ADVANCED ENZYME TECHNOLOGY

APPLICATION OF INDUSTRIAL ENZYMES

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Chapter Description

- Expected Outcomes
  - To describe about the global market of enzyme.
  - To Discuss about the enzymes application in most important industries including food, textile and detergent.

Content

- Introduction
- Enzyme global market
- Industrial application of enzymes
  - Overall
  - Food Industry
  - Detergent Industry
  - Textile Industry

INTRODUCTION

- **Industrialist** were **among the first** to **recognise and explore** the great **potential of enzymes**, for they realized if reaction could be speed up, production processes could be performed in only **a fraction of the normal time**, or at **lower temperatures** or **pressures** or using cheaper starting materials.

- In other situations, enzymes made certain reaction commercially viable for the first time.

- Today the global market for industrial enzymes is growing rapidly. Emergence of a number of new applications that required enzyme usage have been reported such as paper, food and feed, agriculture, textiles and leather industries.

INTRODUCTION…

- **chemistry and pharma industries** also incorporate **enzyme technology** which benefit **raw materials, energy, health** and the **environment**.

- In general, the **use of enzymes** is very **safe, cost effective**, and is regarded as a **green** or environmentally friendly technology.

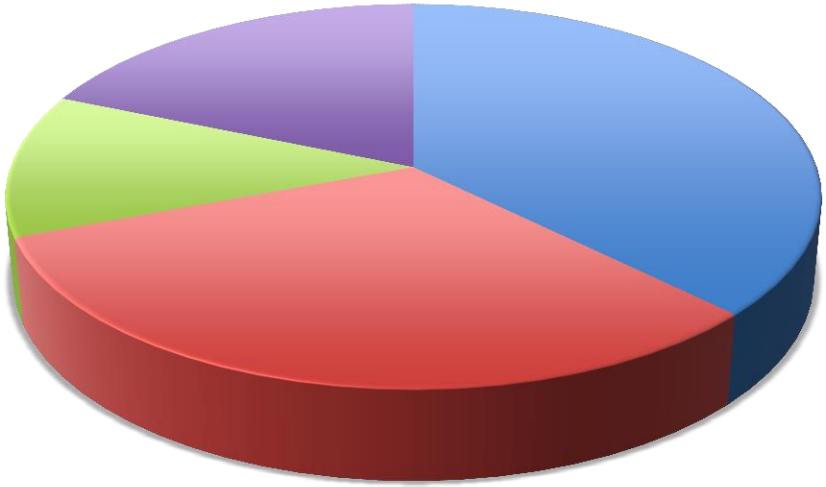
Uses of enzymes

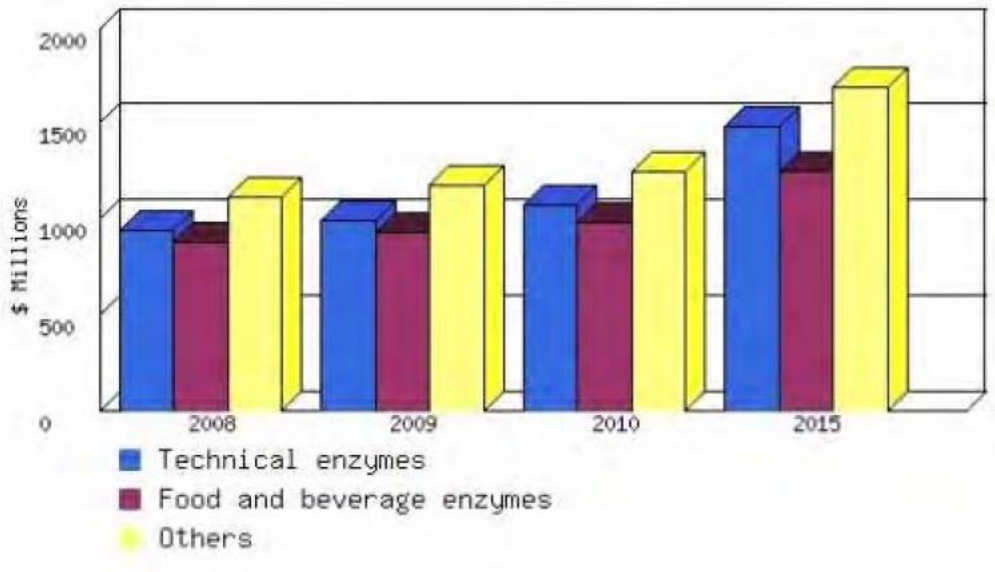
- commercial uses
- medical uses
- industrial uses

Global Market

- In 2010, $3.3 billion is predicted to become the value for the global market of industrial enzymes and estimated to reach $4.4 billion in 2015.
- The market segmentation of enzymes can be divided into:
  - **food and animal feed** (**34%**)
  - **detergent and cleaners** (**29%**).
  - **Pulp and paper (11%)**
  - **textile, leather and fur (17%**)

Estimated Global market for technical enzymes





Global industrial enzymes market , 2008-2015 (source : BCC research).

Enzymes and other proteins are part of everyday life

Examples of enzymes and other commercial proteins

Wastewater treatment
- Environmentally-friendly treatment of organic and toxic waste

Enzyme market size $50mm+[1]

Biopharmaceuticals
- Used to fight diseases such as rheumatoid arthritis and diabetes

Enzyme market size $800mm+[1]

Food and beverage
- Improves flavor/quality
- Facilitates digestion, improves nutritional value and reduces potential allergic reactions

Enzyme market size $1bn

Detergents
- Enhance detergents' characteristics such as cleaning ability, color fading prevention and performance at gentler washing
- Less energy needed for cleaning

Enzyme market size $750mm

Bio-based chemicals
- Reduce use of petroleum-based products
- Reduce pollution and improve product safety

End market size $10bn[2]

Cosmetics and personal care
- Enhance quality/properties of toiletry products
- Increase the moisturizing factor of ingredients in cosmetics
- Reduce usage of chemical load

Active ingredient market size $550mm

Pulp & paper
- Used for bleaching, refining, de-inking and the removal of adhesives
- Enhance desired characteristics such as strength, bulk or softness
- Reduce usage of water, energy

Enzyme market size $50mm[1]

Biofuels
- Reduce use of petroleum-based products
- Large existing food-based ethanol market
- Developing cellulosic biofuel market positioned for rapid growth

Food-based market size $600mm
Cellulosic market size $5bn[3]

Textiles/Leather
- Used in the production of fabrics for clothing, furniture and other household items
- Replaces conventional chemical methods

Enzyme market size $350mm

Nutraceuticals
- Dietary supplements, herbal products, processed foods

End market size $20bn

Animal health & nutrition
- Improve the digestibility of dietary components

Enzyme market size $600mm

Legend

Existing company markets with additional growth opportunities	Markets readily penetrable by company technologies

Source: Freedonia Group, Frost & Sullivan, Verenium press releases, equity research, company estimates
Note: Market size numbers represent latest available current global estimates, unless otherwise indicated
[1] US market size only; [2] Total market for bio-based chemicals; [3] Projected 2022 cellulosic biofuels enzyme market

ENZYMES IN THE HOME

- Often without realising, we use enzymes around the home most of the time.

- Examples:
  - proteinase enzyme in contact lens cleaners, 'biological' detergents or even if you put pineapple to soft the meat during cooking.
  - home-made bread preparation. Many commercial preparations of yeast contain a purified xylanase, which responsible to make bread heavy. In addition, the yeast, *Saccharomyces cerevisiae*, that have been put during bread making will utilize its own a-and ß-amylases to hydrolyse the starch in the flour that will lead into bread rise.
  - Enzymes also can be found in food in our kitchen for example in cheese, yoghurt, beer and wine. Many food additives and sugars are also produced by enzymes.

leather goods

- **Proteinases:** Produce more pliable leather products and usually involve in the process known as leather 'bating' treatment.
- **Lipase:** involve in the recent process of leather degreasing in which this enzyme will degrade the fats.
- **Keratinase:** used in the dehairing process of leather that can replaced the used of extremely toxic sodium sulphide.

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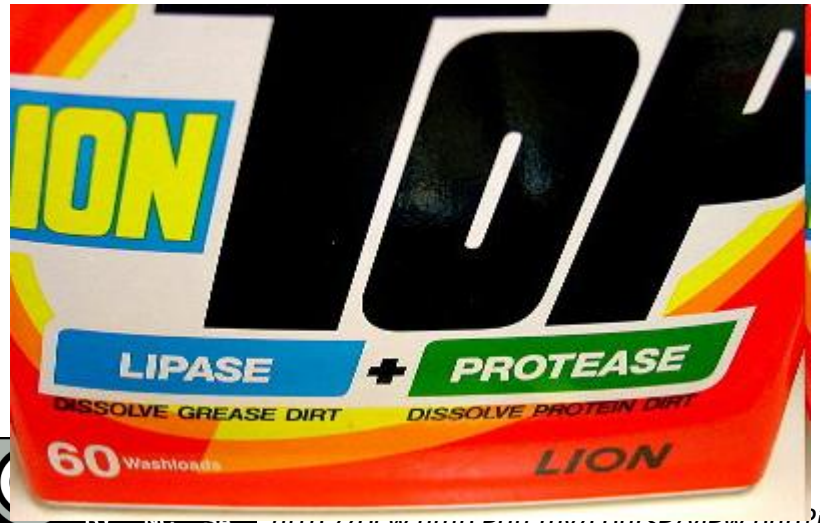
Biological detergents

- Washing can even be done at **lower temperature**

- **Stains** that caused by the insoluble and coloured proteins can be degraded by **proteases** into smaller, colourless soluble polypeptides.



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Beer production

- Industrial enzymes (**amylase, proteinase, xylanase, glucanase**): For production of beer with low-carbohydrate property, to reduce the time for maturation and beer production from produce beer from low cost raw materials.

Bread making

- **Amylase** allows dough to rise properly during the proofing period and also permit the loaves to increase in the normal volume (oven spring) during baking.

- Moreover, amylase assists in the optimal crust colour development that is very essential contributor to good taste. Amylase also can extend the bread's shelf life. bread.

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Cheese making

- **rennet** or bovine chymosin: traditionally important in dairy industry as a milk-clotting agent for the production of cheeses with high quality, good taste and better texture properties.

Baby Food

Proteases: pre- digest proteins for the baby.

Medicine

- **Lipase** is put in capsules for people with pancreatic disease

- The enzyme **streptokinase** is injected into heart attack patients to dissolve blood clots

- Enzymes are used to treat blood cancer in children

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Juice extraction

- **Pectinase:** permit better **juice extraction** by breaking down apple cell walls substances.

- Generally, extracted juices from ripe fruit encompass a large number of pectin that cause a cloudy look.
- **Pectinase will perform on pectin** resulted into a crystal clear juice with preferable characteristics of look, taste mouth-feel, stability and texture.

Chocolate

- **Isomerase:** Produce another type of sugar, **fructose,** from **glucose**.
  - Fructose is needed in smaller quantity rather than glucose due to its **sweeter** properties.
  - Become as a preferred element in **slimming** foods (fructose syrup).
- **Invertase:** used in soft-centered chocolates production by breaking down sucrose into its simple sugars glucose and fructose. Initially, The center comprises **sucrose** (cane sugar) and is hard.
- The used of invertase will produce chocolate with the **soft** and **runny** centre.

Food Industry

- Enzyme usage in the food industry includes **a variety of outcomes** which ranging from **texturizing to flavouring for example**:
  - The manufacture of **food elements** including flavours and fragrances,
  - The **control** of colour, texture, appearance and nutritive value.

- **Main application of enzymes in food**:
  - Production of glucose from starch with **larger yields, higher purity and simple crystallisation** characteristics by using **glucoamylase.**
  - Invention of **immobilised glucose isomerase** enabling the starch hydrolysis for **manufacturing of high-fructose corn syrups**.
  - The use of **amylase** to **extend the shelf life of bread and cakes**.
  - The use of **protease** in the **tenderisation of meat**.

ENZYMES GET THE JOB DONE

Enzyme can be utilize to extend the freshness of bread, to improve the browning of the crust, to guarantee an enough amount of fermentable sugars in frozen dough, to break down the pentosans in rye and wheat flour which hinder the development of gluten, and many more.

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Detergent industry

- Contribute the **biggest application of industrial enzymes**, (**volume** and **value)**.

- **proteases represent large elements – for removal of stain (protein)**

- **However, other hydrolases are also introduced to offer others various profits**, including the effective elimination of particular stains for example:
  - **Amylase**: Starch stain removal
  - **Lipase**: Lipid stain removal
  - **Cellulase**: Cleaning, color clarification, anti-redeposition (cotton)
  - **Mannanase**: Mannanan stain removal (reappearing stains)

Detergent industry…

- In addition, enzymes usage in detergent industry can also offers consumers with **well established advantages**- both in the **washing process itself** and in terms of the **wider environment**.

- Enzymes have proven to **reduce the environmental load** of detergent products since they:
  - **Enable lower wash** at the same time keeping washing performance **: Save energy and CO2 emissions**
  - Partly **replace other chemicals** in detergents including surfactants
  - **Assist compaction**: lessening costs for packaging and transportation
  - **biodegradable**: leaving no toxic residues
  - Give **no negative environmental impact** on sewage treatment processes
  - Preserve **aquatic life- no risk, safe**

Laundry washing is one of the activities that **consume the most energy in an ordinary household**. By washing at **30 rather than 60 or 40 degrees**, the **annual CO2 savings** potential in Europe is **around 12 million tons** – equivalent to the **emission of 3 million cars.**

Detergent industry…

- continuously, **new and improved engineered** versions of **proteases and amylases** which is the '**traditional**' detergent enzymes, are **developed**.

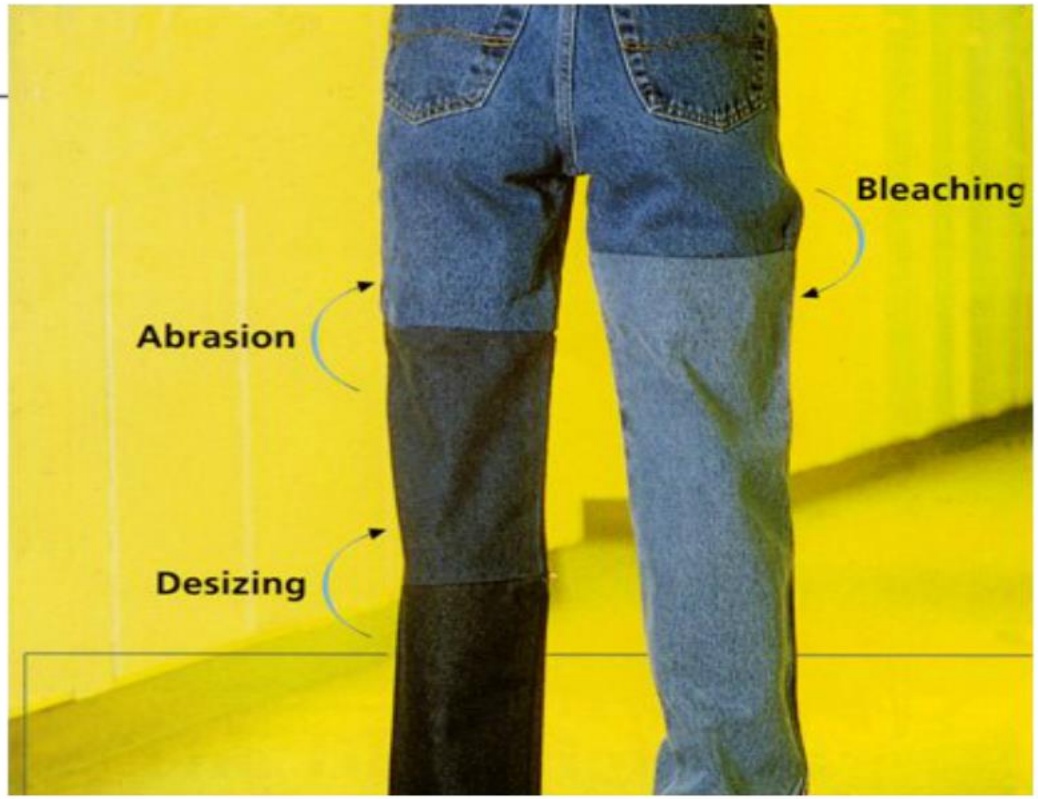
- These **new second- and third-generation enzymes** are **optimized** to meet the requirements for performance in detergents.

Detergent industry…

- Current examples of second-generation detergent enzymes:
  - **Novel amylases**
    - **improved catalysis** at **lower temperatures** and **alkaline pH**, while maintaining the **necessary stability** under detergent conditions.
  - **Mannanase** :
    - the result of a joint development between Procter and Gamble and Novozymes.
    - This enzyme aids in **diverse food stains containing guar gum elimination** (common stabilizer and thickening agent in food products).

Textile industry

Get the Look You Want with Enzymes



Laccase

Cellulase

Amylase

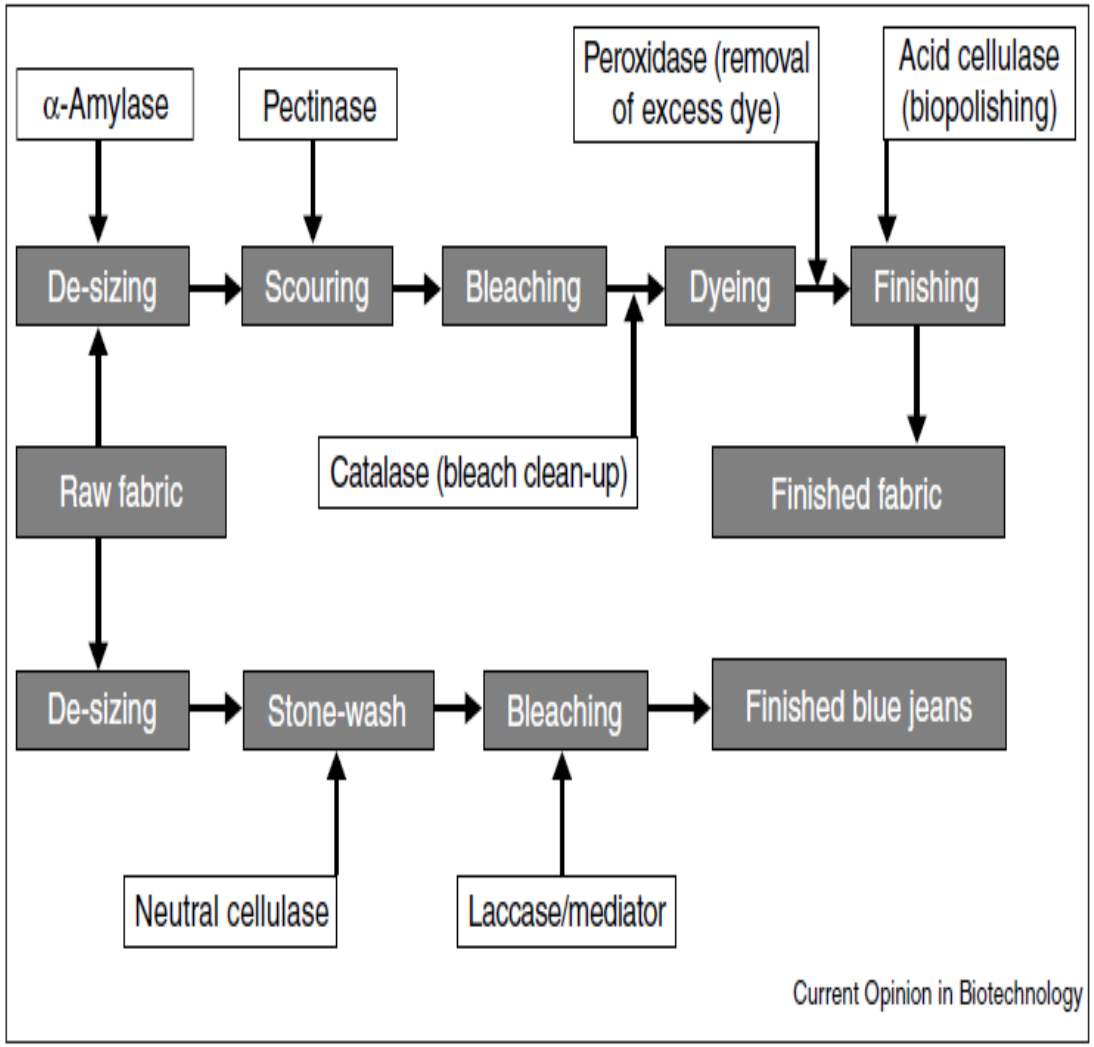
Textile industry…

- A number of enzymes used in the textile industry is increasing since the late 1980s.
- For example, the most of denim finishing laundries had switched from pumice stones to enzymes.
- More than one billion pairs of denim jeans require some form of pre-wash treatment every year.

Enzyme applications in textile processing

- **A small dose of enzyme** replaces several kilogrammes of pumice stones so **the handling of enzymes is easier**.
- The use of fewer stones **results in less damage to the garments, less wear on machines and less pumice dust**
- Biostoning process using enzyme have been proven to **conserve environmental more** than the traditional stoning process using pumice.

Approximately 1 kg of stones is required to stonewash 1 kg of jeans. In a 1-hour wash cycle, the pumice stones will lose up to 50% of their weight. The pumice grit can block drains so it needs to be filtered out from the wastewater. Large amounts of pumice sludge can be produced. For example, a denim fi nisher processing 100 000 garments a week with stones typically generates 18 tonnes of sludge (BioTimes, 1997).



Enzymes used in various unit operations in textile wet processing and the manufacturing of Denim.

Table 1

Impact of enzyme technology in industry.

	Keywords	Comments on publication
Agriculture	Feed additives	Positive effects on environment, animal health, and efficiency
	Heterologous enzyme production	Laccase and trypsin productions in plants
Chemicals	Biocatalysis	Review on preparative biotransformations
	Polymers	Polymer synthesis by *in vitro* enzyme catalysis
	Bulk organic compounds	Review on pathway engineering
Cleaning	New detergent enzymes	Increased competition and lower prices
Energy	Fuel alcohol from biomass	Genencor and Novozymes contract with DOE logen biomass-to-ethanol demonstration plant
Food	Enzymes used in food preparation	Editorial on new enzyme applications in food
	Nutraceuticals	Increased carotene content of tomato
Pharma	Chiral compounds	Enantioselective biocatalysis
	Glycoprotein engineering	*In vitro* protein glycosylation
	Enzymes as pharma targets	Several reviews in edited book
Materials	Paper, textile, leather treatment	New enzymes from extremophiles
	Biosteel (silk)	Heterologous expression of spider silk

Note, only a limited selection of new developments in established fields is shown.

Source: Jan B.van Beilen, Zhi Li, Enzyme technology: an overview, Current Opinion in Biotechnology, Volume 13, Issue 4, 2002, Pages 338-344, ISSN 0958-1669,