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Microbial Enzymes in Detergents: A Review

Sumeyra GÜRKÖK

Abstract— Enzymes are biocatalysts that speed up the rate of chemical reactions. They are vital for all stages of biochemical reactions and catalyze the reactions inside and outside the cell. Enzymes convert specific substrate(s) into specific product(s) and they offer numerous advantages over traditional chemical processes with respect to sustainability and process efficiency. Certain enzymes are of great interest and are employed as biological catalysts in various processes on an industrial scale. Microorganisms are the favored source of these enzymes due to their high yields in a short period of time on cheap media, economic feasibility, ease of product purification and modification. Microbial enzymes have gained great interest for their active and stable natures and for their widespread uses in detergent, food, agriculture, paper, cosmetics, chemical, and pharmaceutical industries.This review will specifically focus on the microbial enzymes used in detergents. Detergent enzymes have been used for a century in laundry. Enzymes are no longer a minor additive and have become an essential ingredient in modern detergents. The major classes of detergent enzymes include proteases, lipases, amylases, and cellulases. Proteases are the first used and the most common detergent enzymes, therefore, presently have many commercial forms on market. Enzymes in detergents actually hydrolyze their substrate in soils attached to fabrics or glassware. Alkaline proteases cleave peptide bonds in protein-based stains and hydrolyze proteins into soluble polypeptides or free amino acids; amylases clean by breaking down the α-glycosidic bonds in starch-based soil and catalyze the hydrolysis of starch into sugars, and lipases cleave ester bonds and catalyze the hydrolysis of fats (triglycerides) into free fatty acids and glycerol. Cellulases clean by hydrolysis of β-glycosidic bonds and remove the protruding fibers, pills and fuzzes from cottons and provide bio-finishing, fabric care and maintenance of whiteness or color clarity of fabrics. Mannanases and pectinases are also added to the detergent formulation in combination with other enzymes in order to hydrolyze mannane and pectin-based stains, respectively.

Index Terms— Detergents, protease, lipase, amylase, cellulase, mannanases, pectinase, surfactant.

1 Introduction

ENZYMES are macromolecular biological catalysts, accelerating chemical reactions. They significantly speed up reactions by providing an alternative reaction pathway of lower activation energy. To catalyze a reaction, enzyme binds to its substrate(s). The substrate binds to the active site of an enzyme and is converted into products. In the end of the reactions, enzymes remain unchanged and are ready to bind to new substrates for the next reactions.

Enzymes are vital for all stages of biochemical reactions and catalyze the reactions inside and outside the cell. Certain enzymes are of great interest and are employed as biological catalysts in various processes on an industrial scale. Microorganisms are the favored source of these enzymes due to their high yields in a short period of time on cheap media, economic feasibility, ease of product purification and modification. In addition, microbial enzymes can be genetically manipulated easily for enhanced enzyme production, activity, stability, and substrate specificity [1,2].

The active and stable nature of the microbial enzymes lead to their wide-spread use in various industries and applications. Many enzymes from microbial sources including bacteria, fungi, and yeasts are already being used in various commercial processes. More than 500 industrial products are being made using enzymes [2,3]. The industrial enzyme market has reached the value expressed in billions of dollars and is expected to grow rapidly in time ahead [4].

• *Sumeyra Gürkök, Atatürk University, Erzurum, Turkey, Email: sumeyrag@gmail.com*

Major factors driving the market are the demand for their increasing application areas and the growing diversity of the microbial sources and enzymes [5]. Enzymes are classified into six categories according to the type of reaction catalyzed: oxidoreductases, transferases, hydrolases, lyases, ligases, and isomerases. In terms of global demands, the industrial enzyme market focuses on carbohydrases (amylases, cellulases, glucanases), proteases, and lipases for the wide-spread applications in food and beverages, healthcare, detergents and cleaning agents, cosmetics, animal feed, bio-fuel production, textile, and leather processing [6].

This review will specifically focus on the microbial enzymes used in detergents and cleaning agents. Nowadays, the main application of enzymes is still in the laundry industry, comprising 30-40% of the total. Detergent enzymes have been used for a century in laundry. The major classes of detergent enzymes are proteases, lipases, amylases, cellulases, mannanases, and pectinases. In 1913, the first detergent, containing enzyme as an additive, was introduced to the household market by Röhm and Haas. They added the protease trypsin obtained from pig pancrease, to the detergent product Burnus using a patent of Otto Röhm [7]. As the activity and the stability of the trypsin did not meet the needs in the presence of conventional detergent ingredients, the detergent enzyme concept did not really catch on until 1963, when Novo developed and marketed a much more tolerant and alkali bacterial protease named Alcalase®. From the 1960s to the present, proteases have been a part of many detergents for removing protein based stains. In addition to proteases, amylases were introduced to the detergents in 1970s for the removal of starch-based stains. The combination of amylase and protease facilitated the removal of sauce stains. Proteases and amylases boost the cleaning of tableware in automatic dish wash and enzymes were also applied in the industrial and institutional cleaning sectors. After the coated granules for solid detergents, liquid enzyme preparations for liquid detergents were initiated with the development of biotechnology. This was followed in the late 1980s by the use of cellulases on cotton fabric to provide fabric care through preventing pilling and protruding microfibrils. In later years, lipases have been introduced to detergents to remove oil stains [8]. The use of enzymes in liquid and solid detergents has increased significantly over time. Presently, the possibility of using redox enzymes, oxidases or peroxidases, to bleach colored stains and enzymes more compatible with the other ingredients in detergent formulations are being investigated.

2 Detergents

2.1 Detergent Ingredients

Cleaning products in the international market are a mixture of several active ingredients varying according to the purpose of the product. Detergents mainly contain surfactants, builders, corrosion inhibitors, optical brighteners, foam regulators, bleaching agents and enzymes among other minor additives. The general composition of a detergent containing enzyme is given in Table 1 [9,10,11,12,13].

Surfactants are the most essential ingredients in laundry and household cleaning products, comprising from 15% to 40% of the total detergent formulation [14]. A surfactant molecule consists of two parts. One part is hydrophobic which is insoluble in water and the other one is hydrophilic which is soluble in water. These molecules are highly active in the interfaces between air and water or oil and water. Surfactants lower the surface tension at interfaces and their function in detergents is to remove soil from solid surfaces and fabrics and to keep it in suspension in the wash solution, preventing redeposition on surfaces and clothes.

The choice of a surfactant for a detergent depends on various factors such as type of fabric, wash temperature, desired foam level, builder used (phosphate or non-phosphate), the form of the detergent (liquid or powder), the manufacturing process, biodegradability and eco-toxicity. Various combinations of different types of surfactants such as anionic (alkyl benzene sulfonate), nonionic (alcohol ethoxylates), cationic (quaternary ammonium compounds), zwitterionic (betaines) and silicone surfactants are used for detergent formulation of different uses [15]. All major types of surfactants such as alkylbenzene sulfonates, alkyl sulfates alcohol ethoxylates, quats, and betaine have been widely used in the detergent compositions.

The effectiveness of the surfactants is highly affected by the hardness of the water. Large amounts of surfactants in detergents significantly increases biological demand in water and also impose heavy load on sewage works and on the environment due to their eco-toxicity. To lower the content of surfactants in the detergent formulations, detergency builders are often used in combination with surfactants. Builders chelate, precipitate or ion-exchange Ca^{2+} and Mg^{2+} ions existing in hard water and in soils. In addition, they provide alkalinity and buffering capacity, while inhibiting soil redeposition and corrosion. [16]. Various types of inorganic (sodium tripolyphosphate), organic (nitrilotriacetic acid, sodium citrate, EDTA) and polymer builders (polycarboxylates, such as polymers of acrylic acid or maleic acid) are employed in detergent formulations [15].

TABLE 1
General Composition of an Enzyme Detergent.

Ingredients	Example	Approximate Composition (%)
Builders	Sodium tripolyphosphate, nitrilotriacetic acid, sodium citrate, EDTA, Polycarboxylates	38
Surfactants	Sodium alkane sulphonate, alkyl sulphate	25
Bleaching agents	Sodium percarbonate, hydrogen peroxide, sodium perborate tetrahydrate, and chlorine	25
Antiredeposition agents	Sodium carboxymethyl cellulose/sodium polyacrylate/ polyethylene glycol	2
Foam regulators/soap	Soap (sodium alkane carboxylates)	3
Water softeners	Sodium sulphate	2.5
Binder /loosens dirt	Sodium metasilicate	1
Enzyme	Protease, lipase, amylase, cellulase	1
Optical brighteners	Triazine-stilbenes, biphenyl-stilbenes, coumarins, imidazolines, diazoles, triazoles	0.5
Solvents	Alcohol, acetone	Trace
Alkalis	Sodium hydroxide, sodium carbonate	Trace
Perfumes	Citronella, lavender oil, vanilla	Trace
Fabric softeners	Imidazolinium salts	Trace

Optical brighteners are synthetic chemicals added to liquid and powder laundry detergents. These chemicals are fluorescent dyes that glow blue-white in ultraviolet light making yellowed fabrics appear whiter, brighter and cleaner.

Bleaching agents such as sodium perborate, hydrogen peroxide and chlorine are included in detergent formulations for whitening and brightening fabrics and facilitate the removal of stubborn soils.

Foam regulators such as lauryl alcohol ethoxylates, paraffins, siloxanes, and soaps (sodium alkane carboxylates) inhibit the formation of suds during the washing cycle. Prevention of foam formation occurs by disrupting the surfactants at the air-water interface of the forming bubble, or bring about the foam bubbles to collapse by forming hydrophobic bridges across the multiple bubbles.

Laundry detergent may also contain anti-redeposition agents such as sodium carboxymethyl cellulose, sodium polyacrylate, polyethylene glycol, polyvinyl alcohol, polyvinyl pyrrolidone, polyethylene glycol in order to prevent the dirt from re-depositing on the fabrics.

Fabric softeners and perfumes are the other ingredients frequently used in laundry detergents

2.2 Roles of Enzymes in Detergents

The global market for industrial enzymes has grown exponentially over the past few years, and this trend is expected to continue. The industrial enzymes market was valued 7 billion dollars in 2017, and is projected to grow at a Compound Annual Growth Rate (CAGR) of 5.7% from 2018, to reach $10.5 billion dollars by 2024 [17,18].

Prior to the use of modern detergent formulations, sodium carbonate and soap were the principal detergent constituents, and the cleaning effect in laundering was dependent basically on mechanical action. Some soils are stubborn and can not be completely removed. The origin of many of these soils is biological. In nature, usually for such biological substances there are suitable enzymes, which hydrolyze the organic macromolecules.

The most important benefit of using biological detergents is that they are effective in removing stains at much lower temperatures and they reduce the water consumption. In this way, it become both environmentally friendly and economical reducing energy consumption without affecting the cleaning performance. Another advantage of enzyme in terms of environmental concerns, enzymes are derived from renewable sources and by incorporating enzymes into detergent structures, cleaning can be performed using less chemicals. The usage of enzymes in detergent formulations also reduces the use and handling of solvent and toxic compounds. The ability to wash at lower temperatures also means that delicate materials such as wool and silk can be washed without any damage and lower temperatures are also useful for protecting the colors of dyed clothes such as jeans. Moreover, the high cleaning effect of the enzymes ensures that the laundry is thoroughly cleaned even in a short wash cycle eliminating the need for repeated washing for the removal of stubborn stains.

The contribution of enzymes in high performance of modern detergents is very large. Enzymes are no longer a minor additive and have become an essential ingredient in modern laundry detergents. The majority of detergent formulations today contain a mixture of enzymes. Proteases are the most common type but lipases, amylases and cellulases, mannanases, and pectinases are often also incorporated into detergents. Enzymes in detergents actually hydrolyze their substrate in soils attached to clothes or dishes. Alkaline proteases cleave peptide bonds in protein-based stains and hydrolyze proteins into soluble polypeptides or free amino acids; amylases clean by breaking down the α-glucosidic bonds in starch-based soil and catalyze the hydrolysis of starch into sugars, and lipases cleave ester bonds and catalyze the hydrolysis of fats (triglycerides) into free fatty acids and glycerol. Cellulases clean by hydrolysis of β-glycosidic bonds and remove soils attached to cotton microfibers and provide fabric care helping to keep clothes like new for longer.

The enzymes to be used in detergents must meet some requirements. They should be stable and perform effectively at wide alkaline pH and at a wide variety of temperatures (from low temperatures for synthetic fibers to high temperatures for cotton) during washing. In addition, they have to be compatible with the other detergent ingredients such as surfactants, builders, oxidizing agents, other detergent enzymes and chemicals mentioned above in detergent formulations.

Now, enzyme containing detergents dominate the laundry detergent market all over the world. Approximately 80% of the detergents contain an enzyme or several enzymes in combinations. Higher cleaning efficiencies are achieved when different combinations are used instead of a single enzyme. Detergents in liquid or solid form contain enzymes ranging from 0.2% to 2%.

3 Enzymes in Detergents

3.1 Proteases

Proteases are the enzymes that catalyze the hydrolysis of peptide bonds. They are found in all organisms, where they play essential roles in metabolic and physiological processes. Proteases are the most widely used detergent enzymes. In 1913, they were introduced for the first time as an active ingredient in laundry detergents for degradation of proteinaceous stains by the German chemist Otto Röhm [7]. In 1959, the first commercial protease containing detergent was produced by Gebrüder Schnyder [19]. Approximately 70% of the heavy-duty laundry detergents in Europe contained enzymes since 1985.

Proteinaceous stains such as blood, egg, grass, and human sweat are removed through the action of proteases in laundry detergents. Protein-based food stains on the cutlery, dishes and other glassware are cleaned by proteases in dishwashing detergents.

Proteases can be classified based on their origin (microbial, animal, and plant), catalytic mechanism (exopeptidases or endopeptidases), optimal pH (acid, neutral or alkaline proteases), and catalytic sites. Proteases are divided into four main groups based on active sites, catalytic residues and three-dimensional structures: serine, thiol, aspartic, and metalloproteases. The serine protease family contains two subgroups: chymotrypsin-like and subtilisin like proteases. The latter is the most important group for detergent applications.

Especially, alkaline serine protease is the most important group for the application in detergent formulations. Thiol (or cysteine) proteases easily get oxidized by the bleaching agents and they are not used in detergents. Metalloproteases lose their metal cofactors due to complexing with the water softening agents or hydroxyl ions [11].

Proteolysis of proteins improves cleaning of fibers and hard surfaces by increasing the solubility of stains and foaming properties, promoting emulsification, and reducing surface tension and redeposition of degraded protein material.

Proteases and other detergent enzymes are granulated and encapsulated in powdered detergents and stay stable in the absence of water. However, in liquid detergents, protease inhibitors should be used to prevent autodigestion of the proteases themselves or degrading of other enzymes [9]. To inhibit protease activity and reduce autodigestion, glycerin, propylene glycol, and polyethylene glycol have been used in combination with boric acid [20,21].

Examples of commercial protease products used for industrial detergents are shown in Table 2 [8,9,13,22].

TABLE 2
COMMERCIAL PROTEASES USED IN DETERGENTS

Product Name	Producer	Origin
Alcalase®	Novozymes	*Bacillus licheniformis.*
Durazym®	Novozymes	*Bacillus spp*. GMO (engineered)
Esperase®	Novozymes	*Bacillus halodurans*
Everlase™	Novozymes	*Bacillus* GMO (engineered)
Flavourzyme™	Novozymes	*Aspergillus oryzae*
Neutrase®	Novozymes	*Bacillus amyloliquefaciens*
Protamex™	Novozymes	*Bacillus spp.*
Savinase®	Novozymes	*Bacillus* GMO
Purafect® Prima	Genencor Intl	*Bacillus lentus*
Properase®	Genencor Intl	*Bacillus clausii*
Excellase®	Genencor Intl	*Bacillus spp.*

3.2 Lipases

Lipases (triglycerol acylhydrolases) are an important class of hydrolytic enzymes. Lipases are ubiquitous in nature and are produced by a broad variety of organisms including animals, plants and microorganisms. They break down the ester bond of triglyserides in the oil-water interface and hydrolyze them to more hydrophilic mono- and diglycerides, free fatty acids, and glycerol. These enzymes have unique features that make them excellent biocatalysts, including stereospecificity, regioselectivity, a wide substrate range and the possibility of catalyzing heterogeneous reactions in an aqueous-apolar interface [23].

Lipases are serine-hydrolases and belong to the alpha-beta hydrolase fold superfamily. They have a Ser-Asp/Glu-His catalytic triad evolved to effectively work on substrates with diverse chemical compositions or physicochemical properties [23]. Lipases do not require a cofactor for their activity. In the presence of organic solvents, lipases remain stable or slightly affected.

A major industrial application area of lipases is in the production of detergents. Several thermostable lipases have been used as additive in detergents successfully [24,25]. In addition to general enzyme requirements to be used in detergent formulation, lipase enzyme should be water soluble and have low substrate specificity [26].

Because of their strong hydrophobicity, fatty stains have always been troublesome to remove from fabrics and glassware. The trend towards lower washing temperatures has made the removal of grease soils an even bigger problem. Lipases in laundry and dishwashing detergents remove fatty stains such as butter, margarine, fats, fat containing sauces, salad oil, soups, human sebum or certain cosmetics.

The first commercial detergent lipase, Lipolase®, was introduced in 1988 by Novo Nordisk. Lipolase was first isolated from *Humicola lanuginosa*, however, the yield was low for commercial usage and it is currently produced using *Aspergillus oryzae* strain transformed with the gene coding for the detergent lipase [27]. Following the development of Lipolase, microbial lipases gained greater industrial interest. In the following years, two bacterial lipases, Lumafast (Genencor International) and Lipomax (Gist Brocades), isolated from *Pseudomonas spp* were introduced to the market in 1993 and 1995, respectively. Lipolase was different from the other detergent enzymes (protease and amylase) in that several washes are needed to observe a significant benefit due to the water effect on the lypolytic activity. The enzyme is slightly active when the water content of the fabric is below 5% or above 80% (w/w), and its activity is maximum at around 25 % water. Such a level is reached during the drying process. Thus the amount of fatty material on the dried load after the first wash is not reduced by the lipase, but during the next wash, trigliserides are hydrolyzed and are much more easily removed. The soil removed after only two washes with a lipase containing detergent equals that achieved by seven washes without lipase. Lipomax and Lumafast are claimed to deliver a perceivable benefit from the first wash.

A second-generation Lipolase called Lipolase Ultra with enhanced wash performance was launched in 1994. To develop first-wash effects in laundry usage, one amino acid substitution (amino acid at position 96, aspartic acid was substituted with leucine) took place to obtain Lipolase Ultra. In 1998, LipoPrime™ was launched as another protein-engineered variant of Lipolase. LipoPrime™ shows superior fat-removing efficacy in comparison to Lipolase® and Lipolase Ultra in most detergent formulations. Lipex® introduced in 2014, is a new fat-hydrolyzing liquid enzyme preparation containing a lipase suitable for use in laundry detergent solutions.

Examples of commercial lipase products used for industrial detergents are shown in Table 3 [9,13].

TABLE 3
COMMERCIAL LIPASES USED IN DETERGENTS

Product Name	Producer	Origin
Lipolase	Novozymes	*Humicola lanuginosa*
Lipolase Ultra	Novozymes	Protein engineered variant of Lipolase
Lipo Prime	Novozymes	Protein engineered variant of Lipolase
Lumafast	Genencor	*Pseudomonas mendocina*
Lipomax	Gist Brocades	*Pseudomonas alcaligenes*
Lipex	Novozymes	*Thermomyces lanuginosus*

3.3 Amylases

Amylases, a class of enzymes that catalyze the hydrolysis of starch into short-chain sugars, have potential application in a wide number of industrial processes such as detergent, food, fermentation and pharmaceutical industries. Two categories of amylases, named alpha and beta, differ in the way they attack the bonds of the starch molecules. α-Amylase is widespread among plants, animals and microorganisms. However, enzymes from fungal and bacterial sources have dominated the industrial applications. α-Amylase breaks down α-1,4 glycosidic bond and hydrolyze starch (amylose and amylopectin) into low-molecular-weight sugars.

The α-amylases are specifically supplemented to the laundry and automatic dishwashing detergent to liquefaction of starch and digest starchy stains from pasta, potatoes, sauces, spaghetti, custards, gravies, pudding, and chocolate [28]. In addition, amylases prevent swollen starch from adhering to the surface of laundry and glassware, otherwise, it acts as a glue for particulate soiling. α-Amylase reduce the viscosity of the gelatinized starch by hydrolyzing α-1,4-linkages and increase the solubility of attached starch, that is then converted to water-soluble dextrins and oligosaccharides [9]. α-Amylases are generally used in combination with proteases and boost the cleaning of tableware in detergents and also applied in the industrial and institutional cleaning sectors [29]. Some of the industrially important α-amylase products are listed in Table 4 [9,13,30].

TABLE 4
COMMERCIAL AMYLASES USED IN DETERGENTS

Product Name	Producer	Origin
BAN	Novozymes	*Bacillus amyloliquefaciens*
Termamyl	Novozymes	*Humicola spp.*
Stainzyme	Novozymes	*Bacillus spp.*
Duramyl	Novozymes	*Bacillus spp.*
Fungamyl	Novozymes	*Aspergillus spp.*
Maxamyl	Gist-brocades	*Bacillus spp.*
Solvay amylase	Solvay	*Bacillus licheniformis*

3.4 Cellulases

Cellulase is the enzyme that hydrolyzes β-1,4-glucoside linkages of cellulose chain. They are ubiquitous in nature and are produced by fungi, bacteria, protozoans, plants, and animals. Cellulose is the most abundant renewable biological resource and a low-cost energy source. In nature, complete depolymerization of cellulose to glucose requires the synergistic action of three main types of cellulases; endoglucanases (EC 3.2.1.4), exoglucanases (EC 3.2.1.91), and β-glucosidase (EC 3.2.1.21).

Most detergent manufacturers use mixtures of different cellulases for biofinishing, fabric care and maintenance of whiteness or color clarity of fabrics. Upon use and several washes of garments made of cotton or cotton blends, microfibrils (microfibrils combine and form pills) are generated on cotton fibers. The garments gradually lose their smooth appearance and look fluffy. Microfibrils and pills scatter light and whiteness turns into grayish color and bright colors appear fuzzy and dull. Cellulases remove these protruding fibers, pills and fuzzes from cottons or other cellulose-portion in synthetic fibers and smooth the fabrics. They also remove solid dirt and prevent the redeposition of stains and dust [8]. In addition, cellulases improves the efficiency of detergents by removing the microfibrils within the particulate soil, such as ink or mud [31].

The great majority of the reported cellulases have pH optima in the acidic or neutral range. However, enzymes should be able to work under alkaline wash conditions and have to be compatible with other detergent additives. In 1980s, researches concentrated on isolating microbial sources of alkaline enzymes that could be used properly in detergent formulations [32,33].

The first commercial detergent cellulase was isolated from a alkaliphilic *Bacillus* species. This enzyme provided a cleaning effect during washing, however, anti-pilling or color revival have not been described for this enzyme. Therefore, improved cellulases were needed in detergent applications. Using a mixture of cellulases, as suggested in international patent application WO-A-95/02675, is supposed to provide the desired performance in laundry washing. The alkaline cellulose (endo-1,4-β-D-glucanase, 4-β-D-glucan 4-glucanohydrolase; EC 3.2.1.4) from alkaliphilic *Bacillus* strain was first introduced into detergents by Kao in 1987. Following that, Novozymes introduced a detergent using cellulase mixture (Celluzyme®) from Humicola insolens. Celluzyme® has properties enabling it to modify the structure of cellulose fibrils on cotton and cotton blends. Later, Carezyme® (one of the cellulose component in Celluzyme®) which is able to remove the fuzz that builds up on cotton clothes was introduced to the market by Novozymes. In 1998, Genencor International marketed the endocellulase, Puradax as a domestic detergent additive. This particular cellulase was isolated from an alkaliphilic *Bacillus* species from a soda lake and was the first enzyme from an extremophile commercialized industrially worldwide. This isolated cellulase has since then been used in detergent industry [34]. Some of the commercial cellulases used in detergents are listed in Table 5 [9,13,35].

TABLE 5
COMMERCIAL CELLULASES USED IN DETERGENTS

Product Name	Producer	Origin
Celluzyme	Novozymes	*Humicola insolens*
Carezyme	Novozymes	*Humicola insolens*
Puradax	Genencor	*Bacillus spp.*

3.5 Mannanases

Mannanase is the enzyme that hydrolyzes β-1-4 linkages in the mannan backbone. Mannans or galactomannans are polysaccharides consisting of a mannose backbone linked together by β-1,4-linkages with side-chains of galactose attached to the backbone by α-1,6 linkages. Mannans are frequently used as thickening agents or stabilizers in ice cream, chocolate, ketchup and personal care products.

The major mannan-degrading enzymes are β-mannanases, β-mannosidases and β-glucosidases. Microbial mannanases are mainly extracellular and are able to work in wide range of pH and temperatures. Therefore, they have found various industrial application areas. Microbial mannanases are specifically supplemented to the detergent to remove mannan based dirts from clothes [36]. Mannan-containing soils easily adsorb to the cellulose fibers of cotton fabrics by hydrogen bonds and are difficult to remove. The mannanase hydrolyzes the insoluble mannan into more water soluble smaller polymers of mannose that can be siphoned out of the washing machine during the spin cycle, which becomes a valuable additive in laundry or dishwashing detergents [37]. Today, mannanase containing detergents introduced by Novozymes (Mannaway®) and by DuPont (Effectenz™) are commercially available on market [38].

3.6 Pectinases

Pectinases are a group of heterogeneous enzymes that hydrolyze the pectin substances, occurs mostly in plants. Although pectinolytic enzymes are widely distributed in higher plants and microorganisms, microbial pectinases are frequently used due to their ease of production and unique physicochemical properties. Pectinases hydrolyze pectin, a heteropolysaccharide consisting mainly of α-1-4 linked polygalacturonic acid residues. Pectinases in detergents break the pectin backbone in pectin-based stains caused by fruits, vegetables, sauces, jams and jellies, and make them easier to remove from the fabrics during wash. In order to remove pectin-based stains, detergent containing pectinase (XPect®) was introduced by Novozymes. [38].

4 CONCLUSIONS

Several advantages of the enzymes over the chemical catalysts make them an ecological and a favorable alternative for almost all industrial applications. The demand for biocatalyst is steadily increasing and the detergent industry is one of the largest market for enzymes.

Enzymes improved the cleaning efficiency of household and industrial detergents by enhancing the removal of tough stains and also provided environmental benefits. Enzymes have decreased the chemical load in detergents and decreased the energy consumption by reducing washing times, washing temperatures and water consumption.

Nowadays, the use of enzymes in detergents is widespread in developed countries and more than half of the detergents contain enzymes. Many laundry detergent products contain at least an enzyme or a mixture of enzymes including proteases, lipases, amylases, cellulases, mannanases and pectinases.

Enzymes incorporated into the detergents are affected by a variety of factors such as pH, temperature and hardness of washing water, other enzymes and components of detergents, soil load and inhibitors, etc. Therefore, several factors are considered for the isolation, screening, and selection of detergent-compatible enzymes, including activity and stability under harsh washing conditions of pH 8–11 and temperatures of 30–60 °C, broad substrate specificity, high soil removal potential, cost-effectiveness, safety and compatibility with other ingredients of the detergent. There is a strong interest worldwide in discovering novel microbial strains with unique enzymes properties. The discovery and development of more enzymes from extremophiles (psychophiles, thermophiles and hyperthermophiles) will allow more enzymes that function under different conditions to be incorporated into detergents. Another approach is the use of recombinant DNA technologies to improve enzyme properties for specific applications.

However, enzyme detergents are not widely used in low-income countries. Developing countries have to keep up with these improvements. The awareness of these countries about the efficiency, economic, environmental, and health benefits of enzyme detergents needs to be increased.

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