Carbohydrate storage determines cell size and cell fate

Yanjie Liu, N Ezgi Temamogullari, Orlando Mirando, Piya Kositangool and Andreas Doncic

Cell fate determination is critical for cell survival and development. Importantly, cell fates are shaped by the integration of external cues, intracellular nutrient storage, and the overall state of the cell. Yeast cell enters into meiosis/sporulation in depletion of nitrogen and fermentable carbon. Even though larger yeast cells tend to sporulate more and that the accumulation of storage carbohydrates is necessary for meiosis [1], it remains unclear how the storage carbohydrate and size interact to shape the cell fate. Here we use biochemical methods, live cell imaging, and genetics to investigate the relationship between storage carbohydrates, cell size and cell fate.

Keywords **— cell fate, meiosis/sporulation, carbohydrates, size, single cell**

I. Introduction

In the absence of nitrogen and a fermentable carbon source, yeast cells starts accumulate carbohydrates and will eventually stop cycling and either become quiescent or enter meiosis/sporulation [2]. Two major factors have independently been implicated in this process: cell size and storage carbohydrates. Specifically, cells need to reach a certain size and accumulate trehalose and glycogen to sporulate.

II. Results

To find the link between carbohydrates, cell size and cell fate, we created a library of trehalose and glycogen deficient mutants and determined their spore frequency, number of spores per ascus, spore viability, amounts and concentrations of trehalose and glycogen by using biochemical, genetic, and live-cell imaging approaches. Specifically, we found that:

A. Cell Size scales with amount of carbohydrates:

We performed size fractionation of cells by using sucrose gradient and measured the amount of trehalose and glycogen in cell fractions. Doing this we found that cell size scales with the amount of carbohydrates, while the concentration of storage carbohydrates remains approximately constant. This result, together with the fact that cell size and nutrient stores can be decoupled in the context of the Meiosis/Quiescence decision [manuscript submitted] suggesting that size is passive readout of storage carbohydrates in the context of this cell fate decision.

B. Glycogen and trehalose play differential role for sporulation:

The following attributes were measured for all strains in our library: the ability to generate spores, the number of spores, the spore viability and the ability store trehalose and glycogen. Doing so, we found that glycogen and trehalose compensate to each other for sporulation. Furthermore, glycogen and trehalose mutants showed differential defects with respect to their ability to store carbohydrates and to initiate sporulation. Specifically, cells that could not produce trehalose had a higher sporulation frequency than cells that could not produce glycogen. On the other hand, glycogen mutants had larger defects with respect to the number of spores per ascus, i.e. a higher percentage of dyads and triads instead of tetrads. These results suggest that glycogen is more important for spore formation while trehalose may play a larger role ensuring spore viability.

III. Conclusion & Future Plans

We conclude that during sporulation cell size is likely a readout of storage carbohydrate pools which in turns are necessary to reach a certain threshold for sporulation.

We are now quantifying the cell size of carbohydrate mutants. We will confirm these results using a live cell trehalose sensor [3], in combination with markers for trehalose and glycogen metabolisms.

References

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Department of Cell Biology, UT Southwestern Medical Center y, 6000 Harry Hines Blvd., Dallas, TX 75390. E-mail: yanjie.liu@utsouthwestern.edu