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Review Article

Potential Applications of Pectinases in Food, Agricultural and Environmental Sectors

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ABSTRACT
Pectinases contains groups of enzymes that degrade the pectin substances. They are mainly synthesized by microorganisms and plants. Pectinases have extensive applications in food, agricultural and environmental sectors. Their recent application is found in bioenergy production. In food sector, these enzymes are used for extraction, clarification, and stabilization of fruit juices. They also increase juice yield and involved in coffee, cocoa and tea fermentation and in preparation of jams and jellies. In pickling industry, they are involved in softening process. In agricultural sector, they have widespread applications in purification of plant viruses, oil extraction, retting and degumming process, bio-scouring of cotton fiber. Pectinases are also used for extraction of pure DNA sample from plants, in maceration of plant tissue, isolation of protoplast from plant cells and in liquification and saccharification of biomass. They are supplementary enzyme of animal feed causes increase in their nutrients absorption. In environmental sector, their vital role is in wastewater treatment by facilitating pectin decomposition. Pectinases are used for bioenergy production by increasing bioethanol level. In industrial sector, pectinases are mainly involved in wine and paper manufacturing industry. The central theme of this review focus on potential applications of pectinases in food, agricultural and environmental sector.

KEYWORDS: Pectinases; food sectors; agricultural sector; environmental sector

INTRODUCTION

Pectinases are the enzymes whose discovery causes revolution in economic and commercial sector. Pectic enzymes may be alkaline or acidic in nature depending upon their source of production. Alkaline pectinases are mainly synthesized by both prokaryotic while acidic pectinases are produced from eukaryotic microorganisms [1, 2]. Among eukaryotic microorganism, yeast has distinct role in synthesis of pectinases [3, 4]. Their optimal pH is 3.5-11 while optimal temperatures is 40-75°C [5, 6]. The data has been shown in Table 1.

Pectinases are defined as a heterogeneous enzymes group that hydrolyzes pectic substances, which is the substrate molecule of pectinases, it is a polymer of chain molecules consisting of rhamnogalacturonan backbone that is linked with carbohydrates and other polymers [2]. Pectic substance is the common name that is used to refer four types of molecules: pectinic acids (galacturonan polymer comprising of >0-75% methylated galacturonate monomers), pectins (75% methylated galacturonate units), pectic acids (contains insignificant amount of

methoxyl groups), and protopectin (present in intact tissue). Protopectinases are not soluble in water, while others are absolutely or partially soluble [7]. Figure 1 highlights the classification of pectic substances.

Chemically, pectinases are defined as, poly α1-4-galacturonic acids, with variable concentration of methylated residues of carboxylic acids (Figure 2). Structurally, pectin has three main regions, smooth (linear), hairy and branched regions. About one third of the dry weight of plant tissues is occupied by pectinases. They have been prominently observed in primary cell walls and middle lamella of plants [8].

On commercial level, pectinases are synthesized by solid state and submerged fermentation. In later type, microbial growth is carried out on liquid broth in the presence of high volumes of water. Fermentation media is continuously agitated and lot of effluents are generated. In SSF fermentation microorganism are cultivated on solid media and product formation is also carried out on or within solid substrate particles under aerobic conditions and in very negligible amount of free water [9]. The Pectinolytic bacteria have more vulnerable genetic modifications so they are more focused by latest enzyme technology [10]. The microorganisms used in submerged and solid state fermentation belongs to filamentous fungi among which most common are *Aspergillus niger* and *Penicillium restrictum,* to synthesize numerous economical products like citric acid and ethanol. Some bacteria and yeasts species also produce pectinases.

Pectinases are among the most economically significant enzymes as they account for 10% of globally produced industrial enzymes and their market value is expanding with the passage of time. In 1995 sale value of all industrial enzymes was about $1 billion, of which 7.5% was measured for pectinases [11].

Table 1: Biochemical properties of some microbial pectinases

Microorganisms	Enzyme	Optimal pH	Optimal temperature (^{0}C)
Bacteria			
Bacillus sp NT-33	Polygalactouranase	10.5	75
Bacillus sp DT&	Pectin lyase	8	60
Yeast			
Saccharomyces cervisae	Endopolygalactronase	5.5	45
Fungi			
Penicillim paxillin	Pectin lyase	5	35
Aspergillus ficuum	Pectin lyase	5	50

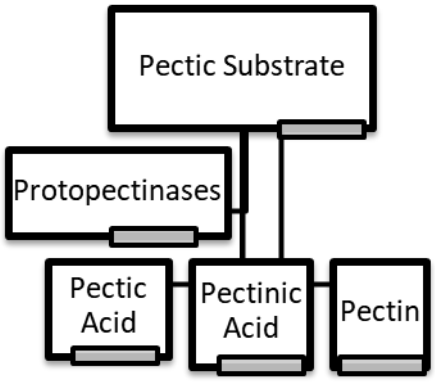

Fig. 1: Classification of pectin substrate

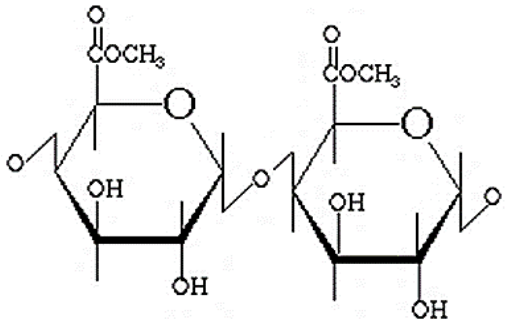

Fig.2: Structure of pectin

CLASSIFICATION OF PECTINASES

There are various classifications of pectinases based on different criteria [12,13] but the most used classification follows the method proposed by [14] Principally, there are three major types of pectinases; pectin esterases which catalyze the removal of methoxyl residues of pectin, a series of depolymerizing pectinases enzymes and

protopectinase, which convert insoluble protopectin into soluble form of pectin [15].

Pectin esterases (PE)

Pectinesterases, also known as pectin methyl hydrolase pectase, pectin methoxylase, pectin demethoxylase, and pectolipase. While its systematic name is Pectin pectylhydrolase and its EC No. is 3.1.1.11. These enzymes catalyze desertification of the methoxyl residues of pectin converting it into pectic acid [2]. PE acts favorably on galacturonate unit that contain units of methyl ester group followed by galacturonate units of non-methylated ester group. Pectin esterases are present in higher plant's fruits, leaves, flowers, stems and roots. PMEs are linked to cell wall of plant by ionic bonding thus by applying the high ionic strength on the plant's cell wall or by shifting the enzymes pH from acidic to the alkaline [13]. Plants and microbial PMEs has molecular weight of 30-50 kDa or 25-54 kDa respectively [16], 40–60ºC optimum temperature and 4-8 pH [17]. The reaction catalyzed by esterases is shown in Figure 3.

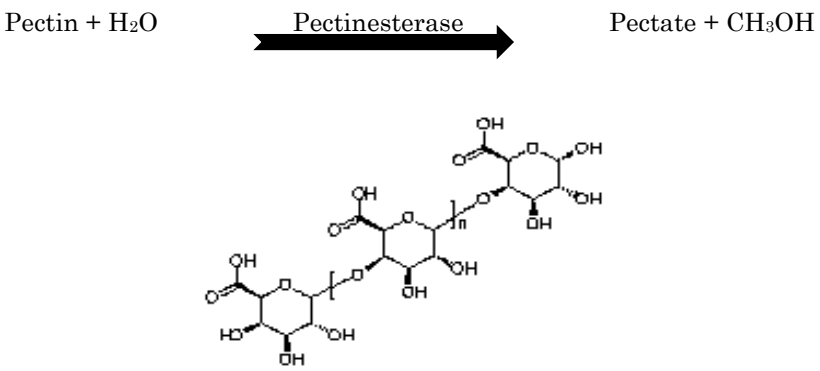

Fig. 3: Reaction catalyzed by pectin esterases

Depolymerizing enzymes

Depolymerases are further classified on the basis of substrate types, cleavage mechanism and the breakdown of glycosidic bonds [13]. Reaction mechanisms of depolymerizing enzymes is given in table 2.

Table 2: Reaction mechanisms of depolymerizing enzymes

Enzymes	Action mechanism	Action pattern	Primary substrate	Product
Hydrolases				
Protopectinases	Hydrolysis	10.5	Protopectin	Pectin
Endo polyglaacturonase	Hydrolysis	8	Pectic acid	Oligogalacturoates
Exopolygalacturonase	Hydrolysis	10.5	Pectic acid	Mono galacturonates
Exopoly galactronan digalacturono hydrolase	Hydrolysis	Penultimate bonds	Pectic acid	Digalacturonates
Oligogalacturonate hydrolase	Hydrolysis	Terminal	Trigalacturonate	Mono galacturonates
Lyases				
Endopolygalacturonase lyase	Trans-elimination	Random	Pectic acid	Unsaturated oligo galacturonates
Exopolygalactruonase lyase	Trans-elimination	Penultimate bonds	Pectic acid	Unsaturated digalacturonates

Hydrolyzing glycosidic linkages

Such enzymes catalyze hydrolytic cleavage of glycosidic bond they include polymethyl galacturonases (PMG) and polygalacturonase (PG). Polymethylgalacturonases (PMG) are the enzymes that catalyzes hydrolytic cleavage of α-1,4-glycosidic bonds. On basis of cleavage mechanism, they are divided into Endo and Exo-

PMG. Endo-PMG catalyzes cleavage of α-1,4-glycosidic linkages of pectin randomly, specifically of highly esterified pectin while Exo-PMG causes cleavage on one end of pectin chain sequentially which is non-reducing end consisting of α-1,4-glycosidic linkage.

Systematic name of polygalacturonases (PG) is Poly 1,4-α-D-galacturonide or glycanohydrolase as they catalyze hydrolysis of α-1,4-glycosidic bonds of pectic acid. As PMG, they may be Endo-PG or Exo-PG. systematic name of Endo-PG is poly 1,4-α-D-galacturonide as their role is in random hydrolysis of α-1,4-glycosidic bonds while Exo-PG are poly 1,4-α-D-galacturonide or galacturonohydrolase and they catalyze hydrolysis of α-1,4-glycosidic bonds sequentially on pectic acid.

Cleaving

Cleavage occurs at the α-1,4-glycosidic linkages of non-reducing end of pectin chain by trans-elimination, in the result galacturonide formed which is an unsaturated compound. The unsaturated bonds of galacturonides are present on carbon 4 and 5 at the non-reducing end. Polymethylegalacturonate lyases (PMGL) and Polygalacturonate lyases (PGL) are included in this category. Poly methylegalacturonate lyases (PMGL) have trans-eliminative cleavage mechanism to degrade pectin. Endo-PMGL catalyzes cleavage of α-1,4-glycosidic linkages randomly in pectin. While Exo-PMGL have mechanisim of trans-eliminative cleavage by which they degrade pectin sequencially.

Polygalacturonat lyases (PGL) also have same mechanism as Exo-PMGL but in pectin acids instead of pectin. Endo-PGL or poly 1,4-α-D-galacturonide lyase as they catalyze random cleavage of α-1,4-glycosidic linkages in pectic acid. And Exo-PGL or poly 1,4-α-D-galacturonide cleave α-1,4-glycosidic linkages sequentially in pectic acid (Fig 4).

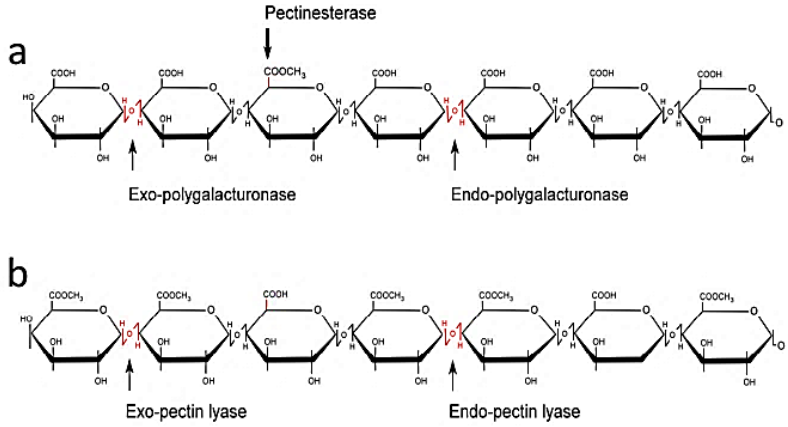

Fig. 4: Mode of action of polygalacturonase (a) and pectin lyase (b)

Protopectinase

The name is given because it solubilizes protopectin by degrading it resulting in the formation of soluble pectin. Protopectinase catalyzes the solubalization of protopectin by the following mechanism:

Protopectin (Insoluble) + H_2O $\xrightarrow{\text{Protopectinase}}$ pectin (soluble)

Table 3: Characterization of different type of pectinases

Producer	Types of Pectinases	Optimum pH	Optimum Temperature (^{0}C)
Aspergillus niger CH4	Endo-pectinase	4.5-6.0	Below 50
	Exo- pectinase	3.5-5.0	
Rhizoctonia solni	Endo-PG	4.8	50
Cloctridium thermosaccharolyticum	Polygalacturonate	5.5-7.0	30-40
Bacillus sp. R K9	PGL	10.0	30-40
Bacillus sp. NT-33	PG	10.5	75
Bacillus polymyxa	PG	8.4-9.4	45
Bacillus pumilis	PATE	8.0-8.5	60

APPLICATION OF PECTINASES

Pectinases in food sector

Application of pectinases in food processing has prolonged significantly in recent years mainly in extraction, clarification and stabilization process [18]. Acidic pectinases have major role in fruit and vegetable juice industry, they are produced by fungi mainly from *Aspergillus spp.* due to its distinct role in food industries. Enzyme preparations are mainly comprising of pectin lyases, esterases and polygalacturonases. Pectate lyases act on the ester group of pectin while the polygalacturonases have opposite action of lyases because they degrade de-esterified pectin followed by the action of pectin esterases. Pectinases can be used with other enzymes like cellulases, arabinases, or xylanases which enhance the pressing fruit efficiency for their extraction of juice [19, 20, 21]. Pectinases along with cellulases increases juice yield up to 100% [7].

Pectinases are present in many fruits and vegetables in large amount as reported in Table 4. Pectinases easily remove the fruit peels by softening process [5]. They increase juice yield by maceration and viscosity reduction. Pectinases increase clarification and reduced filtration time upto 50% [3]. Pectinases are not only responsible for clarification of juices but they also enhanced the flavor of apple juice. Pectinases makes the production process easier [18].

Table 4: Percentage of pectic substance in different fruits and vegetables

Fruits/Vegetables	Tissue	Pectic substance (%)
Apple	Fresh	0.5-1.6
Peaches	Fresh	0.1-0.2`
Banana	Fresh	0.7-1.2
Strawberries	Fresh	0.6-0.7
Cherries	Fresh	0.2-0.5
Orange	Dry matter	12.4-28.0
Potatoes	Dry matter	1.8-3.3
Tomatoes	Dry matter	2.4-4.6

Extraction of clear fruit juices

Pectinases are added during the pressing stage of juice extraction to remove undissolved cloudy matter in the suspension. Commercial enzymes having a mixture of pectinases, cellulases and hemicellulases are used for the treatment of suspension [22,5]. Depolymerizing enzymes that catalyzes depolymerization of the highly-esterified pectin are most commonly used for the clarification of apple juice. Mixture of PG and PME is found to be effective in fruit juice clarification but the most potent enzyme for this purpose is a pure pectin lyase at optimum pH of 3-4. Juice containing 91–92% esterified pectin can be clarified by treating with pure pectin lyase [23]. Apple juice extraction is a two-step process, in first step apple mush after crushing is treated with pectinases to produce the finest juice. Second step consists of pomace liquefaction treatment in which pectinases and cellulases are added in juice at final steps of juice extraction [24]. Pectinases level of 1000 - 2000 U of pectinases should be added in 1 liter of juice for 1 to 3 hours for efficient clarification

[25]. Pectinases are present in many fruits and vegetables in large amount (Table 4) and during extraction pectin passes into juice and gives cloudiness. Enzymatic hydrolysis remove such cloudiness from fruit juices. In clarification of grape juice pectinases are added during crushing of grapes.

Pectinases reduce the processing time and clarify the juice. In addition to this, these enzymes enhancing economic value of orange juice by clarifying it. Traditional processing of orange juice involves heating that spoils the natural flavor of orange juice and it is also very expensive process. But the enzymatic treatment with pectinases clarifies the juice cloud and maintains the juice stability [26, 18].

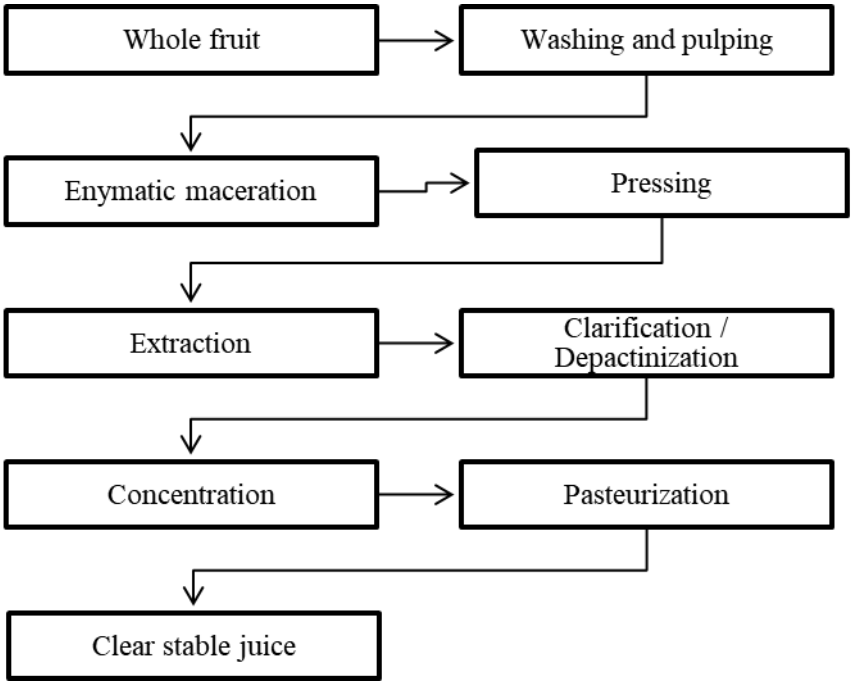

Fig. 5: Extraction of clear stable juice

Extraction of cloudy juices

Pectinases also have role in stabilization of cloud to give cloudy juice especially in citrus, purees and nectars. Pure PL has found to be most efficient for the extraction of cloudy juices [5]. For extraction of cloudy juices, pasteurization is carried out to inactivate leftover enzymes. The large sized residues are removed by centrifugation leaving small particles in suspension. Pectin esterases are present naturally in orange and act on only partially methylated pectin. Viscosity of orange juice can be reduced by treating100 kg of orange pulp with 0.5–2.0 g pectinases at room temperature [27]. The mechanism of these enzymes involves the reduction of viscosity while level of the insoluble pectin remains stable to form cloudy juices. The other way is denaturation of pectin esterases by heating but this method is not much efficient because it is time consuming and also spoils the juice flavor.

Coffee, cocoa and tea fermentation

Pectinases are used in various types of fermentation. They accelerate the fermentation process. During tea fermentation, pectinases enzymes of fungal origin breakdown pectin present in cell walls of tea leaves but extra amount of these enzymes can damage tea leaves, so a specific concentration must be maintained during fermentation. They also act as anti-foaming agent by destroying pectin in the instant tea powders [28]. During coffee fermentation pectinases remove mucilage layer from coffee beans. For this purpose, enzyme pectinases preparations are sprayed onto cocoa beans to carry out fermentation. The filtrate of inoculated fermentations is a cheaper alternative with the same purpose. But the

enzymatic preparations of pectinases are more efficient because the enzymes speed up fermentation process [29, 30]. Cocoa fermentation is essential to develop the chocolate flavor.

In cocoa fermentation, many different microorganisms play role including pectolytic microorganism. These microorganisms are involved in degradation of the cocoa pulp by releasing pectinases and at the end finest quality of cocoa beans are obtained with premium cocoa flavor [31, 32].

Preparation of jams and jellies

The pectin esterase converts high methoxylated pectins into low-methoxylated pectins by demethylation. Pectin esterase has calcium dependent gelation property by which gel formed resulting in reducing sugar requirements. This enzyme is used in the preparation of jellies, jams, compotes, sauces and soups [22].

Pickling

Vacuum Infusion is a technique in which vacuum pressure is applied to drive resin into a laminate. Pectinase have the ability of vacuum infusion so they are extensively used in softening g process of fruits and vegetables. For this purpose, pectin methyesterase along with calcium are used in pickling industry where softening occurs during fermentation and storage [33].

Pectinases in the agriculture sector

Purification of plant viruses

Pectinases are very important in isolation of plant viruses. Particularly alkaline pectinases in conjunction with cellulases releases the plant virus from the phloem tissue and in result a very pure preparation of plant viruses can be obtained.

Oil extraction

Pectinases and other cell wall degrading enzymes are used in oil extraction from plant but olive oil extraction is the most common. Commercial preparations for extraction of olive oil contains cellulases and hemicellulases. During grinding of olives these enzymes are added for easy oil extraction. Pectins resist the emulsification process by interfering with the collection of oils droplets from peel extracts which helps in the oil extraction as in case of lemon [34]. Vegetable oils of sunflower, coconut, lemon, palm or canola can also be extracted by using organic solvents like hexane and by treating with pectinases, preferably of alkaline nature, as they facilitate extraction of oils in an aqueous process. In the result of enzyme treatment, oil yield and stability is improved. The increase in oil yield is greatly affected by enzyme's concentration, pH and temperature.

Olivex is an enzyme preparation which is produced from a fungus, *Aspergillus aculeatus,* this commercial preparation has pectinolytic, hemicellulases and cellulolytic activity which is desired for high yield of oil and its better stability during storage. Olivex treatment result in high level of polyphenols and vitamin E contents and organoleptic quality of oil also increases that have determining effect on oil consumption [35].

Plant fiber retting and degumming

Pectinases play very important role in degumming of fiber crops. The fiber which is obtained from these crop holds gum, ramie fiber is an excellent natural textile but it contains 20-35% ramie gum that mostly contain pectin and hemicellulose so it has to be removed for further treatment for textile processing. Degumming can be carried out either by chemical treatment or with enzymatic treatment. During chemical treatment, 12–20% NaOH in solution form is used to remove gum of decorticated fibers [36]. But chemical treatment is not much efficient and this type of degumming is toxic, contaminating and non-biodegradable. Enzymatic treatment is more efficient, pectinases in combination with xylanase can be used for degumming in an eco-friendly and bio-degradable manner [2]. Utilization of enzyme also reduce the chemicals and energy consumption. Among pectinases, pectate lyase from actinomycetes is most efficient for separation of bast fiber by removing gums.

Retting is a fermentation process in which eukaryotic and prokaryotic microorganisms carry out fermentation in which pectin is degraded and pure quality fiber releases. In retting the most common used bacteria are *Clostridium* and *Bacillus* while most common fungi are *Aspergillus* and *Penicillium*. Water retting of flax involves pectinases of bacterial origin resulting in fiber separation [37].

Bio scouring of cotton fibers

Natural cotton fibers have some impurities of non-cellulosic substance which can be removed by using specific enzyme this process is known as bio-scouring. Commercial preparations derived from pectinases, lipases, amylases, cellulases and hemicellulases are used to remove non-cellulosic impurities from cotton in efficient and safe manner. This process has also ecofriendly effects due to biodegradable nature of enzymes. They are best alternative of conventional method in which caustic soda was used without any harmful effects on cellulose degradation [1].

DNA extraction from plants

The initial extraction protocols of plant nucleic acid are not equally competent for all plants, the reason is that contaminating substances co-precipitate with DNA and these also exists even at the final step of extraction protocol that is DNA hydration. But the use of pectinase help to prevent this contamination of co-precipitate with nucleic acid and in result pure DNA sample can be isolated from plant cell. As it involves in the breakdown of pectin, major component of plant cell wall.

Animal feed

Pectinases are one of those enzymes that help in the production of feed. They have ability to reduce feed viscosity which directly intensify the nutrients absorption ability of animals. These nutrients are released from fibers by hydrolysis process and it also reduces animal defecation [1].

Protoplast isolation from plants

Protoplast isolation is a useful technique of plant biotechnology in which protoplast from somatic cells are fused under controlled environment in culture rooms and in next steps this culture is developed into heterokaryon product and hybrid plant. This is a useful technique of plant tissue culture by which new genetic traits are induced in plant cells which do not exist in nature. Pectinases and cellulases have been used for efficient isolation of protoplast. commer-222 preparations of enzymes have been used for protoplasts isolation [38]. This is a two-step process; firstly, macerated plant tissues are incubated with pectinases. Then cellulosic treatment convert these tissues into protoplast. Another technique used mixture of two enzyme and protoplast are isolated in one step.

Liquefaction and sachharification of biomass

Fermentable sugar is important biomass product of fermentation in which most common raw materials are wheat, rice, potatoes, sugar beet and sugarcane. They are further processed for producing fermentable sugars by the action of pectinases, cellulases and hemicellulases from polysaccharides like carbohydrates, lipids and proteins which are present in plant cell walls, these enzymes degrade and disrupt cell wall matrix result in liquefying material and release of intracellular carbohydrates [39].

Pectinases in the industrial and environmental sectors

Pectinases in wine industry

Wine is the fermented product of grapes. There are many enzymes which are involved in wine making process i.e. commercial preparations contains hemicellulases, glucanases and glycosidases among these, pectinases have major roles in wine making industry. They increase level of methanol in wine because of its activity of PME [40]. The level of methanol should be regulated because its high amount may prove toxic. Therefore, commercial mixtures contain pectinases which have low pectin methyl esterase activity. Pectinases are involved in extraction of wine, increasing juice yield, accelerating filtration, intensifying flavor and color of wine. Pectinases have mechanism to intensify and stabilize wine color by increasing phenolic compound which are secondary metabolites [41,42]. Pectinases treatment of Australian wine containing different commercial preparation of pectolytic enzymes result in faster and better wine color during different phases like maceration, pressing and fermentation. This treatment also improves wine clarification [43]. Pectinases enhance aroma and flavor of wine. Grapes have different aromatic components, which exists in free forms and these components give scent when they are in bound form or in higher concentration.

During ripening process of grapes, some non-odorous glycoside flavor precursors start accumulating in grape skin. These flavor precursors are hydrolyzed by ß-glucosiases which are the olfactory active aglycones [44].

When pectinases are added during extraction and fermentation process of wine and must they increases the number of aromatic precursors in grapes and these precursors become more susceptible of hydrolysis when they are attacked by ß-glucosiases, produced by microbial fermentation, increases aroma of wines [45].

Paper and pulp industry

Pulp and paper industry had extensive use of chemicals for paper manufacturing but enzymatic methods and techniques made this process much easy to get better and efficient paper. In conventional paper industries, different raw materials are used and during continues filtration process they are formed a diluted suspension containing fiber fragments and inorganic particles like clay or $CaCO_3$, and these are molded into sheets. Filter fabrics have large holes so that fines and filler particles can easily pass through it. In modern paper making industries, these particles are retained in paper sheets to swift water drainage. Cationic polymers are most common retention aids [46].

Bleaching treatment of pulps with alkaline peroxide solubilizes polysaccharides, which are interfering agents during paper manufacturing [47]. But use of pectinases in paper manufacturing reduce the use of cationic polymers and bleaching treatment of pulp**.** Alkaline pectinase from *streptomyces sp*. was utilized in bleach-boosting of eucalyptus pulp. Pectinase and xylanases produced from same fungus species act as bio bleaching.

Japanese papers which is prepared by using alkaline pectinases is more uniform and soft to touch than ordinary paper. Alkaline pectinases used in Japanese paper manufacturing are synthesized by *Erwinia carotovora*, *Bacillus sp*. and some other fungi. These enzymes have strong macerating activity preferably for retting of Mitsumata bast to prepare Japanese paper [48, 49]. The Japanese paper made by pectinases treatment has more strength of the pulp as compared to the conventional soda-ash cooking method.

Waste water treatment

Waste water containing effluents from vegetable food processing industries is the major problem of Pakistan. Water treatment is carried out by using different methods like by chemical methods, physical methods and by other treatments. But all of these conventional methods are time consuming and expensive. They can also lead to environmental pollution from the chemicals used in treatment. So, the best alternative of the sewage water treatment is the use of pectinases enzyme which carry out pretreatment of water. Pectinases can easily degrade pectic substances that are present in water and this degraded pectin is further decomposed by activated sludge treatment. This method is cost effective as well as ecofriendly.

Citrus processing industry contains pectins in their effluents which goes in waste water. These materials are easily degraded by microbial pectinases which were obtained from alkalophilic microorganism i.e. treatment with extracellular Endopectate lyase produced by alkalophilic *Bacillus sp*. (GIR 621) at pH 10.0 has proved to be effective in decomposition of pectin residues from wastewater.

Bioenergy production

Bioenergy is the energy produced from living organism by transforming hydrocarbons produced by these organisms like plants and algae, mostly in the form of sugars and lipids into compounds similar to gasoline, diesel, and ethanol. The plants which are rich in pectin source like apple pomace, citrus, and sugar beet have been recommended as possible sources of hydrocarbon for bioethanol production [50]. The most commonly used pectinases to hydrolyze pectin are endopolygalacturonases (EPGs), acetyl and methylesterases, α-arabinofuranosidase and ß-galactosidases. The most studied organisms for bioenergy production are fungi and plants and only fungi EPGs had their 3D structure characterization [51].

CONCLUSION

Pectinases are upcoming enzymes that are involved in pectin degradation so these enzymes are very important in commercial sector due to their extensive applications. The global sale of pectinases is 25% of the industrial enzymes annually. These enzymes can be easily obtained from living organisms including plants, bacteria and fungi. The major applications of pectinases are in food and agricultural sectors. Other than these applications they have inclusive and widespread application in wine industry, paper and pulp industry preferably in making Japanese paper. Recent research has found

applications of pectinases in waste water treatment and in bioenergy production by degrading pectin and producing bioethanol production respectively.

CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest in this research article.

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