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Biotechnology in nutrition and food engineering

Abstract

Biotechnology encompasses the basic and applied sciences of living systems and their engineering aspects required to exploit their bioprocesses to bring products to the market place.

While understanding of bioprocess technology has rapidly advanced in recent years, man has been practicing biotechnology since prehistoric times. Today biotechnology has moved beyond local production of alcohol or fermented foods to the production of bio-ingredients and refined products and it has a tremendous potential for further increasing food production, improving food raw materials and producing ingredients that will improve human health.

It should be understood that biotechnology is a collection of techniques some of which may involve genetic engineering for the production of genetically modified foods (GMO).

Since "biotechnology" can include numerous processes and applications, the term "genetically modified" is applied only to products that have been genetically engineered.

Genetically modified foods (GMO) have been hailed by some people as an indispensable tool for solving the world's food problems, and denounced by others as potentially catastrophic dangers on several grounds, including safety issues, and environmental concerns.

Keywords: food biotechnology, food bio ingredients, functional foods, agriculture biotechnology, food enzymes, bioconversion, genetic engineering, genetically modified foods

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Abbreviations: GMO, genetically modified foods; GRAS, generally recognized as safe; FDA, food and drug administration; USDA, united states department of agriculture; EPA, environmental protection agency; APHIS, animal and plant health inspection service

Introduction: historical perspective (Table 1)

Biotechnology refers to the use of living organisms to make useful products, and overlaps with bioengineering and industrial microbiology.[1]

Biotechnology has been unwittingly used for several thousand years, initially in the area of food production and preservation as exemplified by the early production of alcoholic beverages and bread using microbial "contaminants. Our early ancestors used fermentation without knowing the existence of microbial life. Egyptians were brewing beer and producing baked products by the 4th millennium BC. Distillation of ethanol was developed and applied in China in the 2nd millennium.

The modern biotechnology developed from the 19th century after the discovery of microbiology and microbial life. Today, modern fermentation is still based on the principle of combining living matter (microorganisms) with nutrients under controlled conditions to produce high yield of the desired end products.

In the first half of the 20th century World War 1 drove the development of the first large scale fermentation processes outside of alcohol production, the acetone and butanol process for the production of explosives and the citric acid fermentation in response to the disruption of Italian citrus exports.. The pressures of World War 2 brought us antibiotic fermentations in the form of penicillin and then streptomycin.

In the 1980s, recombinant gene technology led to the production of insulin for diabetes, rennet enzyme for cheese production[2,3] and genetically engineered yeast for baking.[4,5] These genetically engineered bio ingredients were the first products manufactured using recombinant technology.

Today genetically engineered microorganisms for the production of vitamins, organic acids, amino acids, sweeteners ,edible oils and nutritional supplements can be developed from the insertion of a functional gene[6] (DNA) into a host such as Lactic acid bacteria[7] are a Gram positive bacteria present in fermented foods and are identified as Generally Recognized As Safe (GRAS).

These lactic acid bacteria and probiotic microorganisms in fermented foods have been used for many years for health reasons and are now an attractive alternative for treating of intestinal disorders and seem to influence the immune system via stimulating protective immune cells. Through genetic engineering, it is possible to strengthen the effect of existing probiotic.[8] strains and create completely new probiotics[9] with multiple health benefits These natural or genetically engineered beneficial bacteria might alter the ratio of "good to bad bacteria "that inhabit the intestine, and might specifically block activity of food borne pathogens to prevent of gastrointestinal diseases.

Biotechnology, including genetic engineering technology, is going to play an important role in the production for functional foods.

Functional foods also known as Nutraceuticals[10] are going to be come preventive medicines and might help tackle health related issues For example, it is widely believed that omega-3 fatty acids are beneficial against cardiovascular diseases.

In addition, genetically engineered technology has resulted in worldwide significant changes in plant[11,12] and livestock[13] production that will affect all steps of the production chain from agrochemical inputs and breeding to final food processing.

Because biotechnology process (fermentation) uses living materials, they offer several advantages over conventional chemical process (synthetic chemistry). Biotechnology can use renewable resources as raw materials and can operate at lower temperature, pressure and pH to produce high yield of end products with less energy consumption and cost.

In the most of biotechnology processes enzymes in whole microorganisms or extracted from cellular components are used to catalyze the biochemical reactions for the production of desired bio-products that have applications in food processing, functional foods, food supplements, pharmaceuticals, chemical industry, diagnostics, environmental cleanup, etc.

Enzymes are catalysts that can convert raw materials (substrates) to form desired end products.[14] These enzymes carry out the bioconversions. Early in the discovery of bioconversion process, three major challenges were present that are resolved by newly developed advanced technologies.

Table 1 History of biotechnology

Year	Discovery
10,000 BC	Wine making developed in Eastern Mediterranean
7,000 BC	Beer developed in Egypt and Babylon
5.000 BC	Cheese making and some medicinal plants were developed
4,000 BC	Vinegar was referenced in old testament
500 AD	Algae was cultivated for food consumption by Aztecs
500 AD	Yogurt , Sauces and fermented foods were developed
1600	The name fermentation was used
1600	Van Leeuwenhoek observed yeast cells in alcohol fermentation
1781	Pressed Baker's yeast produced by Dutch (this is the first improved process)
1789	Jenner demonstrated ability to confirm the resistance to smallpox infection by vaccination
1837	Cagniard-Latour, Schwann and Kutzing independently hypothesized that yeast is a living thing (this is the first knowledge on cell theory)
1847	Blondeau studied fermentation of lactic acid, butyric acid, acetic acid and urea. He hypothesized that different fermentations carried out by different fungi
1870	The first experimental corn hybrid is produced in a laboratory
1875	Pasteur demonstrated that living yeast cells ferment sugar into ethanol and carbon dioxide Pasteur, noted cylindrical organisms produced butyric acid only in the absence of oxygen (this is the first knowledge on anaerobic fermentation)
1859	Darwin published the Origin of Species
1877	Pasteur noted relationship between microorganisms and infection diseases (this is the first knowledge on pathogenic organisms)
1881	Koch developed techniques for the handling and maintenance of cultures (this is first modern industrial microbiology techniques)
1881	First commercial production of lactic acid by anaerobic fermentation
1894	Takamine patented process to isolate diastase enzyme from mold that break starch (this is the first knowledge on enzymes and its application)
1916	Germany produces baker's yeast grown on molasses as protein supplement. Also, produced glycerol by yeast fermentation
1911	American pathologist Peyton Rous discovers the first cancer -causing virus
1918	Great Britain produces acetone and butanol by anaerobic fermentation process
1923	Commercial production of citric acid by surface culture
1929	Fleming demonstrated that mold contaminant in a Petri-dish causes bacterial death. This is the first discovery of antibiotics
1933	Hybrid corn is commercialized
1934	Gautheret successfully cultured plant cells This is the first knowledge on tissue culture
1940	Florey and Chain isolated penicillin, elucidated its structure and demonstrated its ant-bacterial properties
1940	Waxman discovered streptomycin's This is the first microbial screening method's

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Table continued..

Year	Discovery
1950s	The production of Cortisone at the cost of $200/g (now it's cost is $16/g) The production of polio and peruses vaccines Artificial insemination of livestock is accomplished using frozen semen DNA is made in a test tube for the first time The first synthetic antibiotic is developed
1960s	The production of Xanthus gum The production of alkine protease for detergents industry
1970s	The discovery of glucose isomerase and the production of high fructose corn syrup (HFCS) as a sweetener Human growth hormone is synthesized for the first time Recombinant human insulin is produced for the first time Kohler and Milstein developed monoclonal antibodies
1980s	The production of poly (hydroxybutyrate) The U.S. Supreme Court approves the principle of patenting organisms Smallpox is globally eradicated following 20 years mass vaccination effort The first recombinant DNA vaccine for livestock is developed The first transgenic animals by transferring genes from other animals into mice The first biotechnology drug , human insulin approved by FDA Interferon the first anticancer drug produced through biotechnology The first pest resistant corn (Bt corn) is produced The first recombinant vaccine for human (hepatitis B) is approved by FDA
1990s	The production of amino acids (lysine, threonine and isoleucine) The production of antibodies The production 1,2-propandiol The first successful gene therapy is performed on a 4 years girl suffering from immune disorder The first breast cancer gene is discovered FDA approves bovine somatotropin (BST) for milk production increase in dairy cows Gene associated with Parkinson's disease is discovered A sheep named Dolly in Scotland becomes the first animal cloned from an adult cell Diagnostic test for quick identification of BSE and CJD is developed The first genetically engineered crop is commercialized
2000s	The production 1,2-propandiol The production of xylito.l The production of hydroxpropanoic acid Kenya field test for the first biotechnology crop (virus resistant sweet potato) FDA approves the first gene target drug for patient with chronic myeloid leukemia FDA approves the first transgenic rootworm resistant corn Completes sequencing human genome UN Food and Agriculture organization endorse biotechnology crops FDA approves the first antiangiogenic drug for cancer FDA approves the first recombinant vaccine against human papillomavirus (HPV) USDA grants the first regulatory approval for a plant made vaccine FDA approves the first H5N1vaccine for avian flue Global biotechnology crops acreage reaches 330million acres FDA approves the first genetically engineered animal for the production of rh antithrombine
2010s	The creation of the first synthetic cell Advances in 3-D printing technology leading to skin printing Advances in stem cell technology

First challenge

Maintaining the desired optimum conditions (temperature, pressure, pH, oxygen levels, etc.) for the bioconversion process.

Solution: The development of automated and computerized equipments to assist in maintaining the desired optimum conditions for bioconversion process and monitoring the reactions. These instruments improved the bioconversion efficiency and increased the end-product yield.

Second challenge

The formation of unwanted impurities during the bioconversion process resulted in difficulties to produce the end- products in pure forms.

Solution: The development of separation and purification techniques for downstream process resulted in methods to economically produce highly pure end-products with higher recoveries.

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Third challenge

The cost of catalytic enzymes used in the bioconversion process resulting in higher production cost.

Solution: The developments of Immobilized enzymes and cells systems for both continuous and semi-continuous bioconversion process have dramatically reduced the production cost of end products.

Food biotechnology regulation[15–18]

Food biotechnology is regulated under the same United States laws that govern the health, safety, efficacy and environmental impacts.

Regulatory control on food biotechnology is the responsibility of three federal agencies:

The food and drug administration (FDA)

Regulates novel substances in foods and feeds on the basis of dietary risk evaluating food safety allergy, and toxicity. The FDA has the right to ban any biotechnology food product that it determines is unsafe.

The United States department of agriculture (USDA)

Regulates genetically engineered plants under Animal and Plant Health Inspection Service (APHIS), it is assessing the impact of developed genetically engineered plant on the agriculture industry or the meat processing industry.[19]

The environmental protection agency (EPA)

Evaluates genetically engineered plants for environmental safety and evaluate risk assessments for potential harm to human and animal health. EPA is also, responsible in establishing tolerance and residue levels for pesticides in fruits and vegetables.

Future perspectives of bioprocess industry

Today, the biotechnology industry has reached a rapid growth phase based on a broad understanding of genomics, proteomic,[13] bioinformatics, genetic transformation and molecular breading. These technologies are now being transferred to large scale biotechnology operations.

It is expected that genetically engineered hosts, such as insects, stem and plant cells, and transgenic plants or animals sooner or later will reach broader applications in the production of new bio-ingredients, with applications in both food and pharmaceutical industries.

The use of extreme-thermophilic microbes in recombinant technology will yield unique enzymes active at high temperature as biocatalysts in non-aqueous solutions and broaden the technology platform to produce reservoir of new bio-products with wide applications in medicine, food, agriculture, environment, energy and chemical industries.

Today food biotechnology has a tremendous potential for increasing food production and improving food nutritional value, flavor and texture of food products. In addition, it has the potential for the production of newly food bio ingredients that will improve food processing and producing functional foods as a preventive medicine.

In the future innovations in biotechnology will continue bringing exciting new advances to improve the life of human beings on earth.

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Conflict of interest

Author declares that there is no conflict of interest.

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