Actinomycetes: A Source of Industrially Important Enzymes

Salma Mukhtar1*, Ahmad Zaheer2, Dalaq Aiysha3, Kauser Abdulla Malik1 and Samina Mehnaz1

1Department of Biological Sciences, Forman Christian College (A Chartered University), Ferozepur Road, Lahore 54600, Pakistan
2Environmental Biotechnology Division, National Institute for Biotechnology and Genetic Engineering (NIBGE), Jhang Road, Faisalabad, Pakistan
3Department of Microbiology and Molecular Genetics, University of the Punjab, Lahore 54590, Pakistan

Abstract

Microbial enzymes play a key role as metabolic catalysts, leading to their diverse applications and use in various industries. The constant search for novel microbial enzymes has led to improvements in the industrial processes which is the key for profit growth. Actinomycetes form a significant group of microbial populations in soil, plant tissues and marine environments. Actinomycetes produce many valuable extracellular enzymes which can decompose a variety of organic materials. Enzymes produced by Actinomycetes and applied in different industries are cellulases, proteases, amylases, lipases xylanases, chitinases, cutinases and pectinases. Actinomycetes identified from the extreme environments are known to be producers of novel enzymes with great industrial potential. This review attempts to summarize the applications of enzymes from Actinomycetes in different industries such as food, medicine, pulp and paper, detergent, textile, agriculture and biorefineries.

Keywords: Actinomycetes; Enzymes; Cellulases; Proteases; Amylases

Introduction

To meet the increasing demand of robust, high turnover, easily and economically available biocatalysts, research is always channelized to get novelty in enzyme or improvement of existing enzymes by engineering at gene and protein level [1]. Enzymes produced by microorganisms are considered as potential biocatalysts for a large number of reactions. Enzymes derived from microbial source are generally regarded as safe and they are functional at wide range of temperature, pH, salinity or other extreme conditions. Actinomycetes are one of the most diverse groups of microorganisms that are well characterized and recognized for their metabolic versatility. They play a vital role in decomposition of organic matter, e.g. cellulose, chitin and pectin, therefore, they play an important part in carbon cycle and help to maintain the soil structure [2,3]. Actinomycetes produce a wide variety of chemical compounds, e.g. enzymes, antibiotics, neutrauticals, antitumor agents, plant growth regulators and vitamins [4,5].

Various genera of Actinomycetes have been reported to produce a wide array of potential industrial enzymes that can be used in biotechnological applications and biomedical fields in particular [6]. Continuing advances in sequencing technology and bioinformatics tools make it possible to study the microbial enzyme production by using proteomics and metaproteomics [7]. Actinomycetes have been continuously studied and employed for production of amylases, cellulases, proteases, chitinases, xylanases and pectinase. This review summarized the production of industrial important enzymes by Actinomycetes and representative examples of these enzymes, their characteristics and industrial uses (applications in biomedicine, food, detergent, pulp and paper, agriculture, textile and waste management) are enlisted in (Table 1).

Cellulases

Cellulases are important industrial enzymes for sustainable production of biofuel as they convert the cellulose into fermentable sugars. Cellulases from Streptomyces spp. like S. ruber, S. lividans and S. rutgersiens are highly thermostable [8]. These enzymes are mostly used as a supplement in detergents, textile, animal additives and paper and pulp industry [22,23]. Some members of genera Thermobifida and Micromonospora also produce cellulases that exhibit industrial potential to be used commercially [9]. Cellulases from extremophiles like Thermobifida are stable at high temperature and pH and are used for degradation of cotton and avicel. They have ability to use rice, wheat and other crops as substrates [24,25].

Proteases

Several studies reported production of proteases from Actinomycetes like members of genera, Streptomyces, Nocardia and Nocardiosis [10]. Mostly proteases show tolerance to various abiotic stresses like high pH, temperature and salinity [26]. Proteases from Streptomyces spp. can be used in processing of different agro-industrial wastes like feathers, nails, hair and plant wastes [11]. Proteases produced by Nocardiosis spp. are known as important industrial enzymes and have potential to be extensively used in leather, baking, textile, detergent, brewery, cheese and dehairing industry [27]. More than 48 strains of soil Actinomycetes have been reported for production of proteases along with their cytotoxic effects on cancer cells [28].

Keratinases

Keratinases are industrially important enzymes produced by a number of Actinomycetes strains like Streptomyces spp. and Actinomadura [12]. These enzymes are mostly used for the hydrolysis of keratin. There is a great demand for developing biotechnological alternatives for recycling of keratin wastes, converting unused chicken feather, hairs, nails and wool to useful products with the help of Actinomycetes keratinases [29].

*Corresponding author: Salma Mukhtar, Department of Biological Sciences, Forman Christian College (A Chartered University), Ferozepur Road, Lahore 54600, Pakistan, Tel: +92-42-99231581; Fax: +92-42-99230703; E-mail: salmamukhtar@fccollege.edu.pk

Received October 23, 2017; Accepted December 12, 2017; Published December 19, 2017


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A number of Actinomycetes strains have the ability to hydrolyse oils and fats. Lipases and esterases form a diverse group of hydrolytic enzymes that catalyse the lipids like triglycerides [17]. Members of Actinomycetes e.g. Streptomyces exfoliates and Nocardiopsis alba produce lipases that hydrolyse the ester bonds in triglycerides to glycerol and fatty acids [18]. Lipases have potential to be used in processing of oils and fat, cosmetics, diagnosis and detergents [32].

Chitinases

Chitinases are another group of industrially important enzymes which have the ability to hydrolyse chitin. Chitinases produced by some Actinomycetes are thermostable and active at wide range of pH which make them suitable for industrial applications [33]. Several Actinomycetes strains such as Streptomyces thermoviolaceus and Microbispora sp. are known as chitinases producers. Chitinase from these Actinomycetes strains was used to recover chitibiose, a potential antioxidant which usually have applications in biomedical and food industry [19]. Chitinases from Actinomycetes other than Streptomyces like Nocardiopsis prasina are useful in hydrolysis of chitin oligosaccharides which has potential to use as antioxidant, antimicrobial, anticancer, anticoagulant and antitumor agents [20]. Chitinases are used for the disposal of wastes produced by leather industry. Chitinases from Streptomyces spp. such as S. aureofaciens, S. griseolobulus and S. griseus is the potential antifungal agent and they are useful against phytopathogenic fungi [34].

Pectinases

Pectinases are produced by several species of Streptomyces such as S. lydicus [21]. These enzymes are used in food industry for extraction and clarification of wines, juices, oils, flavouring compounds and textile industry for preparation of linen fabrics and hemp manufacture [35]. Polygalacturonase is one of the most important pectinase which is widely used in different industries.

Other Enzymes from Actinomycetes

Actinomycetes also produce a number of other important enzymes that not listed in (Table 1) such as dextranase, peroxidases,

### Table 1: Commercially important enzymes produced by actinomycetes, their characteristics and potential uses.

<table>
<thead>
<tr>
<th>Enzyme</th>
<th>Producing strain</th>
<th>Optimum pH and temperature</th>
<th>Substrate specificity</th>
<th>Industrial applications</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cellulase</td>
<td>Streptomyces ruber</td>
<td>6 and 37°C</td>
<td>CMC</td>
<td>Detergent</td>
<td>[8]</td>
</tr>
<tr>
<td></td>
<td>Thermobifida halotolerans</td>
<td>7 and 45°C</td>
<td>CMC</td>
<td>Paper and pulp</td>
<td>[9]</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Protease</td>
<td>Streptomyces pactum</td>
<td>7.5 and 40°C</td>
<td>Casein</td>
<td>Pharmaceutical</td>
<td>[10]</td>
</tr>
<tr>
<td></td>
<td>Streptomyces thermoviolaceus</td>
<td>6.5 and 65°C</td>
<td>Keratin</td>
<td>Leather</td>
<td>[11]</td>
</tr>
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<td></td>
</tr>
<tr>
<td>Keratinase</td>
<td>Actinomadura keratinilytica</td>
<td>10 and 70 °C</td>
<td>Keratin</td>
<td>Leather</td>
<td>[12]</td>
</tr>
<tr>
<td>Amylase</td>
<td>Streptomyces erumpens</td>
<td>9 and 45°C</td>
<td>Starch</td>
<td>Detergent</td>
<td>[13]</td>
</tr>
<tr>
<td></td>
<td>Thermobifida fusca</td>
<td>6 and 60°C</td>
<td>Starch</td>
<td>Paper and pulp</td>
<td>[14]</td>
</tr>
<tr>
<td>Xylanase</td>
<td>Streptomyces spp.</td>
<td>9 and 50°C</td>
<td>Xylan</td>
<td>Textile</td>
<td>[15]</td>
</tr>
<tr>
<td></td>
<td>Actinomadura sp.</td>
<td>4 and 70°C</td>
<td>Xylan</td>
<td>Animal feed</td>
<td>[16]</td>
</tr>
<tr>
<td>Lipase</td>
<td>Streptomyces exfoliates</td>
<td>6 and 37°C</td>
<td>Triacylglycerides</td>
<td>Paper and pulp</td>
<td>[17]</td>
</tr>
<tr>
<td></td>
<td>Nocardiopsis alba</td>
<td>7 and 30°C</td>
<td>Triacylglycerides</td>
<td></td>
<td>[18]</td>
</tr>
<tr>
<td>Chitinase</td>
<td>Streptomyces thermoviolaceus</td>
<td>6 and 60°C</td>
<td>Colloidal chitin</td>
<td>Textile</td>
<td>[19]</td>
</tr>
<tr>
<td></td>
<td>Nocardiopsis prasina</td>
<td>7 and 55°C</td>
<td>Colloidal chitin</td>
<td>Leather</td>
<td>[20]</td>
</tr>
<tr>
<td>Pectinase</td>
<td>Streptomyces lydicus</td>
<td>6.5 and 45°C</td>
<td>Polygalacturonic acid</td>
<td>Beverage</td>
<td>[21]</td>
</tr>
</tbody>
</table>
nitrile hydratase, laccases, alginase lyase and cutinase. Dextranase from Streptomyces sp. is able to degrade dextran and useful in the processing of sugar production from sugarcane juice at alkaline pH and high temperature [36]. Peroxidases, tyrosinases and laccases from Actinomycetes (Nocardiia spp.) are used in the treatment of textile dyes and in wastes treatment plant [37]. This can be cost-effective and eco-friendly method in textile industry. Some thermophilic Actinomycetes such as Pseudonocardia thermophila are known producers of nitrile hydratase which is used in the biotransformation of nitriles into different useful compounds, e.g., amides, amines, esters, aldehydes and ketones [38]. Alginatases lyse hydrolyze different polysaccharides to produce alinalate which has potential to be used as antiinflammatory agent, anti-coagulant and anti-inflammatory agent [39]. Some mesophilic Actinomycetes (Streptomyces spp.) and thermophilic Actinomycetes (Thermobifida fusca) produce two types of cutinases which are more thermostable as compare to fungal cutinases [40].

Recently, culture-independent approaches such as metagenomics, metatranscriptomics and metaproteomics have offered rapid screening of novel enzymes from unculturable microorganisms especially identified from extreme environments like arid, saline, thermophilic and arctic regions [41,42]. These technologies help to determine the functional aspects of a micro-environment through innovative approaches like substrate-induced gene expression screening (SIGEX) and preamplification inverse-PCR (PAI-PCR) and provide new insights on the functional metagenomic (metaproteomics) analysis of a particular environment [43].

Conclusion

Industries are looking for new microbial strains, including Actinomycetes in order to produce novel enzymes to fulfill the current requirements because up till now, only 20 enzymes produced by microorganisms are utilized by various industries. Actinomycetes are of great significance since they have ability to produce and secrete a variety of extracellular hydrolytic enzymes that are safe for the environment. However, many of the rare genera of Actinomycetes have been neither manipulated nor explored for their biotechnological potential. Studies on the microbial potential of extreme environments can be utilized to produce novel enzymes that can become future harbingers of green biotechnology.

References