

Amino acids are used to enhance flavors and to act as seasonings, nutritional additives and improvers. Microorganisms overproducing specific amino acids are grown in large fermenters. The acids are secreted into the fermentation medium and harvested. For instance, glutaminic acid produced by microorganisms is used as monosodium glutamate, as a flavor enhancer. The amino acids lysine, cysteine, methionine and phenylalanine are used as supplements in animal feed. Furthermore, citric, acetic, lactic and ascorbic acids are produced in large quantities by microbial fermentation.³²¹

Gums are used widely in the food sector as thickeners, emulsifiers and fillers. Gum obtained from seed has been transformed into a gum similar to the expensive locust bean gum using α -galactosidase. The gene encoding the enzyme was inserted into baker's yeast. Bacterial polysaccharides provide novel gums with improved and valuable properties.³²² Important applications of such enzymes produced by genetically modified microorganisms in the food sector are shown in table 11.

321 *Madden*, Food Biotechnology - An Introduction, ILSI 1995, 15, available at www.ilsil.org/publications/ilsifobi.pdf. For an overview see also Biotechnology Industry Organization, Food Biotechnology (2006), available at <http://www.bio.org/speeches/pubs/er/food.asp>. See also *Kleerebezem*, Molecular Advances and Novel Directions in Food Biotechnology Innovation, 17 Current Opinion in Biotechnology 179 (2006).

322 *Madden*, Food Biotechnology - An Introduction, ILSI 1995, 15, available at www.ilsil.org/publications/ilsifobi.pdf. For an overview see also Biotechnology Industry Organization, Food Biotechnology (2006), available at <http://www.bio.org/speeches/pubs/er/food.asp>. See also *Kleerebezem*, Molecular Advances and Novel Directions in Food Biotechnology Innovation, 17 Current Opinion in Biotechnology 179 (2006).

Table 11:
Uses of enzymes in the production of processed food.³²³

Enzyme	Product	Use
α -Amylase	Sweeteners	Liquefaction of starch
	Beer	Removal of starch haze
	Bread, cakes and biscuits	Flour supplementation
Amyloglucosidase	Sweeteners	Saccharification
	Low-carbohydrate beer	Saccharification
	Wine and fruit juice	Starch removal
	Bread manufacture	Improved crust color
β - Galactosidase (lactase)	Whey syrup	Greater sweetness
	Lactose-reduced milk and dairy products	Removal of lactose for those who are lactose intolerant
	Ice cream	Prevention of "sandy" texture caused by lactose crystals
Glucose oxidase	Fruit juices	Removal of oxygen
Invertase	Soft-centered sweets	Liquefaction of sucrose Sugar syrups
Lipases	Cheese	Flavor development Accelerated ripening
	Flavorings	Ester synthesis
Papain	Beer	Removal of protein
Pectinases	Wine and fruit juice	Increased yield, clarification
	Coffee	Extraction of the bean
Proteases ³²⁴ (various)	Dairy products	Modification of milk proteins
	Caviar	
	Bread, cakes and cookies	Viscosity reduction of "stickwater"
	Meat	Gluten weakening
		Tenderization

323 *Madden*, Food Biotechnology - An Introduction, ILSI 1995, 17, available at www.ilsil.org/publications/ilsifobi.pdf. For an overview see also Biotechnology Industry Organization, Food Biotechnology (2006), available at <http://www.bio.org/speeches/pubs/er/food.asp>.
 See also *Kleerebezem*, Molecular Advances and Novel Directions in Food Biotechnology Innovation, 17 Current Opinion in Biotechnology 179 (2006).

324 A recent review on the application of proteases in food production is provided by *Sumantha et al.*, Microbiology and Industrial Biotechnology of Food-Grade Proteases: A Perspective, 44 Food Technology & Biotechnology 211 (2006).

Biotechnology is applied in milk processing to a large extent.³²⁵ Chymosin and *Lactococcus lactis* are examples of this application of biotechnology.³²⁶ Milk is coagulated by the enzyme chymosin. Originally, this coagulation in cheese production was induced by calf rennet. Chymosin is nowadays produced by genetically modified microorganisms, e.g. *Escherichia coli*, *Khuyveromyces lactis* or *Aspergillus niger*. Today, at least 50% of cheese is made with chymosin from genetically modified microorganisms. Lipases are added in cheese production to accelerate the ripening process. Whey from cheese processing is treated with the enzyme betagalactosidase in order to form a protein-rich syrup with a range of applications in the confectionery segment.³²⁷ *Lactococcus lactis* is the best studied food microorganism. It is used in the dairy segment for fermentation. Phages pose a significant problem in industrial fermentation.³²⁸ Strains with plasmid-encoded phage-resistance mechanisms successfully counter phage proliferation.³²⁹

Biotechnology has also improved the production process of fruit juice.³³⁰ Biotechnology helps to overcome the problems posed by the fruit wall constituent pectin in fruit juice processing. The pectin is altered by enzymes during fruit ripening. As a result, the pectin becomes more soluble. Dissolved pectin makes juice more viscous and difficult to press from the fruit. Pectin also helps to retain important compounds of color and flavor within the fruit, so juice pressed from it is of inferior quality. Juice is difficult to purify and to filter because of suspended pectin particles. In the fruit juice segment, pectinases obtained from microorganisms are used to overcome all of these problems. Enzymes extract, clarify and modify juices from such fruits as juice berries, stone and citrus fruits, grapes, apples, pears and even vegetables.³³¹

325 GMO Compass, Processed Foods – Dairy Products and Eggs (2006), available at http://www.gmo-compass.org/eng/grocery_shopping/processed_foods/29.dairy_products_eggs_genetic_engineering.html.

326 For more information on the use of biotechnology for industrial strain development of *Lactococcus lactis* see Vlieg *et al.*, Natural Diversity and Adaptive Responses of *Lactococcus lactis*, 17 Current Opinion in Biotechnology 183 (2006).

327 Madden, Food Biotechnology - An Introduction, ILSI 1995, 26, available at www.ilsis.org/publications/ilsifobi.pdf.

328 A larger yoghurt factory can process up to 500,000 l of milk, while in the production of cheese, factories may process up to 1,000,000 l daily. Partial phage attacks cause a reduction in the speed of acidification, texture quality, and unpredictable variation in quality.

329 Garvey *et al.*, Molecular Genetics of Bacteriophage and Natural Phage Defence Systems in the Genus *Lactococcus*, 5 International Dairy Journal 905 (1995).

330 GMO Compass, Beverages – Juice, Soft Drinks, Wine, and Beer (2006), available at [ww.gmo-compass.org/eng/grocery_shopping/processed_foods/30.beverages_genetic_engineering.html](http://www.gmo-compass.org/eng/grocery_shopping/processed_foods/30.beverages_genetic_engineering.html).

331 Madden, Food Biotechnology - An Introduction, ILSI 1995, 27, available at www.ilsis.org/publications/ilsifobi.pdf.

Enzymatic treatments are a major way of producing sweeteners.³³² Sweeteners comprise syrups as well as low-caloric sweeteners. Syrups derive from sucrose or starch.³³³ High-fructose syrup from corn starch has now eclipsed sucrose as the major sweetener used in the food sector. The production and use of high-fructose syrup in the EU has been limited by quotas intended to protect European sugar beet growers. Nevertheless, more than 8 million tons of high-fructose syrup are processed annually. High-fructose syrup is an alternative to sucrose or invert sugar. It is used in many products, including soft drinks, jam, ice cream, cakes, canned fruit, pickles and sauces. Unlike sucrose, high-fructose syrup remains stable in chilled, frozen and acidic food without forming crystals or undergoing conversion to other sugars.

High-fructose syrup is made from low-cost raw material starch. The starch is converted into syrup by several enzymes. These enzymes are used in distinct stages comprising α -amylase, an enzyme from the bacterium *Bacillus spec.*, to dissolve the starch and to break down the starch into dextrins. Various fungal enzymes are then used to break down the dextrins to glucose. Finally, glucose isomerase converts glucose to fructose, as glucose is about half as sweet as fructose.

332 *Tornare&Kochhar*, Production of Oligosaccharides Using Engineered Bacteria: Engineering of Exopolysaccharides from Lactic Acid Bacteria, in: *Wang&Ichikawa*, Synthesis of Carbohydrates Through Biotechnology, American Chemical Society Symposium Series 873, 139 (2004).

333 GMO Compass, Ingredients and Additives - Corn Syrup, Fructose, and Glucose – All are Products of Starch (2006), available at http://www.gmo-compass.org/eng/grocery_shopping/ingredients_additives/37.products_starch_corn_syrup_fructose_glucose.html.

II. Functional food

Another important field of innovation in the production of processed food is functional food.³³⁴ Functional food results from biotechnology as well as from the new developments in traditional food technology like fortification and extraction. "Functional food"³³⁵ describes nutrients or nutrient-enriched food that is designed to prevent diseases. Functional food³³⁶ is "any food or ingredient that has a positive impact on an individual's health, physical performance, or state of mind, in addition to its nutritive value."³³⁷ Functional food is rather a concept than a well-defined food. Functional food addresses various components affecting body functions and belongs to nutrition and not to pharmacology, as it does not comprise pharmaceuticals with therapeutic effects. The borderline between functional food and pharmaceuticals becomes more and more fluent with progress in nutrition science.³³⁸ Table 12 shows areas of human physiology addressed by functional food.³³⁹

334 Dietetic food is intended for individuals with a specific disease or condition. While functional food improves or maintains health for consumers, dietetic food aims at physicians or health professionals. Dietetic food must fulfill the requirements set out by the EU: "A particular nutritional use must fulfill the particular nutritional requirements: of certain categories of persons whose digestive processes or metabolism are disturbed; or of certain categories of persons who are in a special physiological condition and who are therefore able to obtain special benefit from controlled consumption of certain substances in foodstuffs." Art. 2(1), Art. 1(2)(b)(i)(ii) of the EU Directive 89/398/EEC.

335 Functional food is also described by "nutraceuticals" and has to be distinguished from the so called "medical food", which the U.S. Food and Drug Administration (FDA) defines as "formulated to be consumed or administered entirely under the supervision of a physician and which is intended for the specific dietary management of a disease or condition for which distinctive nutritional requirements, on the basis of recognized scientific principles, are established by medical evaluation.", 21 U.S.C. 360ee(b)(3). For more details see *DellaPenna*, Nutritional Genomics: Manipulating Plant Micronutrients to Improve Human Health, 285 Science 375 (1999), *Mazut, Krebbers&Tingey*, Gene Discovery and Product Development for Grain Quality Traits, 285 Science 372 (1999), *Pridmore et al.*, Genomics, Molecular Genetics and the Food Industry, 78 Journal of Biotechnology 251 (2000).

336 The European Commission's Concerted Action on Functional Food Science in Europe (FUFOSE = Functional Food Science in Europe) involving about 100 European experts in nutrition and medicine developed a parallel definition of the term functional food: "A food can be regarded as functional if it is satisfactorily demonstrated to affect beneficially one or more target functions in the body, beyond adequate nutritional effects, in a way that is relevant to either improved stage of health and well-being and/or reduction of risk of disease. A functional food must remain food and it must demonstrate its effects in amounts that can normally be expected to be consumed in the diet: it is not a pill or a capsule, but part of the normal food pattern." *Diplock et al.* (eds.), Scientific Concepts of Functional Foods in Europe: Consensus Document, 81 British Journal of Nutrition S1 (1999).

337 *Goldberg*, Functional Foods, Designer Foods, Pharmafoods, Nutraceuticals, London 1994, 3.

338 A European Consensus of Scientific Concepts of Functional Foods, 16 Nutrition 689 (2000).

339 For an overview see *Kotilainen et al.*, Health Enhancing Foods – Opportunities for Strengthening the Sector in Developing Countries, World Bank Agriculture and Rural Development Discussion Paper 20, Washington 2006.