Chapter 5
Psychrophiles: Distribution, Ecology, Physiology, Metabolism, Cold Adapted Enzymes, and Proteins

Shreyas Anantray Bhatt
Hemchandracharya North Gujarat University, India

ABSTRACT

Life on the Earth has evolved in the cold environments. Such cold habitats pose special challenges to the microbes in cold ecosystems, such as minimum metabolic activities, very limited nutrient availability, and often extreme conditions such as pH and salinity apart from temperature. Microbial communities surviving under these extreme conditions must have evolved complex structural and functional adaptations. Prokaryotic adaptations to cold environments are through physiological adaptations by increasing membrane fluidity through large amount of unsaturated fatty acids. These microbes also possess some cold adapted proteins whose steady state levels are maintained. They also produce certain compounds such as polyamines, sugars, polyols, amino acids, and some antifreeze proteins to protect themselves under freezing conditions. They also produce exopolymeric substances that promote adhesion of microbes to moist surfaces to induce biofilm formation which helps getting nutrients and protect the cells from harsh conditions. Antioxidants help destroying toxic reactive oxygen species.

BACKGROUND

Much of the knowledge on the microorganisms inhabiting the cold environments has been accumulated during 1960s and 1970s. Several debatable definitions have been proposed for the range of temperatures for the growth for psychrophiles. It has now been well accepted that the microorganisms defined as psyhrophiles have maximum growth temperature of 20 °C. However, those microbes that grow well at lower temperatures but can also grow at >20 °C are termed as psychrotolerant or also called prychrotrophs. The difficulty faced in defining psychrophiles is because many microorganisms have evolved to withstand the temperature fluctuations and there is no threshold cut off of temperature for the growth

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of microorganisms. However, proposed the definition of psychrophiles as 'Any organism that grows at 5 °C or below' to distinguish from mesophiles that grow well at 37 °C. However, it is difficult to distinguish psychrotolerant from psychrophiles on the basis of metabolic activities because there are several organisms that can grow above 20 °C temperature and can produce enzymes that can show good activity below 20 °C.

The diversity of psychrophiles comprises vast variety of microorganisms as most of the Earth's surface have temperature favourable for psychrophilic organisms. Moreover, these organisms are also reported from harsh environmental conditions such as high pH, high pressure, nutrient scarcity, high salt concentration, deep sea and ice accretions. The capacity of these organisms to produce different hydrolytic enzymes and antifreeze proteins, antioxidants make them competent to grow and catalyse many organic compounds that help them to survive under inhospitable environments.

INTRODUCTION

The initial colonization of life on the Earth has been reported to be evolved in the cold environments. The largest portion of the global biosphere is represented by the communities growing and surviving at temperatures below 5°C (Siddiqui & Cavicchioli 2006; Margesin & Miteva, 2011). Low to extreme low temperature environment have always been fascinating source for scientists particularly for microbial life existing and for long term survival as well as adaptation to some of the very harsh conditions including frost and permafrost temperatures.

Microbial species inhabiting the cold environment are recognized by different terminology such as "Psychrotrophs", Psychrophiles, Psychrotolerant and Cold active etc., and are exploited for their ability to survive and grow at low temperatures. "Psychrophile" is a generic term used generally to include all organisms inhabiting cold climatic conditions. Psychrophilic microorganisms have been an interesting subject for microbial ecologist, physiologists, geneticists and taxonomists for their biochemical and physiological adaptations through complex processes for protein stability and their catalytic function.

It has been reported that about 80% of the biosphere of the Earth experiences an average of 15°C temperature. However, some of the specialized psychrophilic habitats such as permafrost sediments, Antarctic lakes and deep marine ecosystems have been explored for microbial diversity and found greater diversity than expected.

HABITAT

It is well accepted that wherever there is possibility for existence of microbial life, it is found to exist. Microbes are found in very harsh environments of extremely halophilic conditions especially spore forming bacilli are found in a 250 million year old salt crystal. A bacterial spore has also been revived, cultured and identified from 40 million year old amber . Similarly microbial life has also been reported to be found at several kilometres of depth in the Earth's crust and viable bacterial populations have been discovered at depths of 750 m in Pacific Ocean sites. Bacterial population can also grow and reproduce at ≤ 0 °C in the cloud droplet at high altitude.

Microbes might have existed in permanent ice cap some 14 million years ago and their descendants may live in sub glacial rock crevices, lakes and sediments. Some population of psychrophilic bacteria