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Arrhenian growth thermodynamics in a marine-derived tropical *Fusarium equiseti* and polar *Pseudogymnoascus* spp. in a liquid culture system

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ABSTRACT

We hypothesised that the activation energy (E_a) of growth in a marine-derived tropical strain of *Fusarium equiseti* and polar strains of *Pseudogymnoascus* spp. grown for 10 days in a liquid culture system comprised of seawater Mueller-Hinton Broth would differ across the same experimental culture temperature range. The specific growth rates (SGRs) obtained from these experiments were fitted into third-degree polynomial and Brière-2 temperature-dependent models to estimate optimum temperatures for growth (T_{opt}) and maximum SGR (SGR_{max}) of the selected strains. Estimates of SGR values from the Brière-2 model were used to calculate the temperature coefficient (Q_{10}) and E_a for growth in all three fungal strains across the experimental culture temperature range. Our findings indicated that *F. equiseti* is better adapted to utilising higher levels of thermal energy for growth than either *Pseudogymnoascus* strain, consistent with general definitions that classify the former as a mesophile and the latter as psychrophiles. A progressive increase in pH was recorded in the liquid culture system during the growth of *F. equiseti* and *Pseudogymnoascus* spp., suggesting that these strains could tolerate more alkaline conditions for growth until nutrient resources were exhausted, as has been noted in some other fungal studies.

1. Introduction

Fungi adapt to the availability of thermal energy in the environment. A majority of studied species can be given a thermal classification based on their thermal optima and range for growth, which often reflects their distribution across the globe. The four conventional thermal classes of microorganisms in relation to their growth temperature optima are: (i) psychrophily (≤15 °C), (ii) mesophily (25–40 °C), (iii) thermophily (45–80 °C), and (iv) hyperthermophily (> 80 °C). Microorganisms that exhibit optima between 20 and 40 °C but are able to grow (although very slowly) at 0 °C are psychrotolerant, while those that exhibit growth optima ≤40 °C but have maximum (lethal) temperatures ≤50 °C are thermotolerant (Madigan et al., 2014). As a kingdom, fungi are ubiquitous, occurring across marine and terrestrial habitats, and species of terrestrial origin also occur in the marine environment. Fungi that occupy terrestrial habitats but are also found in/on marine substrates are termed as 'marine-derived fungi' (Pang and Jones, 2017).

Fungal adaptation to temperature has long been studied in the context of understanding their responses to thermal stress, which affects proliferation processes in natural and artificial environments. Some of these responses have been quantified through molecular approaches, including measuring the expression of heat shock proteins (Hsp; most commonly Hsp90) and antifreeze proteins (AFPs) (Robinson, 2001). Physiological responses have also been measured by measuring fluidity of the plasma membrane and the production of principal fungal metabolites, such as polyols (glycerol, mannitol, etc.), the sugar alcohol ergosterol, and trehalose (Niemenmaa et al., 2008; Xiao et al., 2010; Cowen, 2013).

Growth rates, being a physical property of growth, can also be used as an indicator of response towards varying environmental conditions and, hence, be instrumental in understanding microbial adaptation to temperature. For bioenergeticists, this concept is used to investigate the flow and conversion of thermal energy into and out of cells (von Stockar et al., 2006). The limited available literature on microbial growth thermodynamics have focussed on yeast, bacterial, and microalgal populations grown under controlled experimental conditions (Sandler and Orbey, 1991), and information on growth thermodynamics in filamentous fungi remains lacking. Filamentous fungi are multicellular organisms growing in a network of hyphae known as mycelia, forming

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