



## Genome Announcement

# Draft genome sequence of sulfur-reducing archaeon *Thermococcus thioeducens* DSM 14981<sup>T</sup>

Sung-Jun Hong, Chang Eon Park, Gun-Seok Park, Min-Chul Kim, Byung Kwon Jung, Jae-Ho Shin\*

Kyungpook National University, College of Agriculture and Life Sciences, School of Applied Biosciences, Daegu, Republic of Korea

### ARTICLE INFO

#### Article history:

Received 31 December 2015

Accepted 25 April 2016

Available online 4 June 2016

Associate Editor: Rodrigo Galhardo

#### Keywords:

Archaea

Hyperthermophile

*Thermococcus thioeducens*

### ABSTRACT

*Thermococcus thioeducens* DSM 14981<sup>T</sup>, a sulfur-reducing archaeon, was isolated from the rainbow hydrothermal vent site on the Mid-Atlantic Ridge. Herein, we report the draft genome sequence of *T. thioeducens* DSM 14981<sup>T</sup>; we obtained 41 contigs with a genome size of 2,052,483 bp and G + C content of 53.5%. This genome sequence will not only help understand how the archaeon adapts to the deep-sea hydrothermal environment but also aid the development of enzymes that are highly stable under extreme conditions for industrial applications.

© 2016 Sociedade Brasileira de Microbiologia. Published by Elsevier Editora Ltda. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

## Introduction

*Thermococcus* taxonomically belongs to the family Flavobacteriaceae and phylum Euryarchaeota.<sup>1</sup> Members of this genus are characterized by thermophilic anaerobiosis with sulfur-type respiration and sulfur stimulation for fermentation.<sup>2</sup> A decrease in S levels in the growth medium leads to the enhanced production of ethanol, butanol, H<sub>2</sub>, and formate at the expense of H<sub>2</sub>S and acetate production.<sup>3</sup> The minimal growth temperature for most species is approximately 50 °C and the maximum is approximately 95–100 °C. Therefore, these microorganisms are generally good sources of enzymes for application in various biotechnological processes in the food, chemical, and pharmaceutical industries.<sup>4</sup>

A strain DSM 14981<sup>T</sup> was isolated from “black smoker” chimney material from the rainbow hydrothermal vent site on the Mid-Atlantic Ridge. It is a hyperthermophilic, heterotrophic, sulfur-dependent, coccoid archaeon inhabiting a deep-sea hydrothermal system in the Mid-Atlantic Ridge (36.2° N, 33.9° W). The optimal growth conditions include a pH of 5.0–8.5, NaCl concentration of 1–5% (w/v), and temperature of 55–94 °C. A strain DSM 14981<sup>T</sup> was identified by 16S rRNA gene sequence, was named as *Thermococcus thioeducens*. And, this strain is an obligate anaerobe and completely dependent upon elemental sulfur as the electron acceptor, but it does not reduce sulfate, sulfite, thiosulfate, Fe (III), or nitrate.<sup>5</sup> In this communication, we present the draft genome sequence of *T. thioeducens* DSM 14981<sup>T</sup>, with the aim to study the extreme adaptation of this archaeon in a hydrothermal environment.

\* Corresponding author.

E-mail: [jhshin@knu.ac.kr](mailto:jhshin@knu.ac.kr) (J.-H. Shin).

<http://dx.doi.org/10.1016/j.bjm.2016.04.031>

1517-8382/© 2016 Sociedade Brasileira de Microbiologia. Published by Elsevier Editora Ltda. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

*T. thioreducens* DSM 14981<sup>T</sup> was cultured in Bacto Marine broth with 0.5% (w/v) sulfur powder and incubated at 80 °C for 48 h. Genomic DNA was then extracted using the method reported by Ramakrishnan.<sup>6</sup> Whole-genome sequencing of the strain was performed using the Ion Torrent PGM sequencer (400-bp library) and 316<sup>TM</sup> chip v2, according to the manufacturer's instructions (ThermoFisher Scientific, Germany).<sup>7</sup> Sequencing generated 755,986 reads with an average read length of 290 bp. *De novo* assembly was performed using the MIRA assembler v4.0.2 and CLC Genomics Workbench v7.0 software. Forty-one contigs with N<sub>50</sub> contig length of 151,544 bp and a maximum contig size of 253,877 bp were obtained. The draft genome size was 2,052,483 bp, with a G + C content of 53.5% and no plasmids.

We used the Rapid Annotation using Subsystem Technology<sup>8</sup> and National Centre for Biotechnology Information's Prokaryotic Genomes Annotation Pipeline v2.6 ([http://www.ncbi.nlm.nih.gov/genome/annotation\\_prok](http://www.ncbi.nlm.nih.gov/genome/annotation_prok)) for gene prediction and annotation. Genes were predicted using the Glimmer 3.02 software.<sup>9</sup> Forty-two tRNA genes were identified using tRNAscan-SE,<sup>10</sup> and 5 rRNAs were identified using the RNAmmer 1.2 software.<sup>11</sup>

Apart from encoding the archaeal-modified Embden-Meyerhof (EM) glycolysis pathway and protein and carbohydrate metabolism pathways,<sup>12</sup> the *T. thioreducens* DSM 14981 draft genome also encodes the archaeal RuBisCo to facilitate carbon fixation.<sup>13</sup> In addition, this genome encodes genes involved in energy synthesis including a V-type ATP synthase gene cluster and NADH – ubiquinone oxidoreductase on the cell membrane. The genome also has a gene cluster for respiration, including membrane bound hydrogenase, sulfurhydrogenase II complex, and formate dehydrogenase H. In order to survive extreme conditions such as high temperature, pressure, and pH, the strain contains heat shock protein 60, a prefoldin protein, and a small heat shock protein.<sup>14,15</sup> The important enzyme-encoding genes for potential use in commercial enzyme production,<sup>16</sup> such as those encoding amylase, protease, pullulanase, glycosyltransferase, and alcohol dehydrogenase, were also found in its genome sequence. Further insights into the genome sequence of this archaeon should facilitate studying extreme environments in hydrothermal vents and aid the development of enzymes that are highly stable under extreme conditions for industrial applications.

### Nucleotide sequence accession numbers

The whole genome sequence of *T. thioreducens* DSM 14981 has been deposited at DDBJ/EMBL/GenBank under the accession number LIXN00000000. The first version (LIXN00000000.1) has been described in this paper.

### Conflicts of interest

The authors declare no conflicts of interest.

### Acknowledgements

This research was supported by the Basic Science Research Program through the National Research Foundation of Korea (NRF), funded by the Ministry of Education (NRF-2015R1D1A1A01057187).

### REFERENCES

- Garrity G, Boone DR, Castenholz RW. The archaea and the deeply branching and phototrophic. *Bergey's Manual of Systematic Bacteriology*. Vol. 1. Bacteria: Springer Science & Business Media; 2012.
- Zillig W, Holz I, Janekovic D, et al. *Hyperthermus butylicus*, a hyperthermophilic sulfur-reducing archaeobacterium that ferments peptides. *J Bacteriol*. 1990;172:3959–3965.
- Ma K, Loessner H, Heider J, Johnson MK, Adams M. Effects of elemental sulfur on the metabolism of the deep-sea hyperthermophilic archaeon *Thermococcus* strain ES-1: characterization of a sulfur-regulated, non-heme iron alcohol dehydrogenase. *J Bacteriol*. 1995;177:4748–4756.
- Littlechild JA. Archaeal enzymes and applications in industrial biocatalysts. *Archaea*. 2015;2015:10.
- Pikuta EV, Marsic D, Itoh T, et al. *Thermococcus thioreducens* sp. nov., a novel hyperthermophilic, obligately sulfur-reducing archaeon from a deep-sea hydrothermal vent. *Int J Syst Evol Microbiol*. 2007;57:1612–1618.
- Ramakrishnan V, Adams M. *Preparation of Genomic DNA from Sulfur-Dependent Hyperthermophilic Archaea*. *Archaea: A Laboratory Manual*. Cold Spring Harbor: Cold Spring Harbor Laboratory Press; 1995.
- Rothberg JM, Hinz W, Rearick TM, et al. An integrated semiconductor device enabling non-optical genome sequencing. *Nature*. 2011;475:348–352.
- Aziz RK, Bartels D, Best AA, et al. The RAST server: rapid annotations using subsystems technology. *BMC Genomics*. 2008;9:75.
- Delcher AL, Harmon D, Kasif S, White O, Salzberg SL. Improved microbial gene identification with GLIMMER. *Nucleic Acids Res*. 1999;27:4636–4641.
- Lowe TM, Eddy SR. tRNAscan-SE: a program for improved detection of transfer RNA genes in genomic sequence. *Nucleic Acids Res*. 1997;25:0955–0964.
- Lagesen K, Hallin P, Rødland EA, Stærfeldt H-H, Rognes T, Ussery DW. RNAmmer: consistent and rapid annotation of ribosomal RNA genes. *Nucleic Acids Res*. 2007;35:3100–3108.
- Verhees CH, Kengen SWM, Tuininga JE, et al. The unique features of glycolytic pathways in Archaea. *Biochem J*. 2003;375:231–246.
- Sato T, Atomi H, Imanaka T. Archaeal type III RuBisCOs function in a pathway for AMP metabolism. *Science*. 2007;315:1003–1006.
- Shockley KR, Ward DE, Chhabra SR, Connors SB, Montero CI, Kelly RM. Heat shock response by the hyperthermophilic archaeon *Pyrococcus furiosus*. *Appl Environ Microbiol*. 2003;69:2365–2371.
- Laksanalamai P, Robb FT. Small heat shock proteins from extremophiles: a review. *Extremophiles*. 2004;8:1–11.
- Gomes J, Steiner W. The biocatalytic potential of extremophiles and extremozymes. *Food Technol Biotech*. 2004;42:223–235.