment nano selenium tea and nano coffee with an average particle size of 100 nm.

A nanocollider was submitted for a patent in China, under a national program entitled "Torch Development," and the technical method went as follows. First, the liquid mixed with raw material was pressurized by a high-pressure pump. Then, it was divided into two jet flows at a high speed. Next, the jet flows entered into a channel composed of two pieces of monocrystalline diamond chip and outflowed after colliding against each other. Because of the high speed of the flow, when they collided, the interface produced a strong shock wave, thus energizing the diamond chip and producing a strong ultrasonic, high-frequency wave field. It could instantaneously make the processed particles dramatically change. Finally, the particles were crashed, dispersed, and emulsified. As the nanocollider converted the raw material into nanoparticles, the chemical components of the raw material did not change, therefore the product's nutrient value and bioavailability could be guaranteed after nanocollision (7).

Jianfeng et al. (2) used biocompatible polyethylene glycol as a carrier to inject fragrance into nanocapsules by melting dispersion. The fragrance-loaded nanocapsules were then able to rapidly dissolve in the aqueous solution. Their particle size was from 50 to 250 nm. Additionally, the loading efficiency of fragrance in nanocapsules could reach up to 98%. In addition, fragrances in the nanocapsules retained their particular fragrance for up to half a year.

Nanotechnology and Food Packaging

In the field of food packaging, nanotechnology can improve the properties of packaging material, prolonging its usefulness and realizing its antibacterial and ventilative properties. Compared with normal packaging materials, there was a remarkable increase in various physical, chemical, and biological properties, such as plasticity, stability, barrier property, antimicrobial ability, and freshness preservation.

Qiuhui et al. (5) described a related patent concerning the freshness preservation of green tea through nanopackaging material. First, 25–35% nanopowder, 50–60% plastic, 10–15% coupling agent, and 4–10% wax were blended for 0.5–1.5 h at high speed. The mixture was then kneaded in the extruder. Following extrusion, the extrudates cooled for 1–2 min and the master batch was finally cut from these extrudates. Afterward, a thin film was created from the mixture which had been blended fully from 30–40 kg of plastic particles and 1–2 kg of master batch particles for 0.5–1 h, meaning this thin film was human-made nanopackaging material. The green tea was packaged with this material, which could isolate the tea from oxygen, avoiding oxidation, and meanwhile, decrease the microbial pollution and moisture loss. This could also effectively inhibit the degradation of the chlorophyll, thus increasing the quality of the green tea.

Qingbiao et al. (4) invented a method of preparing a soluble silver nanopowder with biological materials. This method relates to using microbial cells as a reducing and protecting agent. First,

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a bacterial suspension was created by blending *Bacillus licheniformis* R08 and *Bacillus megatherium* D01 powders. Then, the bacterial suspension was mixed with sodium hydroxide and silver compound solution. After they had reacted for 2–30 h at 30–90°C, a mixture of microorganisms and silver nanocolloid was obtained. Among them, the ratio of mass content of dry microorganism powder to silver compound was 0.3:5 and the ratio of molar concentration of sodium hydroxide to silver was 1:40. The silver solution with biological materials was obtained by centrifuging the mixture and discarding the microorganism residues. The silver solution was evaporated, concentrated, and then precipitated by adding an organic solvent. After filtration and centrifugation, the precipitant was collected and vacuum dried at 30–60°C. Then the soluble silver nanopowder with biological materials could be obtained. The series of silver nanopowder not only had excellent heat resistance, light resistance, and chemical stability but also had a long antimicrobial period. If added to food, it could keep antimicrobial properties in effect for half a year. Meanwhile, it could accelerate the release of ethylene from vegetables and fruits, thus reducing the ethylene content in the package and achieving excellent freshness preservation.

Nanotechnology and Food Detection

A nanobiosensor has a bioprobe selectively combined with the target molecule at the nanometer scale. The combination of nanotechnology with biology and electrical materials could prepare a new biosensor element. For example, the integration of nanotechnology with a biochip could make the molecular detection more effective and convenient. Today, nanobiosensors are widely used in microbial detection for food safety in China.

Ling et al. (3) describes a method to manufacture a nanobiosensor that could detect reduced nicotinamide adenine dinucleotide (NADH) concentration. This invention took the gold nanoparticles immobilized on the surface of the sensor as seed crystal, utilized the principle of gold/silver core-shell nanoparticles growing under the catalysis from NADH reduction and the regularity of spectrum absorption changes, and calculated these changes to determine the concentration of NADH. The linear range of NADH concentration determination by this invention was 2×10^{-4} to 3.2×10^{-3} mol/L, the lower limit was 1.56×10^{-5} mol/L. Compared with present technology, the invention had many advantages, including convenience, low cost, and a strong capacity for resisting disturbance. It solved the problem of how to rapidly determine online the NADH concentration during the degradation of a complicated biological system or an environment pollutant. It also supplied a more convenient technology for measuring the activity of oxidoreductase with NADH as a coenzyme.

Issues on the Forefront of Food Nanotechnology in China

There are several nanoparticlization methods, such as ultrafine milling, spray drying, chemical precipitation, emulsification, supercritical carbon dioxide antisolvent techniques, etc., but these methods all have common problems, including uncontrollable particle size and distribution, no uniformity or roundness, unpredictable function of the materials, and instability of nanostructure. Meanwhile, the industrialization effect of nanotechnology is not good. Many nanotechnological items have a short developing time and lack a seamless connection between fundamental research and industrialization, thus the nanotechnological achievements can't be transformed smoothly. Currently, the production line founded in China mainly focuses on the aspect of nanopowder preparation with low technology.

Food nanotechnology theory and technologies have been studied deeply, including the mechanism of its unique function. Concomitantly, great attention was paid to the following aspects: developing healthy and functional food for the Chinese people, developing manufacturing equipment, solving production problems, transforming theory to production, etc. Based on the properties of different materials, the process techniques and the technical parameters of nanocomponents were selected. The growth kinetics of nanofood material and the stability of nanomaterials were also studied. The bioavailability enhancement, target transportation, and control release by nanofood and nutrients were then studied and large-scale production equipment was developed to produce nanofood and nutrients.

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