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Hydrogen peroxide detoxification by a-keto acid oxidation is required for stimulation of growth of a marine ammonia-oxidizing archaeon

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Thaumarchaeota are abundant in marine environments and are known to be involved in ammonia oxidation. Understanding of metabolism and physiology of these ammonia-oxidizing archaea (AOA) is of global significance. Potential of organic carbon assimilation by AOA is still under debate. In this study, we isolated an ammonia-oxidizing archaeon (designated strain DDS1) from seawater which requires supplementation of organic acids in medium for its growth. Unexpectedly, a tracer experiment indicates that organic carbon incorporation into archaeal cellular lipids (GDGT) was negligible and most of GDGT carbons are from dissolved inorganic carbons. Further, any scavenger of hydrogen peroxide (H2O2) such as dimethylthiourea and catalase could replace organic acid requirement. In fact, all organic acids stimulated the growth of strain DDS1 were a-keto acids which can act as H2O2 scavengers by nonenzymatic decarboxylation. This was verified by that only carboxyl carbon of pyruvate carbons was released into medium and then fixed and incorporated into GDGT. This result indicates that strain DDS1 is a strict autotrophic AOA. Genomic analysis indicates that all known AOA strains including strain DDS1 are lack of putative catalase genes and might be sensitive to high concentration of H2O2. Indeed, strain DDS1 was shown to endogenously produce H2O2 and release upto 0.3 uM in 0.1 mM ammonia oxidation in the absence of a-keto acid, which was inhibitory to the growth of strain DDS1. Growth of strain DDS1 in the absence of a-keto acid could be enhanced by coupling with catalase-positive heterotrophs, indicating H2O2 degradation by extant bacteria are associated with archaeal ammonia oxidation. Our results indicates that reactive oxygen species is implicated as a key factor determining activity and distribution of AOA ecotypes and thus affecting biogeochemical cycles of nitrogen and carbon mediated by AOA in marine environments.