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Introduction to the Technology, Applications, Products, Markets, R&D, and Perspectives of Nanofoods in the Food Industry

– Review –

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Abstract

Nano is a unit that designates a billionth; accordingly nanotechnology could be described as the study and applications of the unique characteristics and phenomena of nanometer size materials. Applications of nanotechnology fall into two categories (one is top-down and the other is bottom-up). Currently, most products are the results of the top-down approach. Nanofoods have distinct functional characteristics stemming from the size, mass, chemical combinations, electrolytic features, magnetic properties of food sources at the nano level and which can be applied for safe absorption and delivery into the body. The greatest advantage of nanofood is that it permits the efficient use of small quantities of nutritional elements by increasing digestive absorption ability and by delivering natural elements without any change in their original characteristics. On the other hand, there are still unsolved problems, such as questions about safety and introduction of harmful material. The demand for new commercial food products is increasing, and commercial food producers are gradually combining nanotechnology and traditional food preparation methods. Nanofoods will improve our eating habits remarkably in the future. Tomorrow we will design nanofoods by shaping molecules and atoms. It will have a big impact on the food and food-processing industries. The future belongs to new products and new processes with the goals of customizing and personalizing consumer products. Nanotechnology is expected to be applied to not only foods themselves, but also to food packaging, production, safety, processing and storage. Also, it is believed that nanotechnology will be applied tracking finished products back to production facilities and even to specific processing equipment in those facilities. The aim of this study is the introduction of technology, applications, products, markets, R&D, and perspectives of nanofoods in the food industry.

Key words: nanofood, nanotechnology, functional food, health food, food industry

INTRODUCTION

It has been predicted that in the 21st century nanotechnology will change our lives, because nanotechnology is already rapidly permeating our daily lives through products such as pharmaceuticals, cosmetics, fibers, computer chips, etc. Experts have estimated that the size of nanofood market in the USA will increase from $ 2.6 billion in the year 2003 to $ 7.0 billion in 2006 and $ 20.4 trillion in 2010 (1-8). At that time, nanofoods are expected to form a huge market, being consumed by half of the population of the world, hence, global food companies are competitively investing in nanofood R&D. Furthermore, every nation that recognizes the potential of nanotechnology sees the development of nanofood technology as a national priority, supports the development of the nanotechnology in their country, and have established national strategies, and systemized policies to pursue nanotechnology efforts on a large scale at the national level. In this competition, the USA leads, followed by Japan, China and Germany.

The Korean government also recognizes nanotechnology as the next generation growth industry, and invested 1.2 trillion Korean Won, and the department of Health and Welfare announced a plan to invest in a large scale 164 billion Korean won program through 2010 (9-12). Nanofood technology has the potential to elevate conventional foods to the status of health and functional foods. However, most nanofood manufacturing, except at a few advanced companies, presently remains at the level of assessment of its application and is usually limited studies of microencapsulation to obtain a micro unit. Because the manufacturing methods of nano materials for food applications are still in the devel-

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opment phase, safety of these foods and the presence or absence of residual toxic materials, are still not well understood and need to be assessed (3,4,13-23).

In Korea, techniques that could grind from a micro unit to a nano unit have been developed, nonetheless, that is only one aspect of nanotechnology, and to realize the dream of widespread commercialization nanofoods (including all food industry such as packaging materials, nano bar code, screening of harmful factors, etc.), much preliminary work remains to be accomplished (18,24,25). In addition, another concern about nanotechnology is that as a new horizon of "cutting edge" scientific technology, it may be at greater risk of using other newer and high risk technologies such as GMO foods. Nobody is sure of the effects of having a substance smaller than micron size, and what various physical and physicochemical properties will appear; the effects on the human body can not be predicted (7,26-28).

If the advantages of nanotechnology can be exploited while minimizing the shortcoming, food production and science would be greatly changed forever. Nevertheless, without procedures in place that accelerates the development of nanofood technology systematically and organically, with pertinent studies covering a wide range of issues, the application of nanotechnology to food industry should not be considered as a rosy dream.

WHAT IS NANO?

Definition of nano

The first words appear upon hearing nano are up-to-date, engineering science, silver nano, etc. which give an impression far away from food. Such nano became a subject of discussion in food industry recently, since functional nanofood that grafted nanotechnology to food science that has been remained at the level of the size of micro (1/1,000,000) may generate high additional values. Nano is a unit that represents 1/1,000,000,000 that is originated from the Greek word nanos (dwarf). One nanometer equivalents to 1/100,000 of hair thickness, and reducing the earth where we live to this ratio, it becomes the size of a 100 Korean won coin, which shows how small it is. The person who suggested the nano field for the first time in the world is Richard Feynman who received the Nobel prize in physics in 1959. He revealed that to pile up atoms one at a time and to assemble according to a blue print, it would be possible to produce all materials and equipment (29,30).

However, other scientists at that time criticized it as an impossible dream and ostracized him. Subsequently, 30 years later, Eric predicted that nanotechnology would change all life of human beings such as health, food, etc. in the 'Engine of creation' (6,31), and in 1998 the term nanofood was first used by Kim in various research reports pertinent to food and defined the term (18,19,24, 25,32-38).

Nanotechnology

Nanotechnology refers to all techniques that find particular characteristics of materials in nano size, arrange and combine nanos, and produce materials with very useful properties or systems. The methods of producing nano materials that have been developed until now are represented by the dry process that utilizes burn, explosion and shock wave and the wet process that utilizes the sol-gel-process, practical application of supercritical fluidic system, chemical reaction, solvent dispersion, participation, vacuum-metallize, organic solvent, etc (8,38).

The gist of nanotechnology is that by manipulating atoms or molecules to produce novel materials or systems with entirely new characteristic and function. In addition, by manipulating a material at the nano level, without changing the chemical characteristic of previous materials, the expression of new characteristics that could not be shown at the present micrometer level becomes feasible, and through this, its physical, chemical, electrical, mechanical characteristic and function are improved noticeable. Nanotechnology that was accelerated by the development of scanning tunneling microscopy (STM) that could view the atomic world in 1982 and atomic force microscope (AFM) that could directly move atoms and molecules in 1990 predict the third industrial revolution presently (6,31).

Presently, the field of nanotechnology as understood worldwide is shown in Fig. 1.

Nanotechnology approach methods

Presently, we accept the will of the miniaturization of materials almost as natural. The vacuum style chips

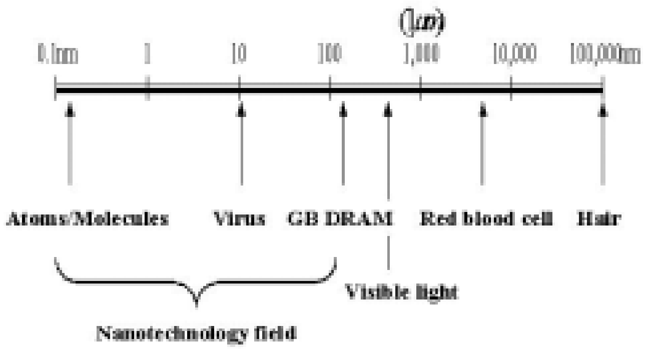

Fig. 1. The nanotechnology field.

that occupied almost an entire room were evolutional to a microchip with the width of a human nail. The methods to produce small materials are two procedures (5,6,8, 16,31).

1) The top-down method: The method of cutting big materials and thus dissecting to small materials.

2) The bottom-up method: The method of assembling atoms or molecules as lego blocks and producing minute nano size structures.

The top-down method is applied in physics and engineering such as non-photo (photolithography) in the microchip manufacturing process. In other words, it could be understood more readily as if the NEMS (Nano Electro Mechanical Systems) of microchips. It is a traditional method that divides continuously, it could control even the nano level, and its accuracy is superior, nonetheless, it requires big equipment, hence, its starting cost is high. The bottom-up method is initiated by IBM writing the word IBM with each atom using scanning prove microscopy (SPM). This method becomes the detonator of the reality of nanotechnology, nonetheless, it has a long way to go to produce required structures with present techniques. In addition to these two methods, a method is to produce desirable structure by applying the self-assembly property of the biological system, and it is very difficult by current techniques, nonetheless, it is predicted that if succeeded, it could bring substantial waves in manufacturing processes (39,40).

Most nanotechnologies that are currently usable by humans use the top-down method with a few exceptions; in contrast, cells have operated the living phenomenon as the bottom-up method from time immemorial. Atoms and molecules are like lego blocks that nature uses to produce something. Upon the development of nanobiotechnology, minute lego games could be played by mimicking the nature. Such technology could be applied to food industry, and in the near future, cleaner, more effective, smaller portions, and more precise functional food that are highly tailored to individual constitution may be available.

Specialists predicted that in the future, in food industry, the areas that nanotechnology could be applied to consists of approximately 180 types, nevertheless, few areas are utilized in its production presently, and in the future, nanotechnology may cause a diastrophism in the field of food industry (8-10,12,24,25).

WHAT IS NANOFOOD?

We started to use the term nanofood for the first time in the world by reporting functional food that grafted the above mentioned nano unit technology to food processing in various research reports pertinent to food from 1998 and defined the term (18,19,24,25,32-38). Defining this as two types, "nanofood is a new approach method in the quantum mechanics field that has been ignored by traditional food science and the size, mass, chemistry, composition, electric, electronic, magnetic property, etc. of food materials are analyzed at the level of nano unit, and by applying them, food could have the function that could more stably absorbed and transduced to the body", and described more in detail, "nanofood could be considered as functional foods that are produced by the technology which establishes and designs the system in the nano technology field and thus produce useful materials or the techniques that produce new materials by utilizing new properties and phenomena". Therefore, nanotechnology applied to food field is an ultra micro technology at the level of molecules and atoms, which could change food science that has been discussed at the micro level to a completely different characteristic that could not be predicted, hence, in developed countries, researches applying this technique are actively ongoing.

The nanofood technology that is most rapidly spread recently in the food-processing field is the production application utilizing the nano particulation technique. In other words, nanofood presently under development or commercialized is food produced by the application of the top-down nano technology to natural materials in most cases (18,19,38).

Most biological phenomenon could be considered to be generated at nano units. Nucleic acid and protein as are nano-constituents of our body as well as various nutrients are produced by the consumption of food and the degradation as well as the synthesis in the chemical factory the digestive system, and they are the best natural nanofood raw materials composed of important nanocomponents exerting biological functions, and human cells could be considered as a true 'nanofood processing factories'. In addition, human cells have operated living activities at the nano level for a long time from time immemorial (32,34,41).

Enzymes treated nutrients as the nano unit, the size of protein is approximately 30 nm, and amino acid is approximately 0.5 nm. A single layer of cells forms capillary blood vessels, and the connection areas of cells contain minute blood vessel holes. Although the size of these holes has deviations depending on tissues, it is approximately 200～600 nm, and through these holes, nutrients and leukocytes migrate (42-44).

The food processing technology until now ignored the absorption in the body in some aspects. Actually, nutrients that have not been degraded sufficiently by digestive enzymes can not be absorbed in the stomach and the intestines. The absorption rate of minerals such as calcium that could be originally difficult to be dissolved is very low in comparison with the intake amount. Particularly, iron deficiency is related to the chewing habits of individuals, hence, it is important to swallow after chewing sufficiently. Nonetheless, even if chewed well, from the point of the view of cells, they are still a huge mass. The food most likely to be developed to maximize absorption rate and to deliver nutrients to each organelle of cells is nanofood (21,45). It is considered that by applying nanotechnology to food, the utilization of the entire food, not a portion of the food material consumed, which has been difficult previously becomes feasible, the food processed by chemical treatment or heat treatment could be consumed as raw food itself, and it allows to endow specific properties to special nutritional components. In addition, it is predicted that by manufacturing nanocapsules, not only its spoilage could be prevented, but also controlled delivery to major action areas in human bodies may be feasible (3,4,13-23).

The advantages of nanofood

The greatest nutritional advantages of nanofood are that due to the increase of digestion absorption rate, natural original components of food could be delivered to human body without changing its characteristic, and the effective use of nutritional components with a small amount is feasible. It could have such advantages because nanotechnology increases the solubility and thus the rate of the usage in vivo could be raised maximally. This is possible as nano particles have the duo-solubility both in water and oil (46,47). In addition, regarding nano nutrients, its surface is increased hence it receives the action of digestive enzymes abundantly, and it has the duo-solubility in water and oil, and thus in vivo utility rate is elevated several times, therefore, it could mediate sufficient effects in small amounts. Such advantages when applied to expensive functional food-*phellinus linteus*, *Agaricus blazei* Murill, red ginseng, could be developed into a higher value added industry (48-50).

In addition, nanofood has the advantages that could save the resource of food, it does not have the waste, it has the effect on energy saving, and it does not use chemical solutes (51).

Shortcomings of nanofood

As nano technology could solve problems which have been difficult to resolve previously such as the increase of surface area, easy to drink, reduction of precipitation, homogenization of particle size, improvement of absorption rate, non-heating sterilizations, therefore, it began to be applied to the development of products in health food and other food field, nonetheless, if several types of heal food materials become nano, it has the shortcoming that the characteristic of the materials is altered. For example, if the absorption rate of the materials was greatly improved, health foods which function as borderline as medicines with vague uses may be developed, the phenomenon of nano modification of beans elevating its sugar level, etc (52-54). In addition, due to the characteristic of food composed of organic materials, the distribution of components is complex and the possibility of its alteration by external environment is large, and thus it is very difficult to change nano sized modify food materials (55,56).

Nano products that are popular nowadays use almost several many thousands of nanoparticles in most cases. The general pattern is to grind gold or silver particles to small pieces and attach to the product surface, filters, etc. Of course, its function and effectiveness have been proven in many cases. However, it appears that not all of them mediate their function properly and exert their effect, and particularly, many areas such as whether it is safe in humans, it causes harms to the nature, etc. have not been validated yet (18,57).

Defining nanofood as "that has been overlooking by traditional food science, to analyze-apply the size of food materials, mass, chemistry, composition, electric, electronic, magnetic, etc. at the nano level and to alter them to functional food is similar to produce a new material", the effect of materials that have not been found in the nature on food supply and environment could not be assessed, hence, it requires substantial studies to demonstrate the safety of nanofood (37,38).

THE TREND OF THE DEVELOPMENT OF NANOTECHNOLOGY

As the width of its application and indication becomes limitless to physics-chemistry-electronics-biotechnology-energy-environment and as its ripple effect becomes enormous, nanotechnology became the next generation key technology. Consequently, in developed countries such as the USA, Japan, etc., a focused investment at the national level has been made, and in Korea, aiming to become one of 5 leading countries utilizing nanotechnology, in 2001, the nanotechnology comprehensive development plan invested in focused research and development for the next 10 years has been reported. In addition, in August 2005, the nanotechnology material field was chosen as the future national potential technology field, etc., and the development of nanotechnology has been promoted at the national level. Korean government also recognized nanotechnology as the next generation industry, and until 2005, 1.2 trillion was invested, and the department of health and education reported the plan that the large-scale 164 billion won would be invested until 2010 (9-12).

According to the patent office data, the number of applications for patents pertinent to nanotechnology reached a total 3,012 cases during the period of 6 years and 8 months from 1999 to August 2005, and among them, Koreans submitted 2,540 applications, 84.3%, and foreigners are 15.7% 472 applications. After the announcement of the comprehensive development plan for nanotechnology by the Korean government in 2001, it showed a rapid increase in 2002 by 42.3% in comparison with the year of 2001, and the year of 2003 and 2004 by 69.4% and 71.4% in comparison with the previous year, respectively, which suggests the heat on nanotechnology in Korea (58,59).

The current situation of the application based on international patent classification (IPC) is as follows. IPC is the classification criterion that is common to the entire world including Korea, the USA, Japan, etc., and it is a classification method that inventions applied for patent are classified depending on their technology field, the total technology field is classified as 8 fields, and thus again subclassify sequentially. It was analyzed that among a total of 2,547 cases applied for from 2002 to August 2005, in the field pertinent to pharmaceuticals, cosmetics, etc. (A61K), 653 cases which was 25.6% were applied, and in the field pertinent to nanostructure, etc. (B82), 548 cases which was 21.5%, the nano material pertinent area, etc. (C07·C08·C01) was 521 cases which was 20.5%, followed by the field pertinent to computer chips that is the nanotechnology application field, etc. (H01) was 480 cases which was 18.8%.

The viable number of application pertinent to the food field could not be seen yet, nonetheless, it is anticipated to be increased gradually in future. In Table 1, patents pertinent to nanofood were briefly summarized. Nanofood materials that nanotechnology is grafted could be used as food, health & functional food and materials for traditional medicine & cosmetics. In regard to food materials, by the nano modification of raw food materials, etc., it could be applied as food for patients with deteriorated digestive absorption, and as health functional food materials, all useful components of red ginseng, mushrooms, herbs, etc. could be contained. As materials for herbal medicine, it may allow the standardization and modernization of herbal medicine, and it could be used as cosmetic materials by the nano modification of natural cosmetic materials and thus increases the absorption rate by the skin.

On the other hand, nanotechnology provides a new paradigm on biotechnology studies, in other words, the effect of nanotechnology on biotechnology could be seen clearly by the example of biochips in the bionano area. Biochip is one of mixed small molecules that are produced by combining enzyme·protein·antibody·DNA·microorganism·cells and organs of animal and plant·neurons and other organic materials derived from living things, chips, and inorganic substances and producing as conventional chip patterns.

The miniaturization of biochips may lead to the result of the reduction of biochip cost, reduction of the use of expensive reagents and experimental chemicals, improvement of reaction rate, improvement of the accuracy of the evaluation of analysis, the possibility of combining several functions in one chip, improvement of the result rate, high treatment rate, etc. Such biochips also mediate an effect on food industries, which could be seen in Table 2 that summarizes the industrial application of bio-

Table 1. A related patents of nanofood

Application number	Applicant	Invention title
10-2004-0065666	NT&B Co. Ltd.	Method for preparing food materials, healthy functional food materials or herbal materials to nanoparticle and composition comprising thereof
10-2005-0065126	Keun-Ho Park	Manufacturing method of wheat flour using nano silver powders
10-2004-7014857	Eugene Science Co. Ltd.	Plant sterol-containing food, and method for preparing the same
10-2004-0062150	Il-Keun Roho	Extraction method of β-glucan from *Sparassis crispa* Wulf. ex Fr. through nano knife and low temperature extraction method
10-2003-0009941	Dong-Myong Kim	Anti-obesity constituents contained natural dietary fiber and functional ingredient, and dietary supplementation food made by using it as the effective component
10-2003-0021447	Mijitech Co. Ltd.	Gum added nano-Ag-Particles and manufacturing method thereof
10-2002-0064416	Woorim Land Co. Ltd.	A composition of nanosphere comprising propolis and tocopherol

Table 2. Industrial application fields of biochip technology

Industrial field	Application examples
Food and biological process	Food safety test, Diagnosis of animal and plant diseases, quality control of meat/agricultural products, Bioprocess measurement and control system, Biomass production system, etc.
Health and medicine	Blood tests, DNA analysis, Human Genome Project, Proteomics, Self tests (blood sugar, HV etc), Medical diagnosis reagents/kit/sensor etc.
Environment	BOD sensor, monitoring of water quality and ocean pollution, Detection and analysis of pollutants, detection of heavy metals/toxic waste, detection of dangerous materials /biochemical weapon, etc.
Precision chemistry	Development of physiologically active drug materials, production of cosmetics, enzymes and Chemical reagents, production and analysis of pesticide, etc.
Information and electronics	Home appliances, Biometrics & security system, Virtual reality system, Bio-electrons, Bio-computer etc.

Table 3. The advancing direction of food grafted nanotechnology

Classification	Required technology	Product groups
1st stage (~2006)	A the HTS level, in vitro/in vivo assay, in vivo mechanism, Bio-transformation technology and Bio process, Effective & Enzymatic method and synthetic technology, high separation technique, etc.	Antioxidants, Constipation-improvement foods, Fatness-prevention foods, Brain-nutrition foods, Anti-aging foods, Immune-control foods etc.
2nd stage (~2010)	Novel assay system, Nutraceutical delivery system, Ultra separation technology, Activation of high molecules, Molecular genomic, Delivery systems, Medical substitution foods etc.	Food improving bone and joint diseases, Food improving the prevention of stroke, Food preventing dementia, Food preventing cancer, etc.
3rd stage (~2020)	Nutrigenomics, High throughput genomics tool, High-density microarray analysis.	Vegetables preventing diseases, personal individualized food, non-allergic dairy products, design of physiologically active materials, etc.

chip technology (10,60).

It appears that rapidly growing nanotechnology requires the application technique at each level, and upon the achievement of such gradual technological development, ultimately, nanofood that we are seeking could be applied actually (Table 3).

Conventional nanotechnology is the traditional top-down method that remains at the level of micro-machining and miniaturization of chips, hence, the possibility of obtaining original patent is small. In contrast, the revolutionary top-down method that grafts the top-down process and the bottom-up process overcomes technical limits and controls material synthesis, and thus patents for original technique could be obtained and achieve the ultimate aim of nanotechnology (9,12).

THE CURRENT SITUATION IN KOREA

Presently, nanotechnology applied to food is nanoparticles and microencapsulation technology, and research and development on new functional food materials with applications for both function and for improved production processes are actively ongoing. Nano particle technology could develop more functions, nevertheless, unknown functions may be newly discovered. The taste, color and viscosity of functional materials are used directly to special processed food (3,4,13-23) and thus causing numerous problems, and a technology to solve such problems is encapsulation. The diameter of capsule becomes smaller from few hundreds micrometers to few tens nanometer, and the absorption and usage rate in vivo is very high, and the choice depending on their function and aim such as the slow release of functional materials in a desired area is possible (Fig. 2).

Drink products such as yogurt using nanocapsules and general food material particles ground to nano sizes and thus their dispersion is increased and absorption is improved began to appear.

Oyster or eggshell contains abundant calcium, however, it is difficult to be digested by human beings. Therefore, in the nanotechnology field, studies on the process of such hard food materials to calcium powder and its application as an additive of various foods are actively ongoing. On the other hand, mid size and small companies are conducting studies on various functional health foods using the antitoxic action of silver and gold primarily. Examples of recently developed nanofood materials or nano products applied to industries pertinent

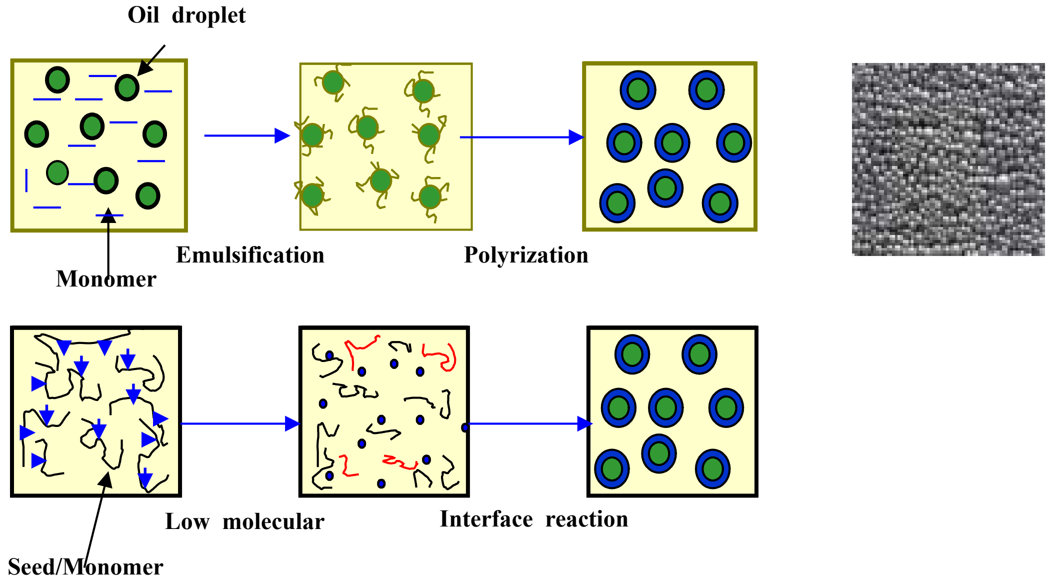

Fig. 2. An example of the manufacturing of nanocapsule.

to food are diet food (green tea leaves and silk peptide) (17), anti-bacterial refrigerator (silver nanoparticles) (33), ginseng processed food (35), PET bottle (16), functional drink and food (18), immune enhancer and regulator (germanium, mineral nano powder) (59), natural aroma (16,18), gold and silver nano colloid (33,35), etc.

Nanotechnology is anticipated to be applied widely to food packaging, production, safety, process, storage, etc. in future. Presently, food to which nanotechnology is grafted is on the development stage, and currently commercialized products are nano powder that grind technology is grafted in most cases.

Seoul National Univ., Medical College and Aminogen Co. Ltd. had been built the 1st Institutional GMP facility in Korea from 2002. Several provincial governments are of great interest for Bio-Cluster of Nanofood products; Daegu Bio Industry Center (www.tbic.or.kr), Chungbuk Osong Health Industry Center (www.cbhic.or.kr), Marine Biotechnology Center for Bio-Functional Material Industries (mcbi.silla.ac.kr) and Gyongbuk Institute for Bio-Industry (www.gib.re.kr).

Eventhough the slow start of Sagra-Queen Gold® the fact that ~70,000 customers have already been used with Sagra-Queen Gold® is encouraging. The estimated private investment for these companies exceeded to ~70.0 billion won (US$ 70.0 million) for last three years. Three venture companies have been publicly listed on KOSDAQ and outside the exchange market.

We are glancing the recent situation of research activities and commercialization in the area of the nanofoods in Korea concisely. Nanofoods remains a dynamic and growing universities, institutes, private sector, and pre-market enterprise like a melting furnace. It will be steadily and continuously increase the engagement of scientist and staff, the supporting of research fund and the investment from private company in Korea, eventually, to prolong and improve the human lives. Even though the fundamental of research and industry field for nanofood looks like a baby right now, it enters an adolescence era through the development of new technology, innovative idea and venture company in the near future in Korea.

THE CURRENT SITUATION IN OTHER COUNTRIES

According to the estimation of specialists, the market size of nanofood in the USA would be from $ 2.6 billion 2003 to $ 7.0 billion and $ 20.4 billion 2010 (1-8). At that time, the nanofood market will have become a huge market involving half of the population of the entire world, therefore, global food companies have been investing in R&D of the nanofood field. Furthermore, each nation that recognized nanotechnology as the industry leading the future growth of the nation, with the widespread belief that the future economic growth of the nation is dependent on maintaining a leading place in nanotechnology, and to support the development of nanotechnology, national strategies have been established, the policy to carry out them has been systemized, and all efforts to support in a large scale have been made at the national level.

The USA leads this competition followed by Japan, China and Germany. Because of the huge potential of nanotechnology, more and more competitors enter the nanofood market. The prediction is that by 2010, the number of competitors may be increased to several thousands. To secure the international technological leadership by the development of original technique, in 2002, the EU chose nanotechnology as a focused research and development subject in the '6th Framework Program' started in 2002, and between the year 2002～2006, 1.3 billion euros have been invested. In the USA, the Clinton Administration announced the National Nanotechnology Initiative (NNI) in January 2002, pan-government research and development policy on science and technology pertinent to nano is ongoing (20,61,62).

In Japan, in September 2001, the promotion strategy of the nanotechnology material field has been firmly established and thus the development of nanotechnology is pursued as a national tactic, and government research institutions and big companies in collaboration have carried out the programs performed by the government. However, the investment on nanotechnology pertinent to food is meager.

The giant company, Kraft Foods with annual sales of US$ 34.0 billion, inaugurated a consortium in the year of 2000 and focused its business on the nanofood field. Products that are under development by the Rutgers University, USA, is the nutraceutical delivery system that applies proteins used to deliver drugs to a specific site of the body, and it has the function of warning consumers the initiation of the decay of the inside of food by changing its color (38). In addition, in Japan, products produced from mushrooms ground smaller than 100 nm in size, almost all nutritional substances are absorbed by the nanospheres in the small intestine 100 nm in size, and increase the nutritional absorption rate by the human body was increased have been introduced (62).

Some companies in the world are already aware of the impact of nanofood industry around 2001. Research facilities are established; potential nanofood applications are standard food, nutrition food, nutraceuticals, food supplements, functional food, dietary food etc., whereas only a handful of nanofood products are market available now.

Examples of recently developed nanofood products applied to industries pertinent to food are diet food (Queen Diet® of Chongqing Kerun Biopharma Co., Ltd., China), ginseng processed food (Mountain Ginseng® of Backsan Food Co., Ltd., China), functional drink and food (Achito-D® of Yamasita Food Co., Ltd., Japan), immune enhancer food (Pinky-Mineral Nanopower® of Guten Food Co., Ltd., Germany), jointfood (Nano Glucosamine Gold® of NBI Co., Ltd., Japan), gold and silver nano colloid processed food (CoQ10 Gold® Sino Biotech Ltd., USA), chito-oligo and chitosan colloid processed food (Nanochito Oligo Gold® Nanochito Ltd., USA), etc.

Nevertheless, the tremendous potential will attract more and more competitors into this still unplugged field. The number of the companies involved in this field will increase from 69 in 2002 to 2004 and to several thousands by 2010.

CONCLUSION

Upon the increased interest in health, not only health functional food but also foods in general, as functional mediators have had a great influence on product development. Because the prevalence of adult diseases due to excess nutrition and bias due to the conversion to the meal pattern of developed countries and the lack of exercise became a social problem, and upon entering to the aging society, the demand of consumers for the quality of life has been elevated greatly. By the legal purpose of establish a law, health functional food is in the stage between foods and medicines. In future, such trends will be continued and thus the borderline between food, health functional food, and medicine may become gradually blurred.

Nanofood technology could elevate more general foods or traditional food to the rank of health-promoting functional foods. For example, flavonoids contained in green tea have the beneficial function of preventing the aging of cells from oxidants, however, unfortunately, it is sensitive to heat as well as it is poorly soluble in water, and it dissolves well only in organic solvent. Nano modified nutrients acquire the property of dissolving in both sides, hence, it could be used as a good method to solve such problem.

The case like nanotechnology that has been widely recognized by the general population is hard to detect. This is because the USA and other developed countries consider nanotechnology as the key technology in the 21st century and thus accelerate the development of nanotechnology.

The ripple effect of nanotechnology on other technologies is very huge and in addition, its additional value is great, several countries in the world such as the USA. Japan, and other technologically advanced countries are conducting numerous researches to become the leader of this field. Developed countries to maintain their current position, and underdeveloped countries suffer from depopulation not to be isolated from the new scientific technology paradigm nanotechnology.

In the 21st century, nanotechnology will change our lives. Because nanotechnology permeates rapidly to pharmaceuticals, cosmetics, bio, textile, chips fields and other our routine life.

This technology that would bring a great change in food industries uses the resource less and generates a larger usefulness, and thus it has the effect of saving the resource. Even now, 14% of the population in the entire world is suffering from hunger, and approximately 20,000,000 persons die of starvation annually. From the year of 2010 when nanotechnology would be generalized, the death caused by starvation may disappear. In addition, during its manufacturing process, chemical extraction solution is not used, it uses less energy, and it does not produce a waste, hence, it is also a good method for the protection of the ecological system.

However, currently, manufacturing of nano substances in food industry remains at the level of the reviewing of its application, and except in a few developed countries, most large companies conduct research primarily only on microencapsulation in micro units. Because to be able to apply the manufacturing method of nano substances developed until now to food, the status of their safety, the presence or absence of residual toxic materials, yields, etc. have to be considered. Recently, the USA, Japan and Europe consider nanotechnology as the competition arena of new technology and thus a huge investment was poured, nonetheless, in some part of the science field, opposing opinions comparable to the limitless benefits have been raised. In addition, it has been also viewed to contain processed hazardous materials like Genetically Modified Organisms (GMO). Because, if the size of particle become smaller than micro, various new physical & chemical properties appear, and its effect on the human body can not be predicted. However, individuals paying attention to the potential of nanotechnology anticipate that this technology may revolutionize medicine as well as the electronic engineering, computer engineering and other comprehensive fields. Therefore, it is certain that by the more development of its advantages and the compensation of its shortcoming, nanofood grafted nanotechnology could greatly change the area of conventional food or traditional food.

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