Cyanide as a Primordial Reductant enables a Protometabolic Reductive Glyoxylate Pathway

Ramanarayanan Krishnamurthy (rkrishna@scripps.edu)
Scripps Research Institute https://orcid.org/0000-0001-5238-610X
Mahipal Yadav
The Scripps Research Institute https://orcid.org/0000-0003-4394-9737
Sunil Pulletikurti
Scripps Research Institute
Jayasudhan Reddy Yerabolu
The Scripps Research Institute https://orcid.org/0000-0003-1712-5136

Article

Keywords: cyanide, prebiotic chemical pathways, metalloproteins

Posted Date: June 21st, 2021

DOI: https://doi.org/10.21203/rs.3.rs-549378/v1

Version of Record: A version of this preprint was published at Nature Chemistry on February 3rd, 2022. See the published version at https://doi.org/10.1038/s41557-021-00878-w.

Abstract

Investigation of prebiotic chemical pathways leading to protometabolic forerunners of metabolism has been largely based on bio-inspired (iron-mediated) reductive conversion of carbon dioxide and of carboxylic acid substrates.1,2 While attractive from a parsimony point of view, this approach has been challenging with debatable outcomes.3,4 Herein, we show that cyanide reacts with citric acid cycle (TCA) intermediates and derivatives and acts as a primordial reducing agent mediating abiotic reductive transformations. The hydrolysis of the cyanide adducts followed by decarboxylation enables the efficient reductive-decarboxylative transformation of oxaloacetate to malate and fumarate to succinate while pyruvate and α-ketoglutarate are not reduced. In the presence of glyoxylate,5,6 malonate7 and malononitrile,8 alternative pathways emerge, which after decarboxylation produce metabolic intermediates and related compounds also found in meteorites.9 These results, along with the previous demonstration of the metal-free alpha-keto analog of the reverse-TCA cycle,4,6 suggest that (a) alternative paradigms of cyanide-based protometabolic reactions bypassing the abiotic reductive-carboxylation steps can be prebiotically viable, (b) a novel reductive glyoxylate pathway can be a precursor to the r-TCA cycle and (c) the type of sophisticated carboxylation and reduction chemistries which are part of extant metabolic cycles10,11 are an evolutionary invention mediated by complex metalloproteins11.

Full Text

This preprint is available for download as a PDF.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- SupportingInformationfinal.pdf