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Advances in Enzyme Technology for Food Processing and Preservation : A Review

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Abstract: *Enzymes are biological catalysts which are essential for the modern food processing industries because of their specificity, efficiency and bioconsciousness. They are used in a wide variety of applications, such as baking, dairy, brewing, starch processing, fruit juice clarification, meat tenderisation and food preservation. Enzymes enhance food quality, flavour, texture, nutritional value and shelf life, and decrease energy use and processing time. The microbial enzymes, particularly amylases, proteases, lipases, pectinases, cellulases and lactases, have been widely used due to their low-cost production, and their stability in industrial processes. Their applications in industry and processing ability have been further improved by recent developments in recombinant DNA technology, enzyme engineering, and biotechnology. The chapter summarizes the classification, microbial sources and mechanisms of enzymes, their industrial applications, advantages and future perspectives in the food industry. The chapter also highlights the significance of enzymes in sustainable food processing and future developments of enzyme technology in the modern food systems.*

Keywords: Enzymes, Food processing, Microbial enzymes, Biocatalysts, Food biotechnology, Baking industry, Dairy industry, Sustainable food processing

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1. Introduction

Biological catalysts, which are called enzymes, are extremely specific and increase the rate of biochemical reactions without being permanently changed in the course of the reaction. Enzymes have the name "*zymase*," which came from the Greek word "*zymos*" meaning "in yeast". Enzymes are proteins which are primarily produced by plants, animals and microorganisms; they have an important role in metabolic and biochemical pathways. Enzymes have become a great importance in the industrial biotechnology, especially in food processing industries because of their catalytic efficiency and specificity toward the substrate.

The use of enzymes in food processing goes back thousands of years by traditional methods of food fermentation such as bread, cheese, beer, wine, fermented milk and milk products. Although early civilizations were unaware of the scientific basis of enzymatic activity, they effectively used enzymatic fermentation in food preservation and product development. Enzymes were first scientifically recognized during the nineteenth century, when Eduard Buchner showed that the enzymatic digestion of sugars to ethanol could be achieved by extracts of yeast. Later, James B. Sumner was able to crystallize urease enzyme in 1926, thus establishing the protein nature of enzymes [1].

Enzymes are widely used in modern food industries for the enhancement of processing efficiency, product quality, texture, flavor, aroma, nutritional value and shelf stability. During the last century, biotechnology and microbial fermentation technologies made it possible to produce enzymes on a large scale for commercial use. The industrial applications of microbial enzymes are the most prevalent today, due to their rapid growth, ease of genetic manipulation, cost-effective production, and high enzyme production by microorganisms. The common microbial sources are Aspergillus spp., Bacillus spp., Candida spp., and Trichoderma spp [7]. Food enzymes find extensive applications in bakery, dairy, brewing, fruit juice, starch, confectionery and meat industry. Specialized enzymes, like amylases, proteases, lipases, pectinases, cellulases, lactases and glucose isomerases, are used in food processing. Amylases convert starch into fermentable sugars in baking and brewing, proteases promote the ease with which doughs are handled and improve meat tenderization and pectinases aid in juice extraction and clarification. Similarly, lactase is used in lactose free dairy products, and lipases help develop the flavor of cheese [9].

Enzymes can be generally categorized as exogenous or endogenous enzymes in food systems. Exogenous enzymes are added externally to the food during the process of food processing for improving the technological properties and quality of the food products. The enzymes are added intentionally to alter carbohydrates, proteins, lipids and other food components. Naturally occurring enzymes, however, are found within food materials and affect ripening, maturation, browning and fermentation processes, as compared to the exogenous enzymes. Endogenous enzymes have a positive effect on flavour and texture development but can also cause undesirable effects like enzymatic browning and nutrient degradation. Enzyme technology is becoming increasingly important in food industries due to the rising demand from consumers for minimally processed, healthy, clean label and sustainable food products. Enzymes have several advantages over chemical processing methods as they are biodegradable, environmentally friendly, energy-efficient and specific. In addition, the recent advances in recombinant DNA technology, protein engineering, immobilization technology, and enzyme modification have made them increasingly

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useful in industries and stable for use under extreme processing conditions.

Hence, enzymes are essential tool in modern food technology and are playing key role in the enhancement of food quality, food safety, sustainability and industrial productivity [4].

2. Classification of Enzymes Used in Food Industry

The food enzymes are generally classified according to their origin, catalytic activity and industrial uses. Enzymes can be endogenous or exogenous, by their source.

2.1 Exogenous Enzymes

The enzymes added externally are enzymes that are intentionally added to the food or raw materials when the product is being processed, called exogenous enzymes. The enzymes are primarily obtained from microbial ferment processes that are found to be bacteria, fungi and yeasts. They are mainly used to enhance food quality and digestibility, shelf life, and processing efficiency [4].

Functions of Exogenous Enzymes

The quality of the dough used in baking is improved.

- Clarification of fruit juices
- Properly enhancing the flavor of the cheese.
- The development of lactose-free dairy products.
- Lactose-free dairy product production.
- Removal of oxygen from foods for preservation
- Starch is broken down to starch sugar and proteins to polypeptides by hydrolysis.

These include α-amylase, protease, lipase, pectinase, glucose oxidase and lactase.

2.2 Endogenous Enzymes

The endogenous enzymes are the enzymes which are present naturally in the food material and affect the physiological changes during post-harvests like ripening, browning and fermentation. These enzymes can either have a positive or negative effect on food quality.

The Endogenous Enzymes perform the following functions:

- Fruit ripening
- The development of flavor and aroma in the product.
- Fermentation processes
- Nutrient digestion

Other enzymes in the plant (endogenous) may produce undesirable browning and spoilage in fruits and vegetables, however, such as polyphenol oxidase & peroxidase.

3. Microbial Sources of Food Enzymes

Microorganisms are the chief naturally occurring sources for the production of food enzymes due to their fast growth rate, high enzyme production, and ease of down stream processing. The main microorganisms used are species of fungi like Aspergillus niger and Trichoderma reesei, species of bacteria like Bacillus subtilis, and species of yeast like *Kluyveromyces lactis.*

Enzyme	**Microbial Source**	**Food Application**
α-Amylase	*Aspergillus spp.*, *Bacillus spp.*	Bread making, starch hydrolysis
Protease	*Bacillus subtilis*	Meat tenderization, cheese processing
Lipase	*Candida spp.*	Cheese flavor

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Enzyme	Microbial Source	Food Application
		enhancement
Pectinase	*Aspergillus niger*	Juice clarification
Lactase	*Kluyveromyces spp.*	Lactose-free milk
Cellulase	*Trichoderma spp.*	Juice extraction
Glucose Isomerase	*Streptomyces spp.*	High fructose corn syrup

(Source adapted from Whitehurst and Law, 2002)

4. Application of Enzymes in the food industry

4.1 Baking Industry

Baking industry is one of the big food enzyme consuming industries. Amylases, xylanases, proteases and lipases are enzymes that enhance dough handling, fermentation, bread volume, crumb softness and shelf life. Amylases break starch into fermentable sugars which aid in the development of the yeast and enhance loaf quality. Proteases break down gluten and enhance the extensibility of dough [2].

4.2 Dairy Industry

Mostly enzymes are used in dairy industry in cheese manufacturing, lactose hydrolysis and flavour development. Lactase is an enzyme that breaks down lactose into glucose and galactose, creating a lactose-free milk product that is suitable for lactose-intolerant people. The lipases help to give cheese its characteristic flavor after the cheese is ripened. Milk coagulation is used to make cheese, and the proteases used are chymosin, etc. [2].

4.3 Brewing Industry

Enzymes are used in brewing to help break down starch, hydrolyse proteins, lower viscosity, and enhance fermentation. α-Acetolactate decarboxylase (ALD) shortens the maturation time and enhances the beer quality [6].

4.4 Fruit Juice Industry

In fruit juice processing, commonly used enzymes for juice extraction, juice clarification, filtration and juice yield are pectinases, cellulases and hemicellulases. These enzymes break down the components of plant cell walls and decrease the viscosity of the juice [5].

4.5 Meat Industry

Meat tenderizer is performed by using the protease enzymes papain, bromelain and ficin which degrade the proteins in muscle tissues and connective tissues. Meat products can be made more tender and better in their sensory qualities by enzymatic tenderization [6].

4.6 Starch and Sweetener Industry

Amylases, pullulanases, glucose isomerases are commonly employed proteins in the hydrolysis of starch and production of sweeteners. In the production of high fructose corn syrup, glucose is converted to fructose with the aid of glucose isomerase (GIF) [3].

5. Advantages of Enzymes in Food Processing:

An advantage of enzymes in food and beverage processing is: In contrast to conventional chemical processing methods, enzymes offer a number of benefits:

- High catalytic efficiency
- Substrate specificity
- Reduced energy requirements Green, environmentally friendly and degradable

- Economic gain and better food quality and nutrition value
- Increased shelf life
- Reduced processing time
- Lower chemical usage
- Enzymes are active only under mild pH and temperature,

Thus they can help to retain the nutritional and sensory properties of food products.

6. Advances in Enzyme Technology

Enzymes have been transformed by recent advancements in biotechnology and have found their applications in food industries. The use of recombinant DNA technology, protein engineering, enzyme immobilization, and metagenomics have facilitated the creation of very thermostable and active enzymes for use in industrial applications. Immobilized enzymes offers greater operational stability, reusability and increased catalytic activity. Moreover, multienzyme systems and bioinspired enzyme engineering are new and promising fields that can enhance the processing efficiency and sustainability in food production. Incorporation of artificial intelligence and computational modelling into enzyme engineering is also being used for predicting enzyme structure, working substrate specificity and industrial performance. These technologies should speed the development of enzymes tailored for specific foods.

7. Challenges Associated with Food Enzymes

The challenges of using food enzymes are discussed in this unit.This unit examines the challenges of food enzymes. Although enzymes have many benefits in the food industry, there are various problems associated with them:

- High cost of production of purified enzymes.
- The stability restrictions to extreme processing conditions.
- Regulatory approval requirements
- Potential allergenicity concerns
- Consumers' acceptance for GM enzyme sources.

Many research efforts are ongoing to address these limitations by enzyme immobilization, protein engineering and the development of new microbial strains.

8. Future Prospects

The enzyme technology in food industries is promising as the demand for sustainable and clean food products is increasing. With the development of new synthetic biology, recombinant technology, nanobiotechnology, and enzyme immobilization methods, the potential for industrial applications is further expected to grow. Enzymes will also be significant in waste reduction, energy efficient processing, food preservation and development of functional foods. Furthermore, enzymes produced using precision fermentation and engineered microbial systems are expected to transform the enzyme industry in the years ahead [8].

9. Conclusion

The use of enzymes has gained great importance in the modern food processing industries because of their efficiency, specificity and environmentally friendly nature. These bring about substantial enhancements of food quality, flavour and texture, nutritional value, digestibility, food shelf life, energy saving and reduction of food processing time. Commercial applications are dominated by microbial enzymes due to their commercial viability and

stability. The applications of enzymes in food systems are continually growing due to their biochemical advances and enzyme engineering. Hence, enzyme technology is a sustainable and innovative method to enhancing the efficiency of food processes and ensure high quality food production in the coming future.

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