

Membrane lipid and expression responses of *Saccharolobus islandicus* REY15A to acid and cold stress

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Archaea adjust the number of cyclopentane rings in their glycerol dibiphytanyl glycerol tetraether (GDGT) membrane lipids as a homeostatic response to environmental stressors such as temperature, pH, and energy availability shifts. However, archaeal expression patterns that correspond with changes in GDGT composition are less understood. Here we characterize the acid and cold stress responses of the thermoacidophilic crenarchaeon *Saccharolobus islandicus* REY15A, showing that each stress results in impaired growth rates, altered GDGT-lipid profiles, and differences in transcriptomes and proteomes. *S. islandicus* GDGT profiles indicated lower average cyclization and differential expression of the GDGT ring synthase *grsB* in response to both acid stress and cold stress. Although the GDGT ring synthase encoded by *grsB* forms highly cyclized GDGTs with ≥ 5 ring moieties, *S. islandicus* *grsB* upregulation under acidic pH conditions did not correspond with increased abundances of highly cyclized GDGTs. Our observations highlight the inability to predict GDGT changes from transcription data alone. Broader analysis of transcriptomic data revealed that *S. islandicus* differentially expresses many of the same transcripts in response to both acid and cold stress. These included upregulation of several biosynthetic pathways and downregulation of oxidative phosphorylation and motility. Transcript responses specific to either of the two stressors tested here included upregulation of genes related to proton pumping and molecular turnover in acid stress conditions and upregulation of transposases in cold stress conditions. Overall, our study provides a comprehensive understanding of the GDGT modifications and differential expression characteristic of the acid stress and cold stress responses in *S. islandicus*.