American Journal of Food Science and Technology, 2017, Vol. 5, No. 4, 143-148
Available online at http://pubs.sciepub.com/ajfst/5/4/4
©Science and Education Publishing
DOI:10.12691/ajfst-5-4-4

A Review of Biotechnological Applications in Food Processing of Animal Origin

Mahendra Pal[1], A.S. Patel[2], A.R. Bariya[2], Vikram Godishala[3], Venkataramana Kandi[4,*]

[1]Narayan Consultancy on Veterinary Public Health and Microbiology, 4 Aangan, Jagnath- Ganesh Dairy Road, Anand, Gujarat, India
[2]Department of Livestock Products Technology, College of Veterinary Science, Junagadh Agricultural University, Junagadh, India
[3]Department of Biotechnology, Vaagdevi Degree and PG College, Warangal, Telangana India
[4]Department of Microbiology, Prathima Institute of Medical Sciences, Karimnagar, Telangana, India
*Corresponding author: ramana_20021@rediffmail.com

Abstract Biotechnology opens numerous opportunities for the food industry. Biotechnological approaches are applied to enhance the nutritional, functional and sensory attributes of food in milk, meat, fish and beverage processing industries. The targeted use of biotechnological methods can, amongst other things, help reduce the quantity and number of unhealthy ingredients in foods as well as remove allergenic substances. Food biotechnology, therefore, contributes significantly to saving resources, optimizing harvest yields and producing healthy and better foods. People have used the properties of microorganisms and their enzymes in food production consciously for thousands of years. Biotechnology has helped in the development of food processing. It can also fight the current challenges of global food and nutritional insecurity. The purpose of this communication is to delineate the importance of biotechnology, and its industrial applications in the processing of foods of animal origin.

Keywords: *biotechnology, food industry, food biotechnology, food production, industrial applications, animal origin*

Cite This Article: Mahendra Pal, A.S. Patel, A.R. Bariya, Vikram Godishala, and Venkataramana Kandi, "A Review of Biotechnological Applications in Food Processing of Animal Origin." *American Journal of Food Science and Technology*, vol. 5, no. 4 (2017): 143-148. doi: 10.12691/ajfst-5-4-4.

1. Introduction

Biotechnology is a diverse field of science, which has been instrumental in human development ever since life has evolved. Historically, it could be dated back to 4000 BC, when man had started using microbes to produce bread and wine. Basically, it integrates human, animals, and microorganisms with the technology for the betterment of life. The research in cell biology, animal sciences, environmental sciences, plant sciences, agriculture, food, and medicine are among a few important areas where biotechnology, and its applications play a key role [1].

Pharmaceutical industry is another area where biotechnology has given a great boost, and has played an important role in the discovery of antimicrobial agents [2]. Production of quality food, paper from the trees (Biopulping), synthesizing fuel from various raw materials, and selective breeding (Bioplastics) with minimal cost and pollution are other significant contributions of biotechnology. Major tools of biotechnology include tissue culture, selective breeding, fermentation, DNA finger printing, and recombinant DNA technology [3-8]. Biotechnology also finds its place in the diagnosis of various genetic disorders, and infectious diseases, by allowing complete genetic/DNA analysis, thereby finding ways to treat them [9-13].

Food processing can be defined as the application of various operations and technologies to convert relatively bulky, perishable and typically inedible raw food materials into more useful shelf-stable and palatable foods or potable beverages [14]. In the present era, there is a growing concern about production of low cost, healthy, safe, nutritious, and value-added food products to improve human health.

2. Biotechnological Applications in Food Industry

There are various food processing sectors where the biotechnological tools can be applied for betterment of the food products. These aspects include increasing the yield of food, improve the nutrition value, use of fermentation process to yield different food products, producing important enzymes, increase the shelf life, improving the organoleptic properties of food, and to enhance the food safety [15,16].

2.1. Biotechnology to Increase the Yield of Food

Transgenesis includes manipulation of a gene of one organism in to another organism of same or other species in a way that the gene is both expressed, and is also transferred to the next generation [17,18]. Fish, mice, rats, pigs, sheep, rabbits, cows etc. are examples of transgenic animals, which have been developed with the aid of biotechnology [19]. Genetically engineered (GE) salmon fish produced with increased growth rate, disease resistance and improved environmental tolerance than its non-GE farm-raised Atlantic salmon counterpart [20,21]. GE salmon fish for was approved as a safe and healthy food for human consumption by US FDA (United states, food and drug administration).Introduction of extra copies of the genes encoding bovine β- and κ-casein into female bovine fibroblasts revealed that milk produced from such animals had8-20% increase in β -casein, two times increase in κ-casein levels, and a clearly altered κ-casein to total casein ratio [22].Transgenic swine was developed by inserting plant gene, which revealed high level of unsaturated fatty acid in their muscle mass and considered as healthy pork [23]. The Rendement and Napole (RN) and Halothane (N) genes were related to meat quality in pigs, and the myostatin gene, was associated with double-muscling in cattle. In poultry, growth traits were associated with poly-morphisms in the ghrelin, lambr1, growth hormone, growth hormone receptor, MC3R, MC4R, IGF-II, TGF-β [24-32].

2.2. Biotechnology to Improve the Nutritional Value of Foods

Every food item does not contain all essential components so every food is not possessing perfect nutrition. With the advances in the biotechnology, bio-fortification of foods using technologies such as recombinant DNA technology and fermentation procedures is gaining advantage in the industry [33]. Designer foods are normal foods fortified with health promoting ingredients [34]. The term was introduced in Japan in 1980s for referring processed food containing nutrient conferring of some additional health benefits apart from its own nutritional value [35]. Designer egg approach was started in 1934 by Cruickshank, who reported the modification of fatty acid composition in egg yolk by making feed interventions [36]. These omega-3 fatty acids enriched designer eggs showed better stability of PUFA during egg storage and cooking, high availability of such nutrients as vitamin E, carotenoids and selenium, which improves antioxidant and omega-3 status of people consuming these eggs [37]. Previously, researchers had developed a variety of designer egg, which was rich in omega-3 fatty acids and antioxidants [38]. Research by Raes et al. produced a designer egg, which was enriched with conjugated linoleic acid (CLA) [39]. Designer eggs with enhanced vitamin A and β-carotene concentrations were also developed [40]. Designer milk developed by biotechnological applications may have a primary structure of casein, alteration in the lipid profile to include healthier fatty acids such as CLA and omega-fats. Such milk contains improved amino acid profiles, more protein, less lactose and devoid of β -lactoglobulin (β-LG) [41]. Previous study has also demonstrated that, by eliminating the β-LG gene from bovines, cow milk allergy in children could also be reduced [42]. Reports also suggested that selenium (Se)-enriched chicken, pork and beef can also be produced by feeding organic Se in the diet of poultry and farm animals [43]. Designer food or functional foods are gaining greater importance due to their role in disease prevention and health promotion [44].

2.3. Biotechnological Application in Fermentation Process

In commercial fermentation processes, to produce different value added fermented foods, starter cultures have been developed to utilize as inoculants. "Starter cultures" made up of single or mixed strains of microorganisms have been found beneficial [45]. Inhibitory activity of these cultures was noted due to the production of one or several substances such as diacetyl, bacteriocins, hydrogen peroxide, and organic acids [46]. Protoplast fusion, cloning, plasmid transfer, and transduction of defined starter cultures were used to explore possibilities to improve anti-cholesterolemic property, defense, resistant against enteropathogenic microorganism, and anti-carcinogenic activities of livestock foods [47]. The fermented dairy products have very good health benefits and influence the intestinal health [48]. *Lactobacillus* strains can be used as potential probiotics for the preparation of fermented dairy and meat products having great health importance [49]. So, the biotechnological tools can be used to produce improved strains of bacteria, yeast, and moulds, which can be used for the preparation of fermented meat and dairy products.

2.4. Biotechnological Applications to Produce Enzymes

Humans have been utilizing enzymes throughout the ages, either in the form of vegetables rich in enzymes, or as microorganisms employed for a variety of purposes, for example in cheese production, baking, and brewing [50]. Today, microorganisms are an important source of commercial enzymes. Biotechnology encompasses the most accurate methods to produce enzymes by optimizing microorganisms. These methods are used to acquire high-yielding enzyme producing organisms [51].

In past decade calf rennet obtained from the fourth stomach of suckling calves was used in cheese manufacturing process. The recent growth in the cheese industry and the scarcity of calf rennet has enthused the research workers for milk clotting enzyme from alternative sources. With the availability of biotechnological tools, many microorganisms are now used to produce proteinases, which can substitute the calf rennet [52]. Microorganisms like *Rhizomucor miehei*, *Aspergillus oryzae*, *Rhizomucor pusillus*, *Irpex lactis*, and *Endothia parasitica*are extensively used for rennet production by cheese manufacturers [53,54]. The aspartyl protease from *Mucor miehei* is commonly used as a chymosin substitute in cheese making [55].

Some individuals might have lactose intolerance and intricacy in consuming milk and dairy products due to less efficiency of intestinal enzyme i.e. β-galactosidase. Some researchers had produced microbial met from different organisms to make it commercially available with low-cost [56]. Successful efforts were made to produce β-galactosidase from *Aspergillus niger* ATCC 9142, *Aspergillus oryzae*, and from *Kluyveromyces lactis* NRRL Y-8279 using response surface methodology [57-59]. Lipases (triacylglycerol acylhydrolases) have been produced by microorganisms individually or together with esterases [60]. Lipase producing microorganisms include: *Pseudomonas aeruginosa, Serratia* *marcescens*, *Staphylococcus aureus*, and *Bacillus subtilis*. Previous reports have noted that various animal or microbial lipases were used to make pronounced cheese flavor, with low bitterness, and strong rancidity, while lipases in combination with proteinases and/or peptidases gave good cheese flavor with low levels of bitterness [61].

2.5. Biotechnology to Increase Shelf Life of Food

Since long time, shelf life of food and beverages are extended by bacterial fermentation of perishable raw materials [62]. Most of the food fermentations involve conversion of sugars to lactic acid by lactic acid bacteria (LAB, which include the genera of *Streptococcus*, *Lactococcus*, *Lactobacillus* and *Pediococcus*). *Lactobacilli* have gained attention nowadays, due to the production of bacteriocins [63]. These substances can be applied in the food industry as natural preservatives. The use of LAB and of their metabolic products is generally considered as safe (GRAS, Grade One) [64]. By providing controlled environment to a specific bacterial culture, bacteriocins of the choice can be obtained. Nisin is the only bacteriocin that has been officially employed in the food industry and its use has been approved worldwide [65]. Not only the use of nisin-producing lactic acid bacteria (LAB) as a fermentation starter culture but also the direct addition of nisin to various kinds of foods, such as cheese, margarine, flavored milk, canned foods, and so on, is permitted [66]. Pediocin PA-1 is another bacteriocin from LAB, which is widely distributed and is more potent in inhibiting the growth of several pathogens associated with food spoilage and food related health hazards so can be explore as a potential food bio-preservative agent [67].Many refrigerated vacuum-packaged processed food products from meat, dairy, fish and vegetable groups contain normally psychrotropic Gram-positive bacterial strains from the genera of *Leuconostoc*, *Lactobacillus*, *Carnobacterium*, *Brochothrix* and *Clostridium* [68]. They are capable of multiplying at refrigerated temperature and causing spoilage of the product. By incorporating pediocin PA-1/AcH during the formulation of the raw product, spoilage problems in the final product could be reduced. Reduction in *Listeria* count was achieved following addition of *Lactobacillus sakei* culture in chilled raw ground meat and chilled cured pasteurized sliced vacuum-packed meats [69-73].

2.6. Biotechnology to Enhance Organoleptic Characteristics of Food

The organoleptic quality of the food can have significant effect in acceptance of food and food products by consumer. The techniques of genetics (selection, molecular biology, transgenesis) and the biotechnologies will play a major role in the evolution of quality mainly for the chemical-nutritional and technological characteristics and for some organoleptic aspects [74]. Microbial cultures used in food production are often referred to as starter cultures that can also enhance the organoleptic quality of foods. A previous research has noted that more than 100 commercial aroma chemicals are derived using biotechnology [75]. Fermented foods are value added products which have higher nutrients, prolong shelf life and easy in digestibility and are more suitable for the intestinal tract [74]. The organoleptic qualities of such foods are higher particularly in terms of flavor, taste, aroma and color [76]. The attraction of producing flavor and color by biotechnology is great. Recombinant DNA technologies have also enhanced efficiency in the production of non-nutritive sweeteners such as aspartame and thaumatin [77]. There is no doubt that some microorganisms can produce flavor and color in food products. The lactic acid bacteria represent a group of genetically diverse but functionally related microorganisms, and are used in the production of a diverse range of foods. The former group, producing much of fermented milk products, includes *Lactococcus lactis* Ssp.*lactis* and *L. lactis* Ssp.*cremoris*, and *Leuconostoc mesenteroides* and *L.dextranicum*. These mesophiles (optimum growth temperature of approximately 30°C) are used to manufacture cheeses such as, Cheddar, Gouda, Camembert, and Cottage, cultured butter, cultured buttermilk and sour cream. The latter group includes *Lactobacillus delbruekii* sp.*bulgaricus*, *Lactobacillus helveticus* and *Streptococcus thermophilus*. These organisms are producing diacetyl compound that is responsible for flavor. These are used in various combinations to produce yoghurt, acidophilus milk and high scalded cheeses such as Emmental, Gruyere and Italian types [78]. At the time of fermentation of sausage some aroma producing volatile compounds were formed from carbohydrate catabolism such as acetic, propionic and butyric acids, acetaldehyde, diacetyl, acetoin, 2, 3-butandiol, ethanol, acetone, 2-propanol and more [79].

2.7. Biotechnological Applications to Enhance Food Safety

Unforeseen and inadvertent compositional changes occur with all forms of genetically engineered foods. The European Food Safety Authority has concluded that bacteria used for or in feed production might pose a risk to human and animal health because of carrying acquired resistance genes [80]. Ensuring as satisfactory level of food quality and safety is utterly indispensable to endow with adequate safeguard for consumers and to facilitate trade. Careful monitoring of microbial contamination in the final product as well as monitoring of the production process and cleaning and sanitation is one of the most essential factors of the manufacturing process in food technology and biotechnology [81]. Proteomics and genomics technologies offer further, more sensitive and specific methods for recognition of microbial food contaminants and their toxins. Various powerful tools of biotechnology, which have already made enormous advances, include genetic engineering, PCR (polymerase chain reaction), random amplified polymorphic DNA (RAPD), amplified fragment length polymorphism (AFLP), rDNA technology, MALDI-TOF MS (matrix associated laser desorption ionization-time of flight mass spectroscopy) etc. [82]. These methods can also help in meat authentication and to check meat speciation. Expansion and development of new novel methods for rapid revealing of emerging high-risk food pathogens in livestock foods is tremendously imperative in context of food safety.

3. Conclusion

Biotechnology has already made significant contributions to livestock, and food industry. Modern biotechnology is helpful in enhancing taste, yield, shelf life, and nutritive values of food. It is also useful in food processing (fermentation and enzyme involving processes). Hence, biotechnology can be used for the benefit of human health, and eliminate hunger, malnutrition and diseases from people living in developing countries, and poor countries. It is imperative to consider any potential human health or environmental risks when foods are developed using biotechnology. It is emphasized to undertake further research for improvement in safety of processed food products. Embracing the potential of biotechnological applications should be done cautiously, keeping in mind the natural ecological niche.

Conflict of Interest

Nil.

References

[1] K R S, V P. Review on production, downstream processing and characterization of microbial pullulan. Carbohydr Polym. 2017; 173: 573-591.

[2] Nielsen JC, Grijseels S, Prigent S et al. Global analysis of biosynthetic gene clusters reveals vast potential of secondary metabolite production in Penicillium species. Nat Microbiol. 2017; 2: 17044.

[3] Ledoux JB, Antunes A. Beyond the beaten path: improving natural products bioprospecting using an eco-evolutionary framework - the case of the octocorals. Crit Rev Biotechnol. 2017 Jun 26:1.

[4] Krasznai DJ, Champagne Hartley R, Roy HM, Champagne P, Cunningham MF. Compositional analysis of lignocellulosic biomass: conventional methodologies and futureoutlook. Crit Rev Biotechnol. 2017 Jun 8: 1-19.

[5] Lucarini S, Fagioli L, Campana R, Cole H, Duranti A, Baffone W, Vllasaliu D, Casettari L. Unsaturated fatty acids lactose esters: cytotoxicity, permeability enhancement and antimicrobial activity. Eur J Pharm Biopharm. 2016 Oct; 107: 88-96.

[6] Nitschke M, Silva SSE. Recent food applications of microbial surfactants. Crit Rev Food Sci Nutr. 2016 Jul 20: 1-8.

[7] Daddiego L, Bianco L, Capodicasa C, Carbone F, Dalmastri C, Daroda L, Del Fiore A, De Rossi P, Di Carli M, Donini M, Lopez L, Mengoni A,Paganin P, Perrotta G, Bevivino A. Omics approaches on fresh-cut lettuce reveal global molecular responses to sodium hypochlorite and peracetic acid treatment. J Sci Food Agric. 2017 Jul 4.

[8] Kamle M, Kumar P, Patra JK, Bajpai VK. Current perspectives on genetically modified crops and detection methods. 3 Biotech. 2017 Jul; 7(3): 219.

[9] Šuster K, Podgornik A, Cör A. Quick bacteriophage-mediated bioluminescence assay for detecting Staphylococcus spp. in sonicate fluid of orthopaedic artificial joints. New Microbiol. 2017 Jul 4; 40(3).

[10] Hamad GM, Taha TH, Hafez EE, El Sohaimy SA, Ali SH. Yeast - Probiotic coctile strains supplemented babies' Cerelac induce highly potential aflatoxins detoxification both in vitro and in vivo in mother and babies albino rats. J Sci Food Agric. 2017 Jul 3.

[11] Lao TD, Nguyen DH, Nguyen TM, Le TAH. Molecular Screening for Epstein-Barr virus (EBV): Detection of Genomic EBNA-1, EBNA-2, LMP-1, LMP-2 Among Vietnamese Patients with Nasopharyngeal Brush Samples. Asian Pac J Cancer Prev. 2017 Jun 25; 18(6): 1675-1679.

[12] Calvo-González E. Low-complexity biotechnology and everyday aspects of "care:" neonatal testing and sickle celldiagnosis in Brazil. Hist Cienc Saude Manguinhos. 2016 Jan-Mar; 23(1): 79-94.

[13] Kavousipour S, Khademi F, Zamani M, Vakili B, Mokarram P. Novel biotechnology approaches in colorectal cancer diagnosis and therapy. Biotechnol Lett. 2017 Jun; 39(6): 785-803.

[14] Swetwiwathana A, Visessanguan W. Potential of bacteriocin-producing lactic acid bacteria for safety improvements of traditional Thai fermented meat and human health. Meat Sci. 2015; 109:101-5.

[15] Nguyen TT, Barber AR, Corbin K, Zhang W. Lobster processing by-products as valuable bioresource of marine functional ingredients, nutraceuticals, and pharmaceuticals. Bioresour Bioprocess. 2017; 4(1): 27.

[16] Lokko Y, Heijde M, Schebesta K, Scholtès P, Van Montagu M, Giacca M. Biotechnology and the bioeconomy-Towards inclusive and sustainable industrial development. N Biotechnol. 2017 Jun 27. pii: S1871-6784(16): 32620-6.

[17] Zhu H, Liu J, Cui C, et al. Targeting Human α-Lactalbumin Gene Insertion into the Goat β-Lactoglobulin Locus by TALEN-Mediated Homologous Recombination. Isalan M, ed. *PLoS ONE*. 2016; 11(6): e0156636.

[18] Song D, Xiong X, Tu WF, Yao W, Liang HW, Chen FJ, He ZQ. Transfer and expression of the rabbit defensin NP-1 gene in lettuce (Lactuca sativa). Genet Mol Res. 2017 Jan 23; 16(1).

[19] Srinivasa V. and Goswami S.L. (2007). Transgenic farm animals – A mobile pharmaceutical industry. *Indian Dairyman.* 59: 26-32.

[20] Cima G. GE salmon gains FDA approval. J Am Vet Med Assoc. 2016 Jan 1; 248(1): 25.

[21] F.Forabosco, M.Löhmus, L.Rydhmer. Genetically modified farm animals and fish in agriculture: A review. Livestock Science 2013; 153 (1-3): 1-9.

[22] Brophy, B., Smolenski, G., Wheeler, T., Wells, D., L'Huilier, P. and Liable, G. (2003). Cloned transgenic cattle produce milk with higher levels of b-casein and k-casein. *Nature Biotechnology*, 21: 157-162.

[23] Niemann, H. (2004). Transgenic pigs expressing plant genes. *Proceedings of the National Academy of Sciences of the United States of America*, *101*: 7211-7212.

[24] De Vries, A. G., Sosnicki, A., Garnier, J. P. and Plastow, G. S. (1998). The role of major genes and DNA technology in selection for meat quality in pigs. *Meat Science*, *49*: 245-255.

[25] Grobet, L., Martin, L. J. R., Poncelet, D., Pirottin, D., Brouwers, B., Riquet, J. and Fries, R. (1997). A deletion in the bovine myostatin gene causes the double–muscled phenotype in cattle. *Nature Genetics*, *17*: 71-74.

[26] Fang, M., Nie, Q., Luo, C., Zhang, D. and Zhang, X. (2007). An 8bp indel in exon 1 of Ghrelin gene associated with chicken growth. *Domestic Animal Endocrinology*, *32*: 216-225.

[27] Huang, Y., Du, X., Deng, X., Qiu, X., Wang, C., Chen, W. and Wu, C. (2007). Single nucleotide polymorphisms in chicken lmbr1 gene were associated with chicken growth and carcass traits. *Science in China Series C: Life Sciences*, *50*: 62-69.

[28] Feng, X. P., Kuhnlein, U., Aggrey, S. E., Gavora, J. S. and Zadworny, D. (1997). Trait association of genetic markers in the growth hormone and the growth hormone receptor gene in a White Leghorn strain. *Poultry science*, *76*: 1770-1775.

[29] Jiang, S. W., Jacobsson, L., Kerje, S., Andersson, L. and Xiong, Y. Z. (2002). Studies of relationship between the melanocortin-3 receptor gene and body weight in chicken for high and low weight lines' intercross. *Yi chuan xue bao= Acta Genetica Sinica*, *29*: 322-325.

[30] Qiu, X., Li, N., Deng, X., Zhao, X., Meng, Q. and Wang, X. (2006). The single nucleotide polymorphisms of chicken melanocortin-4 receptor (MC4R) gene and their association analysis with carcass traits. *Science in China Series C: Life Sciences*, *49*: 560-566.

[31] Yan, B. X., Li, N., Deng, X. M., Hu, X. X., Liu, Z. L., Zhao, X. B. and Wu, C. X. (2002). Single nucleotide polymorphism analysis in chicken insulin-like growth factor-II gene and its associations with growth and carcass traits. *Yi chuan xue bao= Acta genetica Sinica*, *29*: 30-33.

[32] Li, H., Deeb, N., Zhou, H., Ashwell, C. M. and Lamont, S. J. (2002). Chicken QTLs for growth, body composition, and metabolic factors associated with TGF-beta family genes. In *Abstract of a poster presented at the Plant, Animal and Microbe Genomes X Conference*.

[33] Cashman KD, Hayes A. Red meat's role in addressing 'nutrients of public health concern'. Meat Sci. 2017 Oct; 132: 196-203.

[34] Bhat ZF, Kumar S, Bhat HF. In vitro meat: A future animal-free harvest. Crit Rev Food Sci Nutr. 2017; 57(4): 782-789.

[35] Cruickshank, E. M. (1934). Studies in fat metabolism in the fowl: The composition of the egg fat and depot fat of the fowl as affected by the ingestion of large amounts of different fats. *Biochemical Journal*, 28: 965.

[36] Arai, S. (1996). Studies on functional foods in Japan—State of the art.*Bioscience, biotechnology, and biochemistry*, *60*(1): 9-15.

[37] Surai, P. F. and Sparks, N. H. C. (2001). Designer eggs: from improvement of egg composition to functional food. *Trends in Food Science and Technology*, *12*: 7-16..

[38] Sim, J. S. and Sunwoo, H. H. (2002). Designer eggs: nutritional and functional significance. *Eggs and health promotion*, 19-35.

[39] Raes, K., Huyghebaert, G., De Smet, S., Nollet, L., Arnouts, S., and Demeyer, D. (2002). The deposition of conjugated linoleic acids in eggs of laying hens fed diets varying in fat level and fatty acid profile. *The Journal of Nutrition*, *132*: 182-189.

[40] Jiang, Y. H., McGeachin, R. B. and Bailey, C. A. (1994). α-Tocopherol, β-carotene, and retinol enrichment of chicken eggs. *Poultry Science*, *73*: 1137-1143.

[41] Rajasekaran, A., and Kalaivani, M. (2013). Designer foods and their benefits: A review. *Journal of Food Science and Technology*, *50*: 1-16.

[42] Sabikhi, L. (2007). Designer milk. *Advances in Food and Nutrition Research*, *53*: 161-198.

[43] Fisinin, V. I., Papazyan, T. T., and Surai, P. F. (2009). Producing selenium-enriched eggs and meat to improve the selenium status of the general population. *Critical Reviews in Biotechnology*, *29*:18-28.

[44] Fisinin VI, Papazyan TT, Surai PF. Producing selenium-enriched eggs and meat to improve the selenium status of the general population. Crit Rev Biotechnol. 2009; 29(1): 18-28.

[45] Holzapfel, W. H. (2002). Appropriate starter culture technologies for small-scale fermentation in developing countries. *International Journal of Food Microbiology*, *75*: 197-212.

[46] Hutkins, R. W. (2006). Fermented vegetables. *Microbiology and Technology of Fermented Foods*, 223-259.

[47] Singhal, R.S. and P.R. Kulkarni. (1990). Studies on applicability of *Amaranthus paniculatas* (Rajgeeraa) starch for custard preparation. Starch/Starke 42:102-103.

[48] Berni Canani R, De Filippis F, Nocerino R. Specific signatures of the gut microbiota and increased levels of butyrate in children treated withfermented cow's milk containing heat-killed Lactobacillus paracasei CBA L74. Appl Environ Microbiol. 2017 pii: AEM.01206-17.

[49] Pennacchia, C., Vaughan, E. E. and Villani, F. (2006). Potential probiotic Lactobacillus strains from fermented sausages: Further investigations on their probiotic properties. *Meat Science*, *73*: 90-101.

[50] Jiang J, Chen S, Ren F, Luo Z, Zeng SS. Yak milk casein as a functional ingredient: preparation and identification of angiotensin-I-converting enzyme inhibitory peptides. J Dairy Res. 2007 Feb; 74(1): 18-25.

[51] Yamaguchi S. The quest for industrial enzymes from microorganisms. Biosci Biotechnol Biochem. 2017 Jan; 81(1): 54-58.

[52] Sun Q, Wang XP, Yan QJ, Chen W, Jiang ZQ. Purification and characterization of a chymosin from Rhizopus microsporus var. rhizopodiformis. Appl Biochem Biotechnol. 2014 Sep; 174(1): 174-85.

[53] Escobar, J. and Barnett, S. (1993). Effect of agitation speed on the synthesis of *Mucor miehei* acid protease. *Enzyme and Microbial Technology*. 15: 1009-1013.

[54] Neelakantan, S., Mohanty, A. K. and Kaushik, J. K. (1999). Production and use of microbial enzymes for dairy processing. *Current Science*, 77: 143-148.

[55] Thakur, M. S., Karanth, N. G. and Nand, K. (1990). Production of fungal rennet by Mucor miehei using solid state fermentation. *Applied Microbiology and Biotechnology*, 32: 409-413.

[56] Hildebrandt P, Wanarska M, Kur J. A new cold-adapted beta-D-galactosidase from the Antarctic Arthrobacter sp. 32c - gene cloning, overexpression, purification and properties. BMC Microbiol. 2009 Jul 27; 9: 151.

[57] Kazemi, S., Khayati, G. and Faezi-Ghasemi, M. (2016). β-galactosidase Production by *Aspergillus niger* ATCC 9142 Using Inexpensive Substrates in Solid-State Fermentation: Optimization by Orthogonal Arrays Design. *Iranian Biomedical Journal*, 20: 287–294.

[58] Nizamuddin S, Sridevi A, Narasimha G. Production of β-galactosidase by Aspergillus oryzae in solid-state fermentation. Afr J Biotechnol. 2008; 7:1096-1100.

[59] Dagbagli, S., and Goksungur, Y. (2008). Optimization of b-galactosidase production using Kluyveromyces lactis NRRL Y-8279 by response surface methodology. *Electronic Journal of Biotechnology*, 11: 11-12.

[60] Shah AK, Nagao T, Kurihara H, Takahashi K. Production of a Health-Beneficial Food Emulsifier by Enzymatic Partial Hydrolysis of Phospholipids Obtained from the Head of Autumn Chum Salmon. J Oleo Sci. 2017 Feb 1; 66(2): 147-155.

[61] Shinde, V. B. Deshmukh, S. B. and Bhoyar, M. G. (2015). Applications of major enzymes in food industry. *Indian Farmer*, 2: 497-502.

[62] CHAPTER 5: BACTERIAL FERMENTATIONS. http://www.fao.org/docrep/x0560e/x0560e10.htm, Last accessed July1, 2017.

[63] Collins FWJ, O'Connor PM, O'Sullivan O, Gómez-Sala B, Rea MC, Hill C, Ross RP. Bacteriocin Gene-Trait matching across the complete Lactobacillus Pan-genome. Sci Rep. 2017 Jun 14; 7(1): 3481.

[64] Patel A, Prajapati JB (2013) Food and Health Applications of Exopolysaccharides produced by Lactic acid Bacteria. Adv Dairy Res 1: 107.

[65] Kaškonienė V, Stankevičius M, Bimbiraitė-Survilienė K, Naujokaitytė G, Šernienė L, Mulkytė K, Malakauskas M, Maruška A. Current state of purification, isolation and analysis of bacteriocins produced by lactic acidbacteria. Appl Microbiol Biotechnol. 2017 Feb; 101(4): 1323-1335.

[66] Delves-Broughton, J. (1990). Nisin and its application as a food preservative. *International Journal of Dairy Technology*, *43*: 73-76.

[67] Rodríguez, J. M., Martínez, M. I. and Kok, J. (2002). Pediocin PA-1, a wide-spectrum bacteriocin from lactic acid bacteria. *Critical Reviews in Food Science and Nutrition*, *42*: 91-121.

[68] Extended Shelf Life Refrigerated Foods: Microbiological Quality and Safety. http://www.ift.org/knowledge-center/read-ift-publications/science-reports/scientific-status-summaries/extended-shelf-life-refrigerated-foods.aspx. Last Accessed July 1, 2017.

[69] Yang, R. and Ray, B. (1994). Factors influencing production of bacteriocins by lactic acid bacteria. *Food Microbiology*, *11*: 281-291.

[70] Ennahar, S., Assobhei, O. and Hasselmann, C. (1998). Inhibition of Listeria monocytogenes in a smear-surface soft cheese by Lactobacillus plantarum WHE 92, a pediocin AcH producer. *Journal of Food Protection*, *61*: 186-191.

[71] Krockel, L. and Schmidt, U. (1994). Hemmung von Listeria monocytogenes in vakuum verpacktem Bruehwurstaufschnitt durch bacteriocinoge Schutzkulturen. *MITTEILUNGSBLATT-BUNDESANSTALT FUR FLEISCHFORSCHUNG KULMBACH*, *1*: 428-428.

[72] Hugas, M., Pages, F., Garriga, M. and Monfort, J. M. (1998). Application of the bacteriocinogenic Lactobacillus sakeiCTC494 to prevent growth of Listeria in fresh and cooked meat products packed with different atmospheres. *Food Microbiology*, *15*: 639-650.

[73] Devi SM, Halami PM. Detection and characterization of pediocin PA-1/AcH like bacteriocin producing lactic acid bacteria. Curr Microbiol. 2011 Aug; 63(2): 181-5.

[74] Smaldone G, Marrone R, Zottola T, Vollano L, Grossi G, Cortesi ML. Formulation and Shelf-life of Fish Burgers Served to Preschool Children. *Italian Journal of Food Safety*. 2017; 6(1): 6373.

[75] Berger, R. G. (2009). Biotechnology of flavours—the next generation. *Biotechnology letters*, *31*: 1651-1659.

[76] Singh, V. P., Pathak, V. and Verma, A. K. (2012). Fermented meat products: organoleptic qualities and biogenic amines–a review. *American Journal of Food Technology*, *7*: 278-288.

[77] FAO International Technical Conference (2010). Current status and options for biotechnologies in food processing and in food safety in developing countries. http://www.fao.org/docrep/meeting/019/k6993e.pdf.

[78] Coffey, A. G., Daly, C. and Fitzgerald, G. (1994). The impact of biotechnology on the dairy industry. *Biotechnology advances*, *12*: 625-633.

[79] Awan, U. F., Shafiq, K., Mirza, S. and Ali, S. (2003). Mineral constituents of culture medium for lipase production by Rhizopus oligosporous fermentation. *Asian Journal of Plant Sciences*, 2: 913-915.

[80] European Food Safety Authority (2007). Introduction of a Qualified Presumption of Safety (QPS) approach for assessment of selected microorganisms referred to EFSA. *The EFSA Journal*, 587: 1-16.

[81] Ochoa, M. L. and Harrington, P. B. (2005). Immunomagnetic Isolation of Enterohemorrhagic Escherichia coli O157: H7 from Ground Beef and Identification by Matrix-Assisted Laser Desorption/Ionization Time-of-Flight Mass Spectrometry and Database Searches. *Analytical Chemistry*, *77*: 5258-5267.

[82] Naveena BM, Jagadeesh DS, Jagadeesh Babu A, Madhava Rao T, Kamuni V, Vaithiyanathan S, Kulkarni VV, Rapole S. OFFGEL electrophoresis and tandem mass spectrometry approach compared with DNA-based PCR method for authentication of meat species from raw and cooked ground meat mixtures containing cattle meat, water buffalo meat and sheep meat. Food Chem. 2017; 233: 311-320.