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**Review Article**

# Food biotechnology and food safety

**Şirin Oba İlter[1]*, Tuğçe Yıldırım[2]**

[1]Department of Food Processing, Suluova Vocational School, Amasya University, Amasya/Turkey
[2]Department of Biotechnology, Institution of Science, Amasya University, Amasya/Turkey

## Abstract

Food security has a multidimensional nature that has an important and strategic priority in protecting consumers of today and citizens of countries. The application of modern biotechnological methods in food ingredients and food products is evaluated in terms of research and development studies and legal regulations in terms of food consumption and human health. On the other hand, safe food production is important for the detection, management and control of physical, chemical and biological risks that may arise in food. Today, modern biotechnological studies are carried out on transgenic plants, animals and microorganisms for health, safety, economic, cultural and ethical reasons and national, regional and international security in some developed and developing countries. Each country has started to discuss the legal regulations related to the application of modern biotechnology according to its own conditions, especially due to biosecurity concerns. The production of genetically modified foods and control of legal arrangements in Turkey carried out effectively and are continuing to work on this issue.

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## 1. Introduction

Biotechnology is a modern discipline that has revolutionized many fields since the late 20th century, primarily the health, agriculture, and environment (Gultekin, 2005). Research and education studies in the field of biotechnology are of great importance in developed and developing countries and are supported by many national and international organizations, and some countries take on world leading roles by conducting large investment campaigns in

[1]Correspondence: sirin_oba@hotmail.com

these areas (Hall, 2005). Biotechnology has various fields of implementation including industry and science.

Biotechnology is the most important application areas with the production of new and specific products together with technological developments and has a long tradition in the food industry. Biologic systems are used without making any modifications. Traditional biotechnological applications are used in the production process of bread, alcohol, some alcoholic beverages, vinegar, yogurt, etc. On the other hand, Modern Biotechnology is a field where the biological systems are changed using genetic engineering methods to produce useful products such as genetically modified food, enzymes, human hormones, insulin, and biotech vaccines. Both modern and traditional variants are in use today (Pinstrup-Andersen and, 2000; WHO, 2005; Jauhar, 2006). Nevertheless, the rapid increase of biotechnology applications have a strong influence on the need new legal regulations of suitable for the countries themselves. In this way, It is aimed to discuss and research that biotechnology addressed the potential effects on health, safety, economics, culture and ethics in both national and international platforms while at the same time to benefit from the opportunities offered by biotechnology. (Comert, 2011). The progress of biotechnology in food and agriculture created a tendency to share knowledge and cooperate among the industries (Baskaya et al., 2009).

## 2. Role of Biotechnology in Food Processing

Biotechnology can be used in the all ring of this chain in order to improve the safety of the food supply and nutritional quality, as well. The food industry is the lifeline connection between the farmer and the supermarket. Many agricultural products are processed after leaving the farm, except the vegetables and fruits generally eaten raw. Biotechnology can be used in every ring of this chain to improve the safety of the food supply and nutritional quality (Haroon and Ghazanfar, 2016). Thus, the aim of the study is to evaluted the food safety and how food biotechnology can be used to improve food processing following the product from the farm to the table.

### *2.1. Genetic Development of Food Fermentation Microorganisms*

Given the fact that humankind is already benefiting from living systems to produce, process, and serve food for centuries, it could be noted that biotechnology is not something new for the food industry. Mutation and selection methods were used to enhance the bacteria and yeast types used to produce fermented products such as cheese, sausage, bread, and wine. The processed foods including vitamins, stabilizers, enzymes, flavor enhancers, and preservatives are produced by the bacteria. Bacteria, yeast, and fungi have been used for centuries in fermented food production (Harlander, 1990; Fraiture et al., 2020). In traditional biotechnology methods, classical specimen enhancing based on the selection of bacteria and mutations are not under control, although it is not certain. Also, it is impossible to identify from all possible mutations and the screening process is time consuming and laborious (Ross et al., 2002). Modern biotechnology with genetic engineering provides a mechanism that can overcome such boundaries with the method providing selection and transfer of single, well-defined characteristics of many live organisms in a controllable and certain manner (Demain, 2000; Mosier and Ladisch, 2009). Effects of genetically enhanced microorganisms used in food fermentation on production are presented in Table 1.

**Table 1.** Effects of genetically enhanced microorganisms used in food fermentation on production (Harlander, 1990).

| Food Product | Effects | Product Improvement Effects |
|---|---|---|
| Cheese | Bacteriophage (virus) resistance | Eliminate economic losses from loss of beneficial bacterial cultures |
| Wine | Insertion of malolactic gene in industrial yeast strain | Reducing the acidity level of the wine Prevented economic losses |
| Sausage | Bacteriocin production | Inhibition of pathogens |
| Beer | α- amylase producion | Low calorie beer |
| Bread | Higher levels of maltose | Improved leavening |

### *2.2. Food Microorganisms*

Food microorganisms are critically important in flavor-enhancing, preservation, and creating the aroma and texture of fermented foods. Genetic engineering is one of the new applications of the biotechnologies, providing successful results industrially (Koffas and Marienhagen, 2014) by developing genome calibration tools enhancing values or upgrading the microbial beta-galactosidase enzymes produced by Lb. delbrueckii subsp. bulgaricus and *Streptococcus thermophilus* (Markakiou et al., 2020), which are used in yogurt production. Serious studies are conducted on genome engineering for acquiring high yield products in lactic acid bacteria (Rothstein et al., 2020).

## 2.3. Probiotics

Probiotics are capable of implanting and competing many bacteria strains into human and animal gastrointestinal channels (Kerry et al., 2018). These organisms are widely named "probiotics" because they are beneficially helping the host (Gorbach, 2002) and probiotic microorganisms are shown in Table 2. Strains competitively inhibiting pathogenic intestinal organisms potentially have much useful utilization in agriculture and the food industry. Lactic acid bacteria can be found in multiple ecosystems, including food, animal feed, plants, and animals. Considering the importance of Lactic acid bacteria in biotechnology and medicine, this organism group is an important economical factor (Wuyts et al., 2020). Many methods and techniques are being investigated such as DNA and RNA specific sequence region analyses and microdroplet scanning use to describe probiotic isolates effectively and in a cost-efficient manner. Microdroplets can be used to describe isolates that can possibly affect the probiotic activity and are advanced products of short-chain fatty acids (Mekonnen et al., 2020). Detailed analysis of the effects of the probiotic product on intestinal bacteria populations can be made by molecular methods and PCR usage. These techniques being in the development phase today will become the most frequently used methods in the near future (Fuller, 1989).

## 2.4. Microbial Food Ingredients

Microorganisms produce an array of metabolites used as components in already processed food products (Neidleman, 1990). There are some regulators such as acetic acid, benzoic acid, lactic acid (for example, acetic acid is substantially produced by *Bifidobacteria*), aromas like diacetyl, pyrazines, and lactone (for example, ethyl acetate is produced by *E. coli* ATF1) (Lee and Trinth, 2019; 2020), flavor enhancers (for example, glutamic acid is produced by *Corynebacterium glutamicum*) (Nakayama et al., 2019), pigments (for example, the monascus-nata color agent is produced by *Monascus purpureus*) (Sheu et al., 2000) stabilizers and thickeners (for example, dextrans are synthesized by *Lactobacillus acidophilus*) (Gibbon and Banghart, 1967), nutritional additives(vitamins, amino acids) (Revuelta et al., 2016), sweeteners (aspartame) (Erbeldinger et al., 2000) and preservatives (nisin) (Joshi et al., 2009). Using these components in food production make the product more functional, enhance nutritional values, improve food quality, extend shelf life, and provide safety. Most of the ingredients mentioned above are produced by microorganisms with a long history of safe use in the food industry. Moreover, many microorganisms can be found in nature which produces interesting components that can be used in processed foods. For example, many bacteria produce extracellular biopolymers such as stabilizing agents, viscosifiers, surfactants, flavor encapsulating agents, which can be used as non-caloric gelling agents or sources of soluble fiber in regimens. Genes coding the production of these biopolymers are under great interest to transfer them to food-grade microorganisms (Torino et al., 2015; Revuelta et al., 2016).

**Table 2.** Probiotic microorganisms (Holzapfel et al., 2001; Mercan, 2020)

| | |
|---|---|
| *Lactobacillus* species | *L. bulgaricus, L. cellebiosus, L. delbrueckii, L. lactis, L. acidophilus, L. reuteri, L. brevis, L. casei, L. curvatus, L. fermentum, L. plantarum, L. johnsonii, L. rhamnosus, L. helveticus L. salivarius, L. gasseri, L. amilovorus, L. crispatus, L. gallinarum* |
| *Bifidobacterium species* | *B. adolescentis, B. bifidum B. breve, B. infantis B. longum, B. thermophilum, B. animalis, B. lactis* |
| *Bacillus* species | *B. subtilis, B. pumilus, B. lentus B. licheniformis, B. coagulans* |
| *Pediococcus* species | *P.scerevisiae, P. acidilactici, P. pentosaceu* |
| *Streptococcus* species | *S. faecalis, S. cremoris, S. lactics, S.intermedius, S. thermophilus* |
| *Bacteriodes* species | *B. capillus, B. suis B. ruminicola, B. amylophilus* |
| *Propionibacterium* species | *P. shermanii* ssp. *freudenreichii* |
| *Leuconostoc* species | *L. mesenteroides* |
| Yeasts | *S. cerevisiae, C. torulopsis, Saccharomyces boulardi* |
| New generation probiotic bacteria (NGP) | *Bacteroides xylanisolvens* DSM 23694*, Bacteroides ovatus* D-6 , *Bacteroides ovatus* V975, *Bacteroides ovatus* V975, *Bacteroides dorei* D8, *Bacteroides fragilis* ZY-312, *Bacteroides acidifaciens* JCM 10556(T), *Clostridium butyricum* MIYAIRI 588, *Faecalibacterium prausnitzii, Lactococcus lactis::trefoil factor 1* or IL-10 |

### *2.5. Enzymes*

Enzymes are widely used as process helping agents in the food industry to control and enhance processed food texture, flavor, and nutritional values (Niedleman, 1986). In the last couple of years, food processing companies are using enzymes produced by genetically modified organisms. Enzyme groups comprising proteases and carbohydrates are cloned to have them produced with higher yield in a shorter time. These enzymes are used in the food industry to produce food substances such as sweeteners, cheese, and curd cheese. Rennin and α-amylase are such enzymes (Haroon and Ghazanfar, 2016). The first recombinant enzyme (rennin) to be used directly in food is acknowledged by the Food and Drug Administration (FDA) as “generally recognized as safe” (GRAS) status, and it is considered as the first in food biotechnology. It is important to note that the recombinant product comprises more active enzymes per protein unit and it is microbiologically safer than the traditional equivalent extracted from the front stomach of calves (Flamm, 1991).

**Table 3.** Enzyme samples obtained from genetically modified microorganisms (Zhang et al., 2019)

| Enzyme | Application Area | Microorganism | Improvement |
|---|---|---|---|
| α- amylase | Breaking down maltose and dextrin<br>Stain remover<br>Fortification of flour<br>Glucose syrup | *Bacillus licheniformis*<br>*Rhizopus oryzae* | Sensitive to acid<br>Thermostable |
| β-glucosidase | Food, animal feed, textile, fuel and chemical industry | *Aspergillus aculeatus*<br>*Thermotoga maritima* | Hydrolytic has improved efficiency |
| Proteases | Bakery, detergent industry | *Aspergillus* ve *Bacillus* species | Enhanced Glycine Releasing Activity |
| Lipase | Breaking down animal and vegetable oils and paper, cosmetics, pharmaceutical and detergent industry and agricultural chemistry | *B. subtilis* | Thermostability |

Some techniques of genetic engineering (region-specific mutagenesis: specifically changing enzyme primary amino acid sequences) to enhance enzymes’ functionality in food systems. Some genetically modified enzyme examples are presented in Table 3 (Zhang et al., 2019).

## 3. Safety of Products and Foods Produced with the Help of Modern Biotechnology

Food safety is the term defining the rules and measures to be followed in the production, processing, preservation, transportation, and distribution of food safely, and it generally emphasizes topics of safe, healthy, and preserved food (Artık et al., 2021). Food-related risks are considered separately in every aspect of food processing, from the initial production to the final result of consumption (Koç and Uzmay, 2015). In another explanation, food safety is the capacity of all social groups and individuals to acquire the amount and quality of the food which will satisfy their nutritional needs, with the whole process also being sustainable. To this extent, the system that provides food safety needs to meet the basic conditions given below:

*a) Availability:* Capacity of producing, storing, and importing the necessary amount of food to satisfy the needs of all groups.

*b) Accessibility:* To ensure the impacts of international and political imposition are at a minimum and to physically and economically ensure all can acquire food.

c) *Sufficiency:* An environment of trust which can get through seasonal and periodical threats to food acquirement and the food production being nutritional, safe, and environmentally sustainable.

d) *Acceptability:* Food supply being suitable to cultural habits, not hampering human rights and honor.

e) *Individual and Institutional Factors:* The institutions which are the policymakers and manage the whole process, with the responsibility of food safety (Cankaya and Sancar, 2009; Koc and Uzmay, 2015).

In short, food safety is the consumed food not being harmful to health. However, in the 21st century, genetically modified (GM) products are proposed as the only option of providing food safety (Cankaya and Sancar, 2009). Modern biotechnology has various areas of use in medicine and the agricultural- food industry. One of those is the usage of GM in the food production chain. Thanks to the production of genetically modified products in the laboratory environment by humans, the resistance to herbicides, insects and disease factors (bacteria, fungi, virus) has increased and the product efficiency has been increased, the tolerance of the plants to salt, cold and drought has been improved, the nutritional values and shelf life of the products have been increased, It has been made more attractive in terms of color, shape and size, and products that are free or reduced from natural toxic substances and allergens are obtained (Gultekin, 2005). Studies of Codex Commission concentrated on the principles and guidelines of evaluation of food safety of products of modern biotechnology, and the food products of modern biotechnology are evaluated under three main topics as a result of this study (WHO, 2009).

I. Food safety evaluation and management of food products derived from Recombinant-DNA plants

II. Food safety evaluation and management of food products derived from Recombinant-DNA microorganisms

III. Food safety evaluation and management of food products derived from Recombinant-DNA animals.

Generally accepted food safety level by the public for new foods reflects the history of safe consumption by people. In many instances, it is accepted that the knowledge required to manage the risks related to food comes from long histories of use. These foods are generally considered safe. Risk analysis of food produced by the means of modern biotechnological methods provides a platform to designate general principles. The main goal of these principles is to set the ground for the risk analysis of foods produced with modern biotechnology concerning food nutrition and safety. These principles and the Codex Alimentarius Commission report do not address the environmental, ethical, moral, and socio-economical aspects of research, development, producing and marketing of biotechnologically produced foods. Risk evaluation comprises of a safety evaluation designed to identify whether there are any threats, nutritional or any other harms and if any, gather information on the nature and severity of the possible threat. Safety evaluation should focus on the determination of similarities and differences, comparing the modern biotechnologically produced food and the traditional equivalent. If any new or changed threat or any other safety issue is detected in safety evaluation, the related risk should be characterized to identify the relativity of the threat to human health. A safety evaluation is characterized by the comparison of the food or a component and the generic equivalent :

A. Considering both desired and undesirable effects,
B. Determining new threats or threats changed with the product,
C. Determining the changes in nutritional values related to human health

Accordingly, the safety of all new food derived from DNA plants, animals, and the products of these should be evaluated with a generic equivalent with a safe history of use in comparison as a principle considering expected and adverse effects (WHO, 2009; Amin et al., 2011; Kramkowska et al., 2013). The priority is to identify the new or changed threats compared to the traditional equivalent, not trying to identify all the threats of a given food. Safety evaluation of a food product derived from a recombinant DNA plant, animal or microorganism comprises of relative factors given below.

- Evaluation of toxicity
- Assessment of allergy status (proteins)
- Composition analysis of key components
- Evaluation of metabolites
- Food processing
- Nutritional modification
- Potential accumulation of substances important for human health
- Use of antibiotic resistance marker genes

The genetically modified food certification procedure and the conditions of genetically modified products that can be traded and are regulated by legal procedures and rules. Many characteristics are being examined, not only the features of the parent organism, but source of genes also used for the modifications and statement products (WHO, 2009).

## 4. Legal Regulations in Biosafety

Biotechnology products or (GMO) became commercially available 20 years ago. During this time, the effects of biotechnology products on health and food safety remained a controversial topic (Dincoglu, 2016). It is important to regulate some basic points with laws and topple these concerns and controversies for the good of the public. The Europen Union established a lawful frame by various regulations to provide the ground for the safe development of biotechnology and especially GMOs. These topics of regulations cover scientific subjects, measure rules, technological evaluations, trade, and the environment. The European policy and legislations are prepared and acted upon by considering the international statutes. Accordingly, European laws and their applications are in compliance with the following documents.

- Regulations of the World Trade Organization (WTO),

- Provisions of Cartagena Biosafety Protocol, which had been prepared and acknowledged as an additional protocol of the UN Biodiversity Agreement,

- Codex Alimentarius and studies of International Interim Workgroup on Codex of Food Biotechnology

Conditions on which the GMO products or food products derived from GMOs can be developed, used, or marketed are defined by the European Parliament and Council Charter, which had been prepared according to these regulations. All GMO products and products derived from GMOs should also comply with the labeling and traceability regulations. In 2010, Biosafety Law was published in Turkey to establish a biosafety system, to ensure biodiversity is preserved, and to prevent any possible threats of GMOs and related products. Within the light of these evaluations, procedures and principles were determined regarding the tracing, auditing, and indoor activities of GMOs. Biosafety Committee was found to provide necessary scientific evaluations. To make sure the institution is independent, it was established as an autonomous board, never taking any orders from institutions, individuals, or companies. The mission of this Biosafety Committee is: To evaluate applications concerning the indoor use of GMOs, the marketing of GMO and related products as food, feed, and processing agents, and GMO and other related products being decontrolled for experimental purposes; and to provide experts and committees for these evaluations. According to the 5th Article of the Biosafety Law, below actions are prohibited:

a) Releasing GMO and related products to the market without obtaining the approval.

b) Using GMO and related products by the owner or third parties against the decisions of the Committee.

c) Production of genetically modified plants and animals.

d) Using GMO and related products except for the set purposes and goals before releasing to the market by the Committee.

e) Using GMO and related products in infant food, baby formulas, follow-on baby food, follow-on baby formulas, and baby and children supplementary food products (Ministry of Agriculture and Forestry, 2021).

A national inspection of food-related GMOs is the responsibility of the Ministry of Agriculture and Forestry. Controls of imported food and feed samples are made by Provincial Food Control Laboratories and other food analysis laboratories affiliated under the ministry, at a frequency specified by the Ministry according to the risk conditions (Başkaya et al., 2009).

## 5. Conclusion

In conclusion, transgenic plants are not allowed to have free trade and imported to our country. Transgenic plant elements and seeds coming for registry purposes are field-tested by the Ministry of Agriculture and Forestry. Turkish studies on legislations concerning biosafety are greatly affected by the Cartagena Biosafety Protocols, where Turkish government is also a party.

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