

TECHNOLOGY DEVELOPMENT FOR THE FOOD INDUSTRY: A CONCEPTUAL MODEL

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Abstract: The information available on high technology in food industry is systematized. Different approaches to the development and integration of scientific knowledge are discussed. According to the European Institute for Food Processing (EU-IFP), there are three possible areas where a breakthrough in food science can occur: biotechnology (BIOTECH), nanotechnology (NANO), and information and communication technology (ICT). A transition is expected of high technology in food industry to convergent technologies in a combination with cognitive science (COGNITIVE). The four components of high technology are analyzed using food industry examples. We believe that the transfer of scientific knowledge into food industry can facilitate the technological development of the Russian agroindustrial complex.

Keywords: high technology, convergent technologies, food industry, biotechnology, nanotechnology, information technology, cognitive technologies

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INTRODUCTION

The modern pace of scientific progress and the generation of new ideas breaks ahead of their practical application. Scientific findings in various areas of knowledge, including in food industry, do not get a chance to be transformed into a new technology. Thus, the development of a conceptual approach to the implementation of new discoveries in industry is required. The term *high technology* (*high tech/hi-tec*) dates back to the 1950s, when it was used initially in atomic energy research [1]. Later it found use in research papers on economics and finance [2]. In 1971, Robert Metz abbreviated it to *high-tech* [3, 4]. The term was used to denote the leading technologies of its time. The branches of industry that are most dependent on science are usually labeled high technology. According to the presentation (<http://www.highte-cheurope.com>) of the first European Institute for Food Processing (EU-IFP), there are three subdivisions of high-tech: biotechnology (BIOTECH), nanotechnology (NANO), and information and communication technology (ICT).

The project leading to the establishment of the EU-IFP was named HighTech Europe (HTE). It was a joint initiative of European research institutions and industrial associations. This project can be seen as a new era in the history of food industry; it will promote research and development needed to establish a lasting integration of scientific findings with experimental engineering and/or technological developments and the subsequent transfer of knowledge from scientists to industrialists. What are the strategic areas of development in food industry?

The core of the development of HighTech in food processing is the presence of an *lighthouse watcher*, or the principles of evaluation and description of food industry to create a comprehensive database. The

objective is to combine the potential sources of innovation with the needs of the industry, keeping in mind the ethical and social dimension. The lighthouse watcher comprises the following building blocks: scientific knowledge, the needs of the industry, personnel policy, and a sustainable development plan.

Scientific knowledge is a key factor in the development of HighTech in food industry. The three main blocks within the project (BIOTECH, NANO, and ICT) will determine the development strategy for food processing. These areas have the greatest innovation "strength" and are a promising source of the future high-tech food production. The strategic goal is to link together a chain for the transfer of HighTech knowledge, which can lead the way into the future of food industry. The structure combines scientific knowledge (universities) with intermediate centers and/or high-tech pilot institutions that can transfer technology to private entrepreneurs through regional organizations and industrial associations.

We think that this list is clearly lacking the *membrane technology* (MT), which has literally "broke into" food industry, e.g., dairy production, in recent years. It should find a proper place among high technologies, at least along with bio- and nanotechnology, or as an indispensable part of the latter (biomembrane and nanomembrane technologies). Being naturally connected with them, the MT can also be interpreted and viewed (used) as a nanobiomembrane technology. This is the exact direction taken by the members of our leading federal research school 7510.2010.04 Living Systems. By the way, the same route is followed by many teams at research institutes of the Russian Academy of Sciences and higher education institutions. A good example is Kemerovo Technological Institute of Food Industry (KTIFI), which

has successfully systematized virtually all the branches of food industry for Siberia and Central Asia.

Anticipating the development of high-tech, the US National Science Foundation and the Department of Commerce named the new technologies *convergent technologies* [5, 6, 7]. Cognitive research (COGNITIVE) compliments to the three research areas listed above. The convergence of technologies is reflected in the increasing interdependence of the four fields and their combined influence on society. Cognitive studies play a systemic role in the convergence of technologies; i.e., they are a means to check the consistency of products and services to the psychophysiological and ergonomic characteristics of man [8]. Figure 1 shows the architecture of convergent technologies according to the Albright Strategy Group [6].

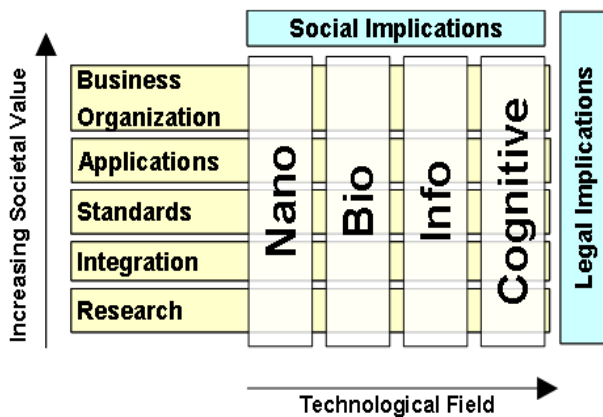


Fig. 1. Architecture of convergent technologies [6].

Biotechnology. The term *biotechnology* refers to any technology involving biological systems, living organisms, or derivatives thereof that is used to make or modify products and processes for a specific purpose [9]. This field is widely applied in food technology and, given the modern level of science, merges with the other two fields (NANO and ICT).

It should be noted that, by the decision of the Federal Government of the Russian Federation of April 2012, Russia adopted a Comprehensive Program on Biotechnology for the period until 2020. The program was developed in accordance with the decision of the Government Commission on High Technology and Innovation [10]. The program emphasizes that the key areas in the innovative development of a modern economy are information technology, nanotechnology, and biotechnology. The program is designed, *inter alia*, to stimulate production and consumption in the existing domestic markets, especially in the agricultural and food sector. It should be noted that the program highlights, among other priorities, agricultural and food biotechnology. The agricultural section of the program is closely related to the food section; its priorities include biological protection of plants, creation of plant varieties using biotechnology methods, molecular breeding of animals and birds, creation of transgenic and cloned animals, soil biotechnology and biofertilizers, biological products for animal husbandry and stock raising, animal feeding protein, processing of agricultural waste, and biological ingredients in premixes and feeds.

The priority area on food biotechnology covers the production of dietary protein; enzyme preparations for food production; engineering of pre-, pro-, and synbiotics; functional foods including therapeutic, preventive, and pediatric foods; and development of food ingredients, including vitamins and functional mixtures. It mentions, as a separate item, deep processing of raw materials, which is believed to drastically reduce the amount of waste in food industry. These issues call for a separate discussion within individual branches of food industry. They can be found in every issue of this journal and in the specialized journal *Food Industry Technology and Equipment* published by the KTIFI.

Nanotechnology in food industry has been formalized only in the past few years. The concept was phenomenologically introduced by Richard Feynman at a conference at the California Institute of Technology in 1979. At that conference he presented a paper "There's plenty of room at the bottom," which dealt with possibilities of manipulating individual atoms and molecules and controlling the creation of materials on a nanometer scale with the prospect of technical, industrial, and biological applications [11]. Afterwards, nanotechnology delivered a breakthrough not only in physics, chemistry, materials and engineering sciences, environmental monitoring, manufacturing sector, and quantum computing but also began to be widely used in clinical research and biotechnology. The studies were focused on new phenomena, properties, synthesis methods, and structures on a scale of 1 to 100 nm [12].

Most of the materials do change their properties on a nanoscale. The properties depend on the projected position of each atom or molecule [13]. Nanotechnology has close connections to other sciences and technologies, including biotechnology, chemistry, physics, and engineering. Nanotechnology can be used in health care, biology, biochemistry, agriculture, and food industry [14]. The US Department of Agriculture (USDA) was the first to promote the application of nanotechnology in agriculture and food industry by publishing a corresponding plan in 2003.

Nanotechnology has a great potential to revolutionize agriculture and food industry. Products manufactured on a nanoscale may influence the safety, bioavailability, and nutritional properties of food and enable molecular synthesis of new products and ingredients [15, 16]. The main prospects of nanotechnology in food manufacturing and agriculture are to improve safety in food and processing industries, increase the ability of plants to absorb nutrients, improve the taste and nutritional value of foods, optimize the methods of food delivery, pathogen detection, and functional food creation, and contribute to the protection of the environment and improvement of the economic efficiency of storage and transportation. When used in food production, nanotechnology can help deal with the issues related to the development of new functional materials, processing of raw materials on a micro- and nanoscale, and development of new approaches, as well as machines and equipment, for food processing [17]. Possible applications of nanotechnology in food processing are shown in Table 1.

Table 1. Application matrix of nanoscience and nanotechnology in the main areas of food science and technology [17]

Application area	Purpose and fact	Approaches
Design of nanomaterials	Nanoparticles, nanoemulsions, nanocomposites, nanobiocomposites (nanobipolymeric starch), and nanolaminates	Novel materials with self-assembling, self-healing, and manipulating properties
Nanosensors and nanobiosensors	Quality control and food safety	Detection of very small amounts of chemical contaminants Monitoring and tagging of food items Electronic nose and tongue for sensor evaluation Food born pathogen identification by measurement of nucleic acid, protein or any other indicator metabolite of microorganism
Processing	Nanofiltration	Selective passage of materials on the basis of shape and size
	Nanoscale enzymatic reactor	Improved understanding of process
	Heat and mass transfer; nanofabrication	Enhanced heat resistance of packages
	Nanocapsules for modification of absorption	Nanoceramic pan to reduce time of roasting and amount of consumed oil, reduction of trans fatty acids due to usage of plant oil instead of hydrogenated oil and finally resulted in safe nano food development of nanocapsules that can be incorporated into food to deliver nutrients to enable increased absorption of nutrients
New products	Packaging	Nanocomposites application as barriers, coating, release device, and novel packaging modifying the permeation behavior of foils, increasing barrier properties (mechanical, thermal, chemical, and microbial), improving mechanical and heat-resistance properties, developing active antimicrobial surfaces, sensing as well as signaling microbiological and biochemical changes, developing dirt repellent coatings for packages
	Delivery	Nanomyccells for targeted delivery of nutrients (nutrition nanotherapy). Nanocapsulation for controlled release of nutrients, proteins, antioxidants, and flavors
	Formulation	Production of nanoscale enzymatic reactor for development of new products. Nutritional value enhancement by omega 3 fatty acid, haemo-, lycopene, beta-carotene, phytosterols, DHA/EPA
	Evaluation	Enzyme and protein evaluation as nanobiological system for development of new products
	DNA recombinant technology	Recombinant enzyme production in nanoporous media with special numerous applications

Since nanotechnology is promoted using a variety of strategies and new approaches based on the formation, interpretation, and prediction of structural and physicochemical properties of nanoparticles and nanomaterials, one needs the third building block-ICT-of the HighTech food industry concept.

Information and communication (computer) technologies have been little known in food industry so far. Studies in the field of computer technology, computer science, and molecular modeling have been the key to the development of procedures in nanobiotechnology and nanoinformatics. These techniques can be used to create high-quality concepts and project design assumptions. Now bioinformatics is used as a computer tool for DNA and protein sequence

data analysis, and nanoinformatics is used to describe particles and materials in nanobiotechnology applications through their modeling in different states at the atomic level by means of computational chemistry strategies. A major challenge is, of course, to safely insert foreign objects into the intricate system of the human body. Computer methods are a natural opportunity to accelerate the development of innovation in life sciences. The computational approach is important in the early stages of project development on a nanoscale. It can be used to predict the structures of nanotransport systems for specific drugs or molecular devices [18, 19]. Large molecular systems are currently used as vehicles or platforms because they can be divided into different chemical groups depending on

their properties (solubility, affinity, and selectivity) and used for different types of cells [18, 19, 20].

In recent years, computational molecular design has become an extremely important area in the studies of new materials [21]. This outcome has become possible due to the increase in processing power and the integration of methods of computational chemistry [22].

Computational chemistry is a powerful tool for the design, modeling, simulation, and visualization of nanomaterials [22] and nanoparticles such as dendrimers [23, 24, 25, 26, 27], metal nanoparticles [28, 29, 30], nanocapsules [31], nanospheres [32], and quantum dots [20]. These nanoparticles are used in nanomedicine as carriers, sensors, and early disease detection systems [20, 23, 24]. Owing to the recent discoveries in computational chemistry, it has been possible to build computerized nanomolecule models. The latter can be used by experimental researchers as a method to design new nanostructures [33]. The main advantage of computer-aided nanodesign is that it allows one to explore, relatively quickly and at low cost, a large number of engineered structures in order to, *inter alia*, test their stability and predict their properties [34].

Cognitive Technologies. This area has its roots in computer technology. Currently, the term *cognitive* is undergoing a transformation: its meaning is being broadened to embrace the connotations of *knowledge* and *behaving like an intelligent being*. The concept of cognitive studies that is developed by B.M. Velichkovskii [8] considers this area as an interdisciplinary field in its

origin, methods, and prospects of practical use. In the coming convergence of technologies, cognitive studies play a systemic role since they enable the testing of products by means of the psychophysiological characteristics of humans. The central objective is to create cognitive technologies, i.e., high-tech tools, materials, and procedures that improve case analysis carried out by a human and increase the effectiveness of human activity. As applied to food industry, a notable example is the development of functional foods that influence human cognition and psychophysiology in general [35]. These developments [36] can be already discussed in the context of cognitive studies. The prospects of these technologies are intertwined with those of bionics and devices such as the electronic nose and electronic tongue [37] that are used to test products and improve their safety [37].

Thus, being based on the four pillars of the modern progress—biotechnology, nanotechnology, information technology, and cognitive technologies, including membrane technologies, the food technology is becoming a growth point of high-tech both in Russia and worldwide.

The world biotech industry is developing at a rapid pace; in one or two decades, there will be solutions and products suitable for mass use. We hope that by that time Russia will have an environment for the development of biotechnology and will be among the stakeholders and beneficiaries of high technology in general and food high-tech in particular.

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