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*Review*

# Psychrophilic yeasts and their biotechnological applications - A review

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**More than 70% of earth's surface is covered by cold ecosystems and these ecosystems have been colonized by a class of extremophilic microorganisms called as psychrophiles. Thus psychrophiles are true extremophiles that has the ability to live in extremely low temperature conditions. Psychrophilic yeasts are important due to their physiological adaptation at low temperature and they have potential application in biotechnology. Psychrophilic yeast produces cold-active enzymes having numerous applications in textile, medical and pharmaceuticals, fine chemical synthesis, food industry, domestic and environmental applications. Psychrophilic enzymes from yeast have attracted attention of researchers to explore the new application of these enzymes because of their high activity at low and moderate temperatures. The present review describes various immune biotechnological applications of different cold-active enzymes produced by psychrophilic yeast in different industries.**

**Key words:** Extremophilic microorganisms, cold-active enzymes, environmental applications.

## INTRODUCTION

Microorganisms which are able to grow at low temperature have been known for long time (Morita, 1966; Farrell and Rose, 1967). Psychrophiles are the microorganisms that have colonized all permanent cold environments. Psychrophilic organisms have been classified in two groups:

i) Which are obligate psychrophiles with optimal growth temperature of ≤ 20°C.
ii) Which are facultative psychrophiles with optimal growth temperature of > 20°C (Stokes, 1963).

Cold-adapted microorganisms can grow at 0°C and are classified as psychrophilic if their optimum and maximum temperatures for growth are ≤15 and ≤ 20°C, respectively, or as psychrotolerant (psychrotrophic) if

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their maximum temperature for growth is above 20°C (Robinson, 2001; Gounot, 1986). Psychrotolerant microbes have an optimum growth temperature between 20 and 40°C, but are also capable of growth at 0°C (Morita, 1975). As the name suggests, these are cold loving microbes that are commonly found in Polar region and also in deep sea, mountains, glaciers, fresh and marine waters, polar and high alpine soils, all together constituting about three-fourth of the biosphere. These organisms produce cold evolved enzymes that are partially able to cope with the reduction in chemical reaction rates induced by low temperatures (D'Amico et al., 2002). The mesophilic yeasts grow between 5 to 35°C. In comparison, the psychrophilic yeasts grow below 5°C and exhibit no growth above 20°C (Shivaji and Bhaskar, 2008). As a group the mesophilic yeasts are the most predominant and constitute the vast majority of the yeasts studied so far as compared to psychrophilic and thermophilic yeasts. Cold-active enzyme might offer novel opportunities for biotechnological exploitation based on their high catalytic activity at low temperature, low thermo stability and unusual specificities (Russell, 2000).

Because of potential biotechnological applications, cold-adapted microorganisms have become increasingly studied in recent years, of the microorganisms most isolated and studied from cold environments, the majority are bacteria, while yeasts constitute a minor proportion (Margesin and Miteva, 2011). Oceans represent 71% of earth's surface and 90% by volume, which are at 5°C. It has been estimated that more than 90% (by volume) of the marine water masses are colder than 4°C (Morita, 1966). Antarctica is considered the coldest and driest terrestrial habitat on Earth. It is covered almost totally with ice and snow, and receives high levels of solar radiation (Holdgate, 1977).

The range of species within a particularly cold habitat reflects many different parameters (for example, primary nutrient, ability to withstand desiccation, pH, salinity) to which an organism must adapt (Blaise et al., 2004).

In this review, we focus on psychrophilic yeast and their cold-active enzymes having biotechnological applications in different industries like; detergent, medical and pharmaceuticals, fine chemical synthesis, food, textile, and domestic industries.

## PSYCHROPHILIC YEASTS AND THEIR HABITATS

Psychrophiles are more likely to be found in permanently cold environments such as polar region (Sabri et al., 2001), marine environment and deep water (D'Amico et al., 2006). Psychrophilic yeasts have been isolated from marine waters, Arctic and Alpine glaciers, and Antarctic ecosystems; their occurrence and abundance in these environments have been described (Vishniac, 1999; Díaz and Fell, 2000; Bergauer et al., 2005; Buzzini et al., 2005). Most of the work particularly on psychrophilic yeast and their cold-active enzymes have been reported from Antarctica. The first report of Antarctic yeasts was published 50 years ago (Menna, 1960) current reports have focused on cold-tolerant bacteria and archaea, with yeasts receiving less attention. The occurrence of psychrophilic yeasts has been reported in glacial melt-water rivers originating from glaciers of Argentinean Patagonia (García et al., 2007). Butinar et al. (2007) reported the occurrence of viable yeasts in the different ice layers of Arctic glaciers located in the Svalbard Islands Norway.

In these environments, psychrophilic and psychro-trophic microorganisms are believed to play key roles in the biodegradation of organic matter and the cycling of essential nutrients (Welander, 2005; Lambo and Patel, 2006; Ruberto et al., 2005). Psychrophilic yeasts, particularly *Cryptococcus sp*. have been isolated repeatedly from soil samples and some researchers have described them as the most important life form in Antarctic desert soils (Vishniac and Klinger, 1986). Yeasts dwelling in Antarctic and Sub-Antarctic maritime and terrestrial habitats belong mainly to the *Cryptococcus*, Mrakia,

*Candida* and *Rhodotorula* genera (Buzzini et al., 2012; Vaz et al., 2011). The presence of organic carbon and nitrogen sources in waters, originated from melting glacier ice, have been demonstrated and the occurrence of yeast strains degrading a variety of organic compounds including polysaccharides, esters, lipids and pectin's have been observed in the yeasts isolated from Alpine glacier environments (Skidmore et al., 2000; Margesin et al., 2002).

Other than Antarctic, psychrophilic yeast *C. capitatum* SPY11 were isolated from the soil of northern region of India Kashmir valley; the yeast was able to grow up to 20°C above which it couldn't grow normally (Hamid et al., 2012). Shivaji and Bhaskar (2008), reported novel psychrophilic yeast *Rhodotorula Himalayans* sp. Nov; isolated from a Roopkund lake of Himalayan mountain range.

## BIOTECHNOLOGICAL APPLICATION OF COLD-ACTIVE ENZYMES

Extremophiles are a potent source of extremozymes, which show outmost stability under extreme conditions. Consequently, much attention has been given to the microorganisms that are able to thrive in extreme environments. Thus, biocatalysis using extremophiles as well as extremozymes is rapidly being transformed from an academic science to an industrially viable technology. Each group of the extremophiles has unique features, which can be harnessed to provide enzymes with a wide

range of application possibilities (Adams et al., 1995; Hough et al., 1999). Microbial enzymes are also more stable than their corresponding plant and animal enzymes and their production is more convenient and safer (Wiseman, 1995). Psychrophiles produce cold-adapted enzymes that have high specific activities at low temperatures (Feller and Gerday, 2003). These enzymes have the ability to support transcription and translation at low temperatures (Goodchild et al., 2004). Psychrophilic enzymes isolated from psychrophilic yeasts exhibit high activity at low and moderate temperatures and thus offer potential economic benefits (Allen et al., 2001). Kourkoutas et al., (2002) reported that psychrophilic yeast can be used in low temperature fermentation. Cold-active or cold-adaptive enzymes have attracted great attention as biocatalysts because they have the ability to resist quite unfavorable reaction conditions in industry (Deming, 1998; Singh et al., 2012; Sahay et al., 2013). Psychrophilic and psychrotolerant microorganisms and their unique cold shock and cold-acclimation proteins and enzymes (for example, proteases, lipases and cellulases) having a host of biotechnology applications (Gounot, 1991). Industrially interesting enzymes that are screened from yeasts are lipase / esterase, amylase, cellulase and β-glucosidases (Middelhoven, 1997; Laitila et al., 2006; Kudanga et al., 2007; Strauss et al., 2001; Buzzini and Martini, 2002; Rodríguez et al., 2004).

There are nearly 4000 enzymes known today and of these about 200 are in commercial use (Sharma et al., 2001). As a rule, enzymes produced by microorganisms existing in cold environments display higher catalytic efficiency at low temperatures and greater thermo sensitivity than their mesophilic counterparts (Gerday et al., 1997). Psychrophilic yeast has been reported to be used in low temperature fermentation (Pfeffer et al., 2006; Liu et al., 2006; Kourkoutas et al., 2002). The high activity of psychrophilic enzymes at low and moderate temperatures offers potential economic benefits (Cavicchioli et al., 2002). There is an industrial tendency to treat foodstuffs under mild conditions in order to avoid spoilage, and changes in taste and nutritional value at an ambient temperature. Therefore, cold-active enzymes are used for processing foods, (Margesin and Schinner, 1994; Russell and Hamamoto, 1998; Gerday et al., 2000). Cold-active enzymes with unique molecular adaptabilities (Feller and Gerday, 1997) have opened up potential newer areas of applications (Singh et al., 2012; Sahay et al., 2013). Processes catalyzed by cold-active enzymes have two advantages, they have potential to economise the processes by saving energy (Deming, 1998; Cavicchioli et al., 2002), and they protect the processes from contamination (Gardey et al., 2000). Over 91 basidiomycetous yeasts (belonging to the genera Cryptococcus, Leucosporidiella, Dioszegia, Mrakia, Rhodotorula, Rhodosporidium, Sporobolomyces, Sporidiobolus, Cystofilobasidium and Udeniomyces) have been screened for extra cellular amylolytic, protolytic, lepolytic, esteric, pectinolytic, actenolytic activities (Brizzio et al., 2007). These findings suggest that cold environments of Patagonia (Argentina) may be considered as a potential source of cold adapted yeasts producing industrially relevant cold-active enzymes (Brizzio et al., 2007). The majority of the industrial enzymes are of microbial origin. Several microbes are capable of using these substances as carbon and energy sources by producing a vast array of enzymes in different environmental niches (Kaur et al., 2004; Antranikian, 1992).

The ability to heat-inactivate cold-active enzymes has particular relevance to the food industry where it is important to prevent any modification of the original heat-sensitive substrates and product. This is also of benefit in sequential processes (example, molecular biology) where the actions of an enzyme need to be terminated before the next process is undertaken; with cold-adapted enzymes this might be accomplished by heat inactivation rather than chemical extraction (Russell et al., 1998; Gerday et al., 2000). Cold-active enzymes from psychrophilic yeasts can be applied to the food industry, for clarification of fruit juice at low temperature.

The enzymes from microorganisms are used in various industries such as dairy, food, detergents, textile, pharmaceutical, cosmetic and biodiesel industries, and in synthesis of fine chemicals, agrochemicals and new polymeric materials (Saxena et al., 1999; Jaeger and Eggert, 2002). Several yeast strains have been explored in regards to the biological treatment of industrial and domestic waste water (Thanh and Simard, 1973; Ohno et al., 1991). Katayam et al. (1997) reported psychrophilic yeast *Candida* sp. which was isolated from water samples from Lake Vanda in Antarctica it can be used for the treatment of dissolved organic matter at low temperatures.

In recent years, the potential of using microorganisms as biotechnological sources of industrially relevant enzymes has stimulated interest in the exploration of extracellular enzymatic activity in several microorganisms (Akpan et al., 1999; Abu et al., 2005). The properties of cold-active enzymes provide numerous avenues for industrial application; however, specific properties may be improved through enzyme engineering.

## Pectinases

Pectinolytic enzymes or pectinases are a heterogeneous group of enzymes that hydrolyze the pectic substances present in plants. They include polygalacturonases (PG), pectin lyase (PL), and pectin esterase (PE) that hydrolyze the glycosidic bonds of pectic substances (Fogarty and Kelly, 1983). Psychrophilic yeast strains *C. cylindricus* and *M. frigida* have been isolated from soil of Abashiri

(Nakagawa et al., 2004). The isolated strains can grow on pectin as the only carbon at below 5°C and showed the activities of several cold-active pectinolytic enzymes (Nakagawa et al., 2004).

Eight cold-adapted polygalactu-ronase producing yeasts have been isolated from frozen environmental samples of Iceland, which belong to *C. larimarini, C. capitatum, C. macerans and C. aquaticus* (Birgisson et al., 2003). It have been demonstrated that yeasts such as *Kluyveromyces wickerhamii* (Moyo et al., 2003) and moulds such as *Aspergillus niger* CH-Y-143 (Aguillar and Huitron, 1990), are capable of producing polygalacturonases constitutively.

The cold-active pectinolytic enzymes (Pectin methylesterase PME, endo-PG and exo-PG) from the newly isolated and identified psychrophilic yeast *C. capitatum* SPY11 and psychrotolerant yeast *R. mucilaginosa* PT1that exhibited 50 to 80% of their optimum activity under some major ecological conditions pH (3 to 5) and temperatures (6 and 12°C) could be applied to wine production and juice clarification at low temperature (Sahay et al., 2013). Pectinolytic enzymes are used for the degradation of pectin compounds in the fruit and vegetable processing industries (Alkorta et al., 1998). Cold-active pectinolytic enzymes are required in wine industries both for extraction and for clarification (Merin et al., 2011). Cold-active pectinases in addition has potential to maintain nutritional value, taste and sensory features (Nakagawa et al., 2002).

Most studies that involve the screening of yeasts for enzyme production target proteinase or pectinase, mainly because these are important enzymes used to clarify fruit juices (Braga et al., 1998). Earlier cold-active pectinase produced by psychrophilic yeast *C. capitatum* strain PPY-1 (Nakagawa et al., 2002) had been reported; these enzymes may be used for processing foods (Margesin and Schinner, 1994; Russell et al., 1998; Gerday et al., 2000). It have been reported that PPY (Pectinolytic-psychrophilic yeast) were examined for pectinolytic activities at 5°C and strains exhibited pectin esterase activities (Nakagawa et al., 2004). Six psychrophilic fungal isolates has been reported earlier from the new geographical region of Jammu and Kashmir, India as a source of cold-active pectinolytic activities of oenological grade (Singh et al., 2012).

## Lactases

Lactose is the main part of daily intake carbohydrate. β-Galactosidase hydrolyzes lactose into glucose and galactose, so it's commercially called lactase (Shukla and Wierzbiciki, 1975). Hamid et al. (2013) reported that psychrophilic yeast *C. capitatum* SPY11 and psychro-tolerant yeast *R. mucilaginosa* PT1 strains produce cold-active β-galactosidases that are able to degrade lactose at low temperature; β-galactosidase activity of both strains was found highest at 4°C, thus reflecting the nature of cold active enzymes. The β-galactosidase enzyme produced by these strains will have potential application at low temperature in dairy as well as in biotechnological industries.

Use of cold-active lactase has added advantage to catalyze lactose hydrolysis at storage temperature (that is 4°C) with no extra effort to change place and at the same time no risk of contamination which is possible at higher temperature. A number of important genes coding for cold-active β-galactosidase have been detected in yeast (Nakagawa et al., 2006a, b). Therefore, cold-active lactases have recently been attracting attention, as there is an increasing industrial trend to treat dairy products under mild conditions to avoid spoilage and changes in the taste and nutritional value, and cold-active lactase can be inactivated at a low temperature without heat treatment (Margesin, and Schinner, 1994). The psychrotrophic yeasts (PPY-1) *C. capitatum* with β-galactosidase activity have been isolated (Nakagawa et al., 2002). It has been reported that *A. psychrolactophilus* strains B7, D2 and D5 produce cold-active β-galactosidase (Loveland et al., 1993). Cold-adapted β-galactosidase with high activity levels at low temperatures might prove to be useful for removing lactose from refrigerated milk enabling it to be consumed by lactose intolerant individuals, and for converting lactose in whey into glucose and galactose. *K. lactis*has been used for its industrial potential in the production of β-galactosidase enzyme which could be used to reduce the lactose content of milk (Suarez et al., 1995).

## Amylases

Amylases are enzymes that hydrolyze starch molecule to give diverse products including dextrin and progressively smaller polymers made up of glucose units (Pandey et al., 2000; Syed et al., 2009). Amylases have been estimated to comprise approximately 30% of the world's enzyme production (Maarel et al., 2002). These enzymes can be divided basically into four groups: endoamylases, exoamylases, debranching enzymes and transferases (Maarel et al., 2002). Though amylases originates from different sources (plants, animals and microorganisms), the microbial amylases are the most produced and used in industry, due to their productivity and thermo stability (Burhan et al., 2003). Fungi, bacteria and yeasts have been reported to produce these enzymes (Salvakumar et al., 1996).

Amylases are one of the most important industrial enzymes that have a wide variety of applications ranging from conversion of starch to sugar syrups, to the production of cyclodextrins for the pharmaceutical

industry (Maarel et al., 2002; Satyanarayana et al., 2005). Processes catalyzed by cold-active enzymes have two advantages: they have potential to economise the processes by saving energy (Deming, 1998; Cavicchioli et al., 2002), and they protect the processes from contamination (Gardey et al., 2000). Mould amylases are used in alcohol production and brewing industries (Van and Smith, 1968). Amylases are significant enzymes for their specific use in the industrial starch conversion process (Nigam and Singh, 1995).

Amylases have been found in many yeast species (Gupta et al., 2003; De Mot et al., 1984) including *Lipomyces kononenkoae* (Prieto et al., 1995), *Schwanniomyces alluvius* (Wilson and Ingledew, 1982; Moranelli et al., 1982), *Trichosporon pullulans* (De Mot and Verachtert, 1986), *Candida antarctica* (De Mot and Verachtert 1987) and *C. flavus* (Wanderley et al., 2004). A cold active α-amylase from Antarctic psychrophile *Alteromonas haloplanktis* was reported to exhibit maximum α-amylase production at 4°C (Ramachandran et al., 2004; Hayashida and Teramoto, 1986; Moller et al., 2004). A mutant strain of yeast (*S. cerevisiae*) has been found to secrete amylases (Wang et al., 2001).

## Proteases

Proteases represent one of the three largest groups of industrial enzymes and have traditionally held the predominant share of the industrial enzyme market accounting for about 60% of total worldwide sale of enzymes (Rao et al., 1998). Cold active proteases have found their way into many applications like in industries of detergents, food, textiles, cosmetics, beverages, pharmaceutical, bioremediation and bakery (Hamamoto et al., 1994; Baghel et al., 2005; Anwar and Saleemuddin, 1998; Gupta et al., 2002).

Cold-adapted or low temperature tolerant proteases suit well in waste management in cold environments, where the degradation capabilities of endogenous microflora are reduced due to low temperatures. Probably the largest application of proteases is in laundry detergents, where they help in removing protein based stains from clothes (Banerjee et al., 1999). Psychrotrophic, dimorphic yeast *Candida humicola,* isolated from Antarctic soil, secretes an acidic protease into the medium (Ray et al., 1989). Earlier studies have indicated that yeasts belonging to the genera *Kluyveromyces, Endomycopsis, Cephalosporium, Aureobasidium, Saccharomycopsis, Rhodotorula, Candida* and most sporobolomycetes and trichosporons secrete proteolytic enzymes (Ahearn et al., 1986). Many of these yeasts are probably also psychrotrophic (Ahearn et al., 1986), but the proteolytic enzymes secreted by them has been neither purified nor characterized. Cold-adapted proteases thus can be used to optimize present day industrial processes and for developing future technologies with less energy inputs and process cost by removing the cost of heat inactivation step (Cavicchioli et al., 2002; Deming, 2002; Margesin et al., 2002).

## Phytases

Phytase is an enzyme that releases digestible phosphorus, calcium and other nutrients from phytic acid (myo-inositol hexakisphosphate) and thereby, help to reduce environmental phosphorus pollution (Mllaney et al., 2000). Phytases are found naturally in plants and microorganisms, particularly fungi (Stanley, 1961; Somoilova, 1980; Valikhanov et al., 1981; Wang et al., 1980). Several yeast species have been screened for their extracellular phytase activity and it was also reported that yeasts are important source of phytases (Nakamura et al., 2000; Vohra and Stayanarayan, 2001; Wodzinski and Ullah, 1996). Cold-active phytases from psychrophilic yeasts will help in reducing the phosphorus pollution in the cold environments. Earlier reports also attest the stability of yeast phytate (Quan et al., 2001) from *C. krusei.*

Phytase is already used as a supplement in diets for monogastric animals to improve phosphate utilization from phytate, the major storage form of phosphate in plant seeds. In recent years, this class of enzymes has also been found increasingly interesting for use in processing and manufacturing of food for human consumption, particularly because the decline in food phytate results in an enhancement of mineral bioavailability. Different strategies could be applied to optimize phytate degradation during food processing and digestion in the human alimentary tract such as adjustment of more favourable conditions during food processing for the phytases naturally occurring in the raw material, addition of isolated phytases to the production process, use of raw material with a high intrinsic phytate-degrading activity either naturally present or introduced by genetic engineering and the use of recombinant food-grade microorganisms as carriers for phytate-degrading activity in the human gastrointestinal tract (Greiner and Konietzny, 2006). Furthermore, phytases may find application in the production of functional foods or food supplements with health benefits.

## Lipases

Lipases are a class of enzymes which catalyze the hydrolysis of long chain triglycerides and constitute the most important group of biocatalysts for biotechnological applications (Joseph et al., 2007). Lipases were first discovered in 1856 by Claude Bernard when he studied the role of the pancreas in fat digestion (Peterson and

Drablos, 1994). Lipolytic enzymes are grouped into three main categories, which are esterases, phospholipases and lipases (Arpigny and Jaeger, 1999). Permanently cold regions such as glaciers and mountain regions are another habitat for psychroplillic lipase producing microorganisms (Joseph, 2006). Microbial lipases are also more stable than their plant and animal derivatives and their production is easier and safer for industrial and research applications (Schmidt-Dannert, 1999).

Although a number of lipase producing sources are available, only a few bacteria and yeast were exploited for the production of cold adapted lipases (Joseph, 2006). Psychrotrophic fungi such as *Rhizopus sp*., *Mucorsp*., have been reported to produce cold active lipases (Coenen, 1997). An extensive research has been carried out in the cold active lipase of *C. antarctica* compared to other psychrophilic fungi. Use of lipase B from *C. antarctica* for the preparation of optically active alcohols has been reported (Rotticci et al., 2001). Lipase from *C. antarctica* has been evaluated as catalyst in different reaction media for hydrolysis of tributyrin as reaction model (Salis et al., 2003). *C. lipolytica*, *G. candidum* and *P. roqueforti* have been isolated from frozen food samples and reported to produce cold active lipases (Alford and Pierce, 1961).

Cold active lypolytic enzymes are currently attracting an enormous attention because of their biotechnological potential (Benjamin and Pandey, 1998). Psychrophilic enzymes are highly approached for different industrial applications; it has been reported that alkaline yeast lipases are preferred because they can work at lower temperatures as compared to bacterial and fungal lipases (Ahmed et al., 2007; Saxena et al., 1999). Various industrial applications of cold-active microbial lipases in the medical and pharmaceuticals, fine chemical synthesis, food industry, domestic and environmental applications have been reported (Joseph et al., 2007). Cold active lipase A and lipase B from *Candida antarctica* have been expressed in *C. antarctica* and *E. coli*, respectively, for their biotechnological applications (Pfeffer et al., 2006; Liu et al., 2006). Research on microbial lipases, has increased due to their great commercial potential (Silva et al., 2005). Cold-active lipases could be a good alternative to mesophillic enzymes in brewing industry and wine industries, cheese manufacturing, animal feed supplements and so on (Collins et al., 2002).

## Xylanases

Xylan is the major component of hemicellulose consisting of β-1, 4-linked D-xylopyranosyl residues. The hydrolysis of xylan in plant materials is achieved by the use of a mixture of hydrolytic enzymes including endo-β-1, 4-xylanase and β-D-xylosidase (Polizeli et al., 2005). The importance of xylanase has tremendously increased due to its biotechnological applications for pentose production, fruit-juice clarification, improving rumen digestion and the bioconversion of lignocellulosic agricultural residues to fuels and chemicals (Nigam and Pandey, 2009; Srinivasan and Rele, 1995; Garg et al., 1998).

Xylanase from an Antarctic yeast *C. adeliae* that exhibits optimal growth at low temperature has been reported (Petrescu et al., 2000). The xylanase from *C. adeliae* is less thermostable than its mesophilic homologue when the residual activities are compared, and this difference was confirmed by differential scanning calorimetry experiments. In the range 0 to 20°C, the cold-adapted xylanase displays lower activation energy and a higher catalytic efficiency (Petrescu et al., 2000).

It has been found that yeast, unlike bacteria, can perform certain post translational modifications, such as glycosy-lation which particularly affects the enzymatic activity of recombinant proteins, as demonstrated for the xylanase from yeast *C. albidus* (Runge et al., 1988). Scorzetti et al. (2000) isolated a *C. adeliensis* sp. nov. from Terre Adelie, Antarctica, this produced a cold-active xylanase. Amoresano et al. (2000) reported that a common folding motif might occur within the entire xylanase family isolated from psychrophilic yeast. Alkaliphilic xylanases would also be required for detergent applications where high pHs are typically used (Kamal et al., 2004).Cold-adapted family eight xylanase is more efficient in baking than a commonly used commercial enzyme (Dutron et al., 2004). Xylanase from psychrophilic *Coprinus psychromorbidus* have been reported (Inglis et al., 2000).

## CONCLUSION

There are a lot of industrial processes to which cold active enzymes can be applied to improve the quality and the yield of final products. It is important to investigate the production conditions and physico-chemical characteristics of psychrophilic enzymes produced by psychrophilic yeasts. Cold-active enzymes having a set of biochemical and physical properties can be generated for each specific industrial process. These studies can provide valuable tools for biotechnologists and microbiologists to improve microorganisms and make them able to produce efficient cold-active enzymes. More studies are required to find out newer venues of applications as the field of cold active enzymes is yet at infancy.

## Conflict of Interests

The author(s) have not declared any conflict of interests.

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