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Toxicity of diatom polyunsaturated aldehydes to marine bacterial isolates reveals their mode of action

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HIGHLIGHTS

- Six marine bacterial isolates tolerant to PUAs were characterized by 16S rRNA sequencing.
- Bacteria react to PUAs by changing their membrane properties.
- PUAs cause a toxicity-dependent increase in the degree of saturation of membrane lipid fatty acids.
- PUAs act as contact poisons probably due to their high hydrophobicity and additional chemical toxicity.

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ABSTRACT

Diatoms produce and release polyunsaturated aldehydes (PUAs) during senescence in culture and at the end of blooms in nature and these compounds play different ecological roles, as infochemicals, allelochemicals and pheromones In order to elucidate the toxic effects of PUAs, we isolated six bacterial strains from the Mediterranean Sea during a diatom bloom and tested their tolerance to PUA in terms of growth and cell membrane properties. Based upon 16S rRNA sequencing, these bacteria were assigned to the genera *Pseudomonas*, *Sufflavibacter, Halomonas*, *Vibrio*, *Idiomarina*, and *Labrenzia*. Growth of these strains was reduced by 50% (EC_{50}) at PUA concentrations ranging from 600 to 1700 μM of 2E,4E/Z-heptadienal (HEPTA), 400–800 μM of 2E, 4E/Z-octadienal (OCTA), and 70–400 μM of 2E, 4E/Z-decadienal (DECA). Two of these strains, *Vibrio* sp. and *Halomonas*, sp. were also investigated for membrane fatty acid composition in terms of adaptive modifications of their degree of saturation (ratio between saturated and unsaturated fatty acids) by GC-FID. A direct correlation between hydrophobicity and PUA toxicity was observed, and these bacteria were also found to react to PUAs by increasing the degree of saturation of their membranes fatty acids.

Tested PUAs were 4-fold more toxic than the well-investigated *n*-alkanols, most probably due to their additional chemical aldehyde toxicity to disrupting proteins by the formation of Schiff's bases, and therefore, they act as very toxic and effective poison, probably accumulating in cytoplasmic membranes because of their high hydrophobicity.

1. Introduction

Bacteria are fundamental players in any ecosystem and contribute to key processes and elemental cycles in the marine world, both for their numerical abundance and high functional diversity (Jørgensen, 2006). Diatoms are ubiquitous photosynthetic eukaryotic microorganisms, able to carry out about 20% of global photosynthesis on Earth (Armbrust, 2009), and are at the base of the marine food web. They also release high amounts of Dissolved Organic Carbon (DOC) that is directly degraded and used by heterotrophic bacteria. Diatoms play a key role in the biogeochemical cycles of silica and other elements in the oceans and they significantly contribute to the so-called "biological pump" by withdrawing CO_2 from the atmosphere through photosynthesis. All

Abbreviations: PUA, Polyunsaturated aldehydes; HEPTA, 2E,4E/Z-heptadienal; OCTA, 2E,4E/Z-octadienal; DECA, 2E,4E/Z-decadienal.

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