Journal of
Proteomics & Bioinformatics
ISSN: 0974-276X

Mukhtar et al., J Proteomics Bioinform 2017, 10:12
DOI: 10.4172/jpb.1000456

Mini Review Open Access

Actinomycetes: A Source of Industrially Important Enzymes

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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 improvisations 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 biocatalyst, 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, neutraceuticals, 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 industrially 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. rutgersensis* 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 *Nocardiopsis* [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 *Nocardiopsis* 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 *Streptomycetes* 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 keratic wastes, converting unused chicken feather, hairs, nails and wool to useful products with the help of Actinomycetes keratinases [29].

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

Citation: Mukhtar S, Zaheer A, Aiysha D, Malik KA, Mehnaz S (2017) Actinomycetes: A Source of Industrially Important Enzymes. J Proteomics Bioinform 10: 316-319. doi: 10.4172/jpb.1000456

Enzyme	Producing strain	Optimum pH and temperature	Substrate specificity	Industrial applications	References
Cellulase	*Streptomyces ruber*	6 and 37°C	CMC	Detergent	[8]
	Thermobifida halotolerans	7 and 45°C	CMC	Paper and pulp	[9]
				Textile	
Protease	*Streptomyces pactum*	7.5 and 40°C	Casein	Pharmaceutical	[10]
				Leather	[11]
	Streptomyces thermoviolaceus	6.5 and 65°C	Keratin	Detergent	
				Food	
				Brewing	
Keratinase	*Actinomadura keratinilytica*	10 and 70 °C	Keratin	Leather	[12]
Amylase	*Streptomyces erumpens*	9 and 45°C	Starch	Detergent	[13]
				Baking	
	Thermobifida fusca	6 and 60°C	Starch	Paper and pulp	[14]
				Textile	
Xylanase	*Streptomyces* spp.	9 and 50°C	Xylan	Paper and pulp	[15]
	Actinomadura sp.	4 and 70°C	Xylan	Animal feed	[16]
				Baking	
Lipase	*Streptomyces exfoliates*	6 and 37°C	Triacylglycerides	Paper and pulp	[17]
	Nocardiopsis alba	7 and 30°C	Triacylglycerides	Detergent	[18]
				Cosmetics	
Chitinase	*Streptomyces thermoviolaceus*	6 and 60°C	Colloidal chitin	Textile	[19]
	Nocardiopsis prasina	7 and 55°C	Colloidal chitin	Leather	[20]
Pectinase	*Streptomyces lydicus*	6.5 and 45°C	Polygalacturonic acid	Beverage	[21]
				Textile	

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

Amylases

Amylases are considered as important group of enzymes that hydrolyse starch into high fructose, glucose and maltose syrups and can be categorized into endoamylases and exoamylases. Actinomycetes strains e.g. *Streptomyces erumpens* and *Thermobifida fusca* have ability to secrete amylases to the outside of the cells to carry out extracellular digestion [13,14]. These thermostable enzymes can be used in baking, pharmaceutical, paper and pulp industry. Amylases from some alkaliphilic Actinomycetes strains can be used in detergent formulation to improve the detergency of compounds [30]. Amylases from *Streptomyces* spp. play an important role in biotechnological applications in different industries and having approximately 25% of demand in the world enzyme market.

Xylanases

Members of the genus *Streptomyces* are main producers of xylanases among Actinomycetes. Xylan is the most dominant component of hemicelluloses and it is usually used in improvement of pulp and biobleaching industry [15]. Cellulases-free and thermostable xylanases are produced by Actinobacterial genera, *Actinomadura*, and *Thermoactinomyces* with optimum temperature of 70°C [16]. Some species of Streptomyces are able to hydrolyse various agricultural residues like straw waste and oil cake which resulted in increased biogas production [31].

Lipases

A number of Actinomycetes strains have ability to hydrolyse oils and fats. Lipases and esterases form a diverse groups 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 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. griseoloalbus* 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 enyzmes 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, nitrile hydratase, laccases, alginate lyase and cutinase. Dextranase from Streptomyces spp. 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 (*Nocardia* 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]. Alginate lyases hydrolyze different polysaccharides to produce alinate which has potential to be used as antitumor agent, anticoagulant and anti-inflammatory agent [39]. Some mesophilic Actinomycetes (*Streptomyces* spp.) and thermophilic Actinomycetes (*Thermobifida fusca*) produces 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 (PAIPCR) 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 fulfil 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.

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