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HALOPHILIC BACTERIA FROM LOW AND HIGH INTERTIDAL ZONE OF MANGROVE SOIL IN BLUE LAGOON, PORT DICKSON, NEGERI SEMBILAN

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Introduction

Mangroves are among the world's most productive marine ecosystems, providing a distinctive habitat for many species as well as essential services and supplies for humans. Mangroves are believed to be one of the most specialized ecological abundances of halophytic plants, appearing as a transition zone between land and sea. Mangrove forests have a unique ecosystem that can dwell in a challenging environment with limited oxygen levels in the water (Othman & Wan Daud, 2018). Mangroves spend most of their life period submerged in seawater, where the sea level affecting the mangroves varies depending on the tidal surges (Wan Ahmad et al., 2018). Since mangroves are capable of living in high-salinity environments, microorganisms such as halophiles exist in the rhizosphere of the mangrove forests.

Halophilic bacteria are considered a unique microbe as they can tolerate and live in the high salinity of the soil which may give a lot of benefits to Malaysian industries.

Halophiles consist of both prokaryotic and eukaryotic species that can regulate osmotic potential in extreme conditions and prevent salt denaturation of their membranal structures. This microorganism is capable of tolerating and surviving in extreme salinity due to the special biological structure that it possesses. Halophilic bacteria can tolerate a wide-ranging salinity level (2-30% NaCl). Hence, halophilic bacteria have adaptations to moderate and high salt concentrations where they can modify themselves so they can thrive in a salty environment even when tidal surges occur over an extended period along the mangrove shoreline (Mahadevaswamy & Nagaraju, 2018). A limited number of halophiles have been isolated from mangrove areas in Malaysia, for example, *Robertkochia* and numerous other *Flavobacteriaceae* members that were collected at Tanjung Piai National Park (Lam et al., 2020).

Mangrove Forest

Mangrove habitats, which are located at the boundary between terrestrial and marine ecosystems and are dominated by independent plant communities, are suitable for a variety of changing substrate, oxygen level, salinity, and temperature conditions (Awuku-Sowah et al., 2022). Mangroves also form intertidal plant formations that are typical of protected tropical and subtropical coastlines. They have also been referred to as "mangrove woods," "tidal forests," "coastal woodlands," and "mangals" (Saenger, 2002). Mangrove forests are particularly known for their resilience to harsh environmental conditions such as high salinity, an extended hydroperiod, water surges, and the buildup of toxic pollutants (Javid et al., 2020). It is usually located in the estuary where land and sea converge. The sea tidal system always exerts an impact on this region, allowing the biological, chemical, and physical components of both land and seawater to coexist (Ambeng et al., 2019).

Figure 1: Mangrove forest.
(Source: https://www.newindianexpress.com/states/tamil-nadu/2023/jun/19/invasive-plants-remain-a-major-hurdle-for-mangrove-forest-plantation-2586285.html)

Special adaptation of mangrove forest

Mangrove trees effectively provide protection to its coastal regions from erosion, tsunamis, and storm surges. Distinct characteristics include having such tough root systems, special bark and leaf structures, and other adaptive responses that allow them to thrive in harsh ecological systems. Most mangrove plants have aerial or prop roots, which are known as pneumatophores, or respiratory roots. They also have buttressed trunks as their habitat is soft with sandy clay, shallow and flow of water provides almost no support. The uniqueness that mangrove forests possess helps maintain the shoreline structure and hence prevent the occurrence of shoreline erosion which in turn can act as a storm barrier to reduce damage to the region (Omar et al., 2020). Mangrove plants have adapted in a variety of ways, including aerial roots, vivipary, the presence of salt glands on the leaves, thickness of the leaves and waxed leaved epidermis to confront the salty environment and thus, endure in intertidal zones (Srikanth et al., 2015). They tolerate the salt water and so outcompete other plants by excreting the salt through pores in their roots and leaves. Figure 2 presents the mangrove specialized adaptations to its ecosystem.

The role of microbes in mangrove ecosystem

Various species of microorganisms can be found in mangrove microbial populations. Algae, fungi, bacteria, and protozoa are present in the biosphere and execute specialized ecological functions (Palit et al., 2022). Microorganisms that exist in the mangrove ecosystem play a significant role because they can tolerate high salinity conditions. Bacteria that can be found in the rhizosphere contribute to the fertility of soil and help in the bioremediation of toxic materials in the soil and water (Mohanta et al., 2020).

Most of the nutrient cycle in mangrove areas is essentially managed by the bacterial community (Thatoi et al., 2020). Even though mangrove forests are high in organic matter, they are low in nutrients, especially nitrogen and phosphorus (Holguin et al., 2001). Microorganisms contribute significantly to nitrogen cycling in mangrove sediments through a wide range of actions such as fixation, denitrification, and anammox, or anaerobic ammonium oxidation. Microbes have the capability of recycling nutrients, producing, and consuming greenhouse gases, destroying pollutants, handling anthropogenic waste, and biologically controlling plant and animal pests. Moreover, microbes on root and leaf surfaces can provide pathogen defence and initiate decay processes upon senescence. The substances were isolated from three different types of mangrove resources, which are plant and plant companions, actinobacteria, and endophytic fungus (Awuku-Sowah et al., 2022).

Moreover, manipulation of microorganisms can be used to remedy or reduce specific problems in mangrove ecosystems. *In situ* characterization of microbiological degradation capability, for instance, promotes the development of microbiome modification approaches as a tool for combating or alleviating the oil effect on mangroves due to oil spills. Oil-degrading, health-promoting (ODHP) microbial communities are of considerable interest because they offer two primary functions: promoting oil degradation and enhancing ecosystem and plant health. In fact, microbial communities in mangrove sediments have been discovered to have efficiency in breaking down oil structures, making them an excellent reservoir of effective hydrocarbon-degrading bacteria that can be used as an inoculum for bioremediation (Allard et al., 2020).

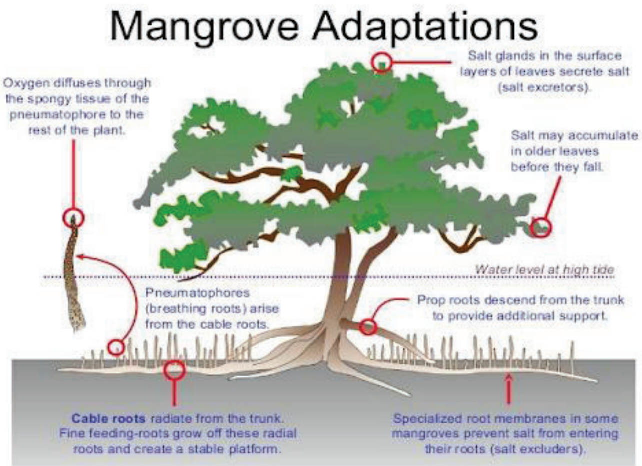

Figure 2: Mangrove specialized adaptations. (Source: Officer's Pulse, 2022)

Halophilic bacteria

Mangrove ecosystems are home to a variety of halophilic bacteria due to their saline environment. Halophilic bacteria are acknowledged to be predominant in mangrove habitats due to their remarkably unique adaptations that allow the bacteria to thrive in saline water (Khan et al., 2009). Halophilic bacteria or halophiles are those that can survive in enormously high salinity conditions and require salt to grow and reproduce. Since halophiles possess charged amino acids on their membranes, it enables their cellular machinery to adapt to high salinity, which enables the retention of water molecules surrounding these components (Mahadevaswamy & Nagaraju, 2018). Microorganisms that have no adaptation to high salinity conditions will tend to lose water, which will initially cause the cells to shrink before they ultimately lose both their morphology and function. The highly acidic amino acid level in these bacteria's proteins, which contributes to the increment of the negative protein surface potential, has been associated to their ability to adapt to hypersaline conditions. Figure 3 shows the authors had been collecting the soil sample where the halophilic bacteria reside in different zones of mangrove soil.

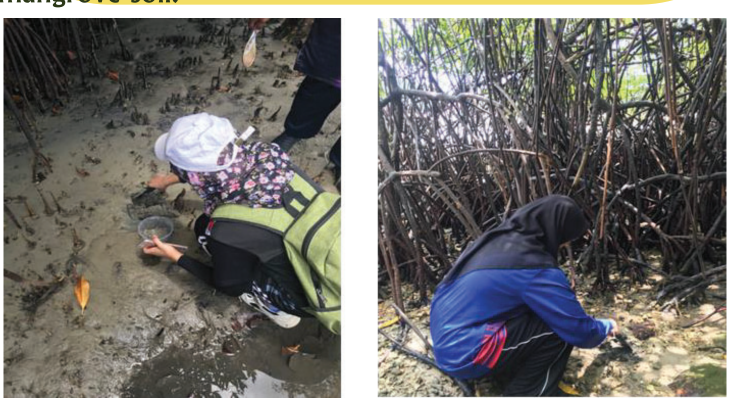

Figure 3: Authors had been collecting the soil sample from different zones of mangrove sediments prior to isolate the halophilic bacteria in the laboratory.

In mangrove habitats, a few bioactive compounds with diverse biological functions ranging from antioxidant to anticancer and antidiabetic have been recovered from many bacterial and fungal species (Sadeer & Mahomoodally, 2022). Enzymes such as amylase, α-amylase, xylanase, and esterase produced by halophilic bacteria exhibit remarkable effects that can be used in industry. Many companies are drawn to the adaptability of protein stability under osmotic pressure, high pH, and salinity as the best suitable choice for enzymes. Halophiles provide stable enzymes that can help all industrial biotechnology goals succeed. Halophiles may also be used in the food industry and biotechnological applications such as making solar salt from seawater and fermenting traditional foods. The development of beta-carotene by the green alga *Dunaliella* and the production of ectoine, an enzyme stabilizer now utilized in cosmetic products, are two highly effective biotechnological processes employing halophiles (Oren, 2010). Figure 4 shows the habitat, the adaptation of halophiles to their environment and their biotechnological potentials.

Low and high intertidal zone in Blue Lagoon, Port Dickson, Negeri Sembilan

The intertidal zone is an ecological area found on maritime coastlines where a variety of organisms dwelling on the shore tolerate tide changes. A low intertidal zone correlates with low tide when it is exposed to the air. This area is closest to the sea and is submerged most of the time with seawater. This zone has the most living organisms because it provides preferable conditions for organisms that are unable to withstand prolonged air exposure. Low tide zone organisms have no requirement to be highly adapted to drying out and extreme fluctuations in temperature (Mohan & Swathi, 2020).

The high intertidal zone is the zone that floods during the peaks of daily high tides but remains dry for lengthy periods between high tides.

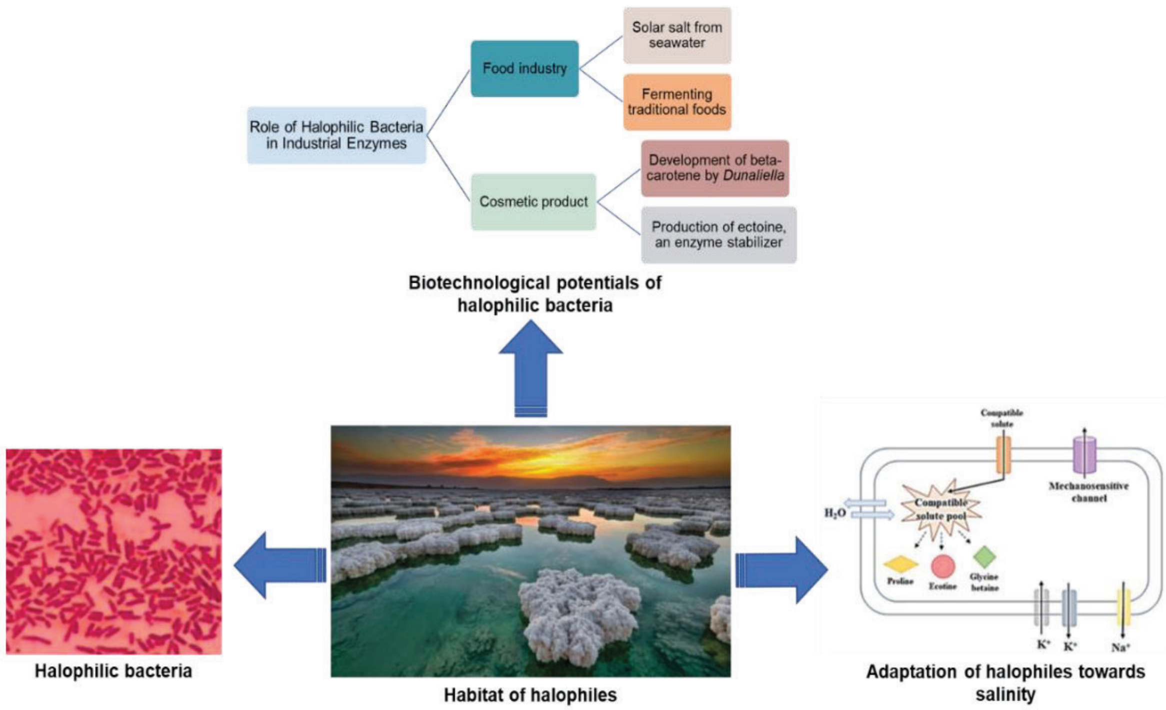

Figure 4: Halophile's habitat, adaptation of halophiles to its environment and its biotechnological potentials.

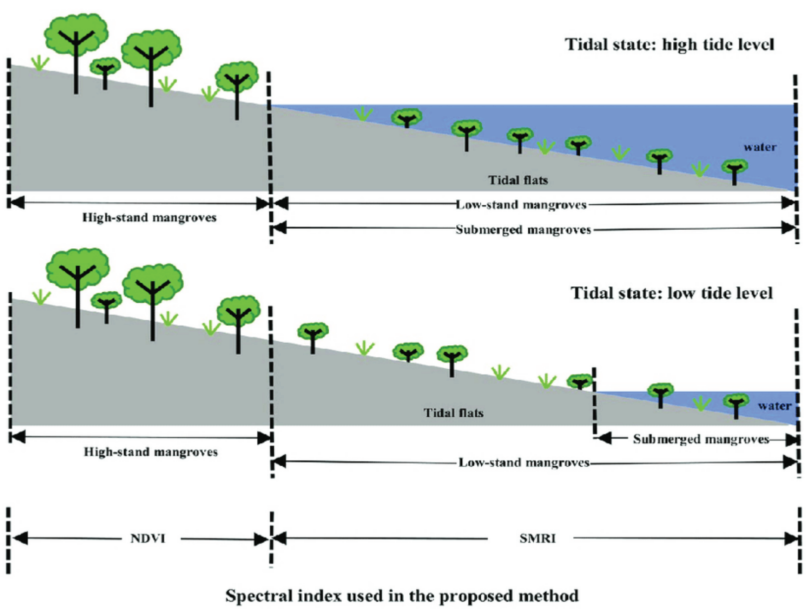

Figure 4: Mapping mangrove forests based on multi-tidal high-resolution satellite imagery. (Source: Xia et al., 2018)

They are commonly found near tropical and subtropical shores and estuaries affected by tides. Mangrove communities are classified as intermediate zones because they are characterised by vegetation that differs significantly from maritime communities yet shares traits with land communities (Soeprobowati et al., 2022). Mangrove forests frequently inhabit the higher intertidal zone in tropical climates. The highest amounts and richness of benthic organisms often occur in the intertidal zone in coastal and estuarine systems, with subtidal habitats frequently depauperate due to persistent predatory pressure (Mattone & Sheaves, 2019).

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