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Can mitochondria produce ATP in anaerobic conditions?

Research project objectives/Hypothesis

Biomass fermentation by yeast (or fungi) requires both aerobic and anaerobic conditions. Aerobic condition is required to produce ATP necessary for yeast reproduction while anaerobic phase leads to production of alcohol and other fermentation products. The use of hydrolyzed wood for fermentation to obtain biofuels causes another problem. In trees there are natural organic antibiotics which are protecting trees from microbiological biodegradation. These antibiotics can stop the fermentation process. ATP dependent metabolism is required to eliminate these natural antibiotics from wood products. Thus when fermenting wood products there is a need to alternate between aerobic and anaerobic conditions what greatly reduces yield and speed of the process (Xiros et al., 2011; Fan et al, 2012).

ATP is produced in mitochondria in aerobic condition. The hypothesis has been put forward (Dolowy, 2013) that mitochondria can produce ATP even in the absence of oxygen by using electrochemical energy stored in the mitochondrial matrix in the form of hydroxyapatite accumulated during aerobic conditions. The figure describes the hypothetical mechanism.

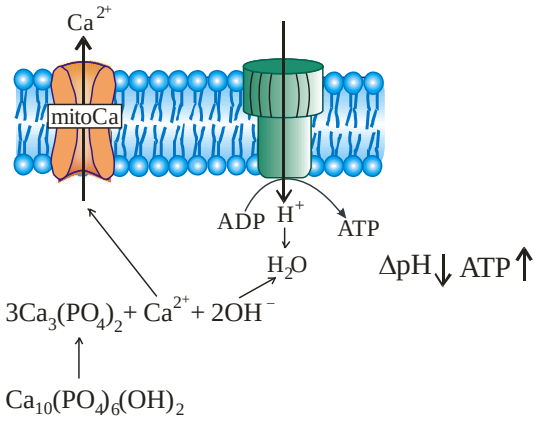

Figure. During anaerobic conditions oxidative chain no longer expels protons from the matrix. The ATP can still be produced by ATP-synthase on the expense of ΔpH providing that electroneutrality of the process will be maintained by the efflux of calcium ions. Transformation of hydroxyapatite to apatite in the matrix can provide large pH buffering capacity of the matrix and the supply of ATP in anaerobic conditions.

If the hypothetical mechanism is correct one can greatly improve the process of wood fermentation reducing the need of alternating aerobic and anaerobic conditions by simply adding inorganic phosphate and calcium to fermentation batch. The test of the hypothesis will be the subject of Ph.D. project.

It should be mentioned that the use of $Ca(OH)_2$ improved the ethanol production (which was still very low) in experimental conditions (Rocha et al., 2009), however inorganic phosphate was missing in their experiment.

Research methodology

We are planning to use luminescence method to determine ATP production kinetics and fluorescence and/or ion selective microelectrodes to measure pH and calcium concentration using mitochondria or mitoplasts obtained from yeast. To mimic anaerobic conditions we will block oxidative chain pharmacologically or by introducing oxygen free atmosphere. Ion channels blockers and activators will reveal the role of particular ion channel in the process of ATP production. We will test fermentation process in the presence of substrates leading to accumulation of hydroxyapatite in mitochondrial yeasts.

References

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