Chapter 3
Alkalophiles: Environmental Distribution, Taxonomy, Physiology, Bioenergetics, Survival Mechanism, and Enzymes

Vishal Arvindlal Mevada
Directorate of Forensic Science, Gandhinagar, India

Urvisha Himmatbhai Beladiya
Veer Narmad South Gujarat University, Surat, India

Himani Rajendrakumar Gandhi
Christ College, Saurashtra University, Rajkot, India

Amitsinh Vijaysinh Mangrola
Shri Alpesh N. Patel Post Graduate Institute of Science and Research, Anand, India

Rajesh Kanjibhai Patel
Veer Narmad South Gujarat University, Surat, India

ABSTRACT

Alkalophiles are a class of extremophiles capable of survival in alkaline (pH roughly 8.5–11) environments, growing optimally around a pH of 10. At such high pH, the normal cellular functions are detrimentally affected for mesophilic organisms. The alkalophiles successfully manage stability of DNA, plasma membrane, and function of cytosolic enzymes, as well as other unfavorable physiological changes at such an elevated pH. A recent development in NextGen sequencing technology facilitates identifying uncultivable organisms amongst the extreme environments. In recent years, distribution of alkalophiles was reported from Soda Lake, marine environments, saline deserts, and natural thermal vents to natural water bodies. Although alkalophiles were first reported in 1889, their enzymatic and industrial applications still make them an interesting area of research. This chapter provides basic information on environmental distribution, taxonomy, physiology, bioenergetics, and survival mechanism and enzymes produced by alkalophilic organisms.

DOI: 10.4018/978-1-7998-9144-4.ch003

INTRODUCTION

Microorganisms are the most common living things on Earth. They are also highly diverse organisms found in almost every corner of the blue planet. Extremophilic microorganisms are a largely unexplored group that can survive in extreme conditions. Among the extremophiles group, Alkaliphiles or alkalophiles can thrive in alkaline (pH 8 to 11) environments. At such a high pH, normal cell functions for mesophilic organisms are adversely affected including inactivation of cytosolic enzymes, instability of DNA and plasma membrane. The adaptations in the genetic and metabolic machinery of these organisms allowed them to thrive in hostile conditions.

Chester (1889) reported bacterium *Sporosarcina pasteurii* (formerly *Bacillus pasteurii*) as the first alkaliphilic organism (Chester, 1897). The organism has capability to generate ammonium carbonate from urea in the presence of ammonia and alkaline environment. Later on in 1934, Vedder reported *Bacillus alcaliphilus* as a second example of isolation of alkalophiles. After the initial discovery, Takahara and Tanabe isolated indigo-reducing alkalophile capable of growing at pH 12.1 in 1960. During 1970-1980s, several studies reported for the applications of alkalophiles industrial applications. However, due to lack of proper methods to classification most of the isolates could not be appropriately classified upto species level. In 1990, Fritzie *et al.,* reclassified such alkalophiles based on their physiological and characteristics up to species level. With the advent of technology, the taxonomic classifications were revised based on DNA G+C mol% values, presence of diaminopimelic acid (DAP) in its cell wall, DNA–DNA hybridization and 16S rRNA gene. Initially, most of the species of *Bacillus* from phylum Fermicutes were proposed in Alkalophiles. However, several research studies have greatly isolated the organisms from phyla Cyanobacteria, Actinobacteria, Proteobacteria, Bacteroidetes, Thermotogae, Spirochaetas, Archaea (Euryarchaeota), and Yeast. The current scenario is still in favor of increased isolation and identification of alkalophiles due to their enormous capability for industrial applications. In recent years, distribution of alkalophiles was reported from soda lake, marine environments, saline deserts, natural thermal vents to natural water bodies. There are innumerous examples of these fascinating organisms have been discovered now and these include primarily prokaryotes (bacteria and archaea) and some eukaryotes (algae, yeast and fungi) (Kumar and Hovik, 2019).

BACKGROUND

Alkalophiles are a class of extremophilic microbes capable of survival in alkaline (pH roughly 8.5–11) environments, growing optimally around a pH of 10. These are generally categorized into two major physiological groups: Alkali-tolerant organisms that show optimal growth in the pH range of 7.0–9.0 but cannot grow above pH 9.5 and alkalophilic organisms that show optimal growth between pH 10.0 and 12.0. Furthermore, the extreme alkalophiles subdivided into facultative alkalophiles, obligate alkalophiles etc. Along with that, alkali tolerant strictly anaerobic strains and obligatory anaerobic species reported in lake Magadi Kenya in 1988 (Norton and Grant, 1988).

As alkalophiles were able to sustain at high temperature under aerobic and anaerobic conditions, the enzymes produced by such organisms were alkalostable and thermostable. Such physiological features allow us to explore new applications in protein engineering and production of thermostable enzymes industries (Reed *et al.,* 2013). Most of the alkalophiles are spore formers, the environmental effects would not directly affect in spore form (Tayyem *et al.,* 2021). However, the organism faces a central problem in