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Thermodynamic analysis of *Saccharomyces cerevisiae* growth: a theoretical-experimental approach

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Abstract
The yeast *Saccharomyces cerevisiae* is able to oxidize the glucose molecule through the metabolic pathways of fermentation and respiration, storing the released energy in the chemical bonds of the ATP molecule. However, less than half of this energy is used for ATP synthesis, supporting the hypothesis that the cell stores the spare energy in the chemical bonds of other components, in addition to releasing some of the energy in the form of heat. To verify this hypothesis, the present work validated a series of analyzes for the determination of the cell's composition, whether in relation to macromolecular and elemental components or metabolites. These analyzes will be applied in bioreactor cultivations under anaerobiosis or under aerobiosis, allowing to evaluate if the composition of the cells varies in these two conditions.

Key words:
Yeast physiology, Gibbs energy, Saccharomyces cerevisiae

Introduction

Yeasts utilize the glucose molecule for two purposes: obtaining energy and as a carbon source [1]. In the case of *Saccharomyces cerevisiae*, the yeast is able to perform fermentative and/or respiratory metabolism and, through a sequence of reactions, release energy that will be stored in the chemical bonds of the ATP molecule [1].

In the case of fermentation, the overall reaction $C_6H_{12}O_6 \rightarrow 2CO_2 + 2C_2H_6O$ is characterized by a Gibbs energy variation of approximately $\Delta G^{\circ\prime} \cong -237$ kJ/kmol and 2 ATPs are generated [2]. In the respiration, the overall reaction $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$ presents $\Delta G^{\circ\prime} \cong -2870$ kJ/kmol, with about 30 ATPs being synthesized [2].

The reaction of ATP synthesis, described as ADP + P → ATP, presents $\Delta G^{\circ\prime} \cong 32$ kJ/kmol [2]. Comparing the Gibbs energy variation associated with the fermentation to the required energy to produce 2 ATPs, it is noted that only approximately ¼ of the energy released is stored in the ATP chemical bonds. In the case of respiration, 30 ATPs is the equivalent to ⅓ of the total energy released during this process.

It is possible that the spare Gibbs energy that is not converted into ATP is simply dissipated. However, considering that this portion of Gibbs energy represents more than half of the total energy released in both of the metabolic pathways, it is likely that the cell is using the glucose molecule for another purpose than strictly as a carbon or energy source (in the form of ATP).

Results and Discussion

Comparing the macromolecular composition of the cells during the cultivations in purely fermentative or exclusively respiratory metabolism, it will be possible to evaluate if there was a variation of the contents of these compounds and to verify if the cells in different metabolisms store energy in the chemical bonds of these components. Therefore, several experiments were carried out on a sample of dried baker's yeast (Dona Benta Fermix Instant Dry Biological Yeast) for comparison purposes and the results are presented below:

Chart 1. Centesimal and elemental composition of the cell

Macromolecular composition	Moisture	4,34 % ± 0,09
	Ashes	5,31 % ± 0,02
	Lipids	3,07 % ± 0,06
	Carbohydrates	33,24 % ± 2,11
	Proteins	38,79 % ± 0,60
Elementary composition	Carbon	43,85 % ± 0,06
	Hydrogen	6,88 % ± 0,01
	Nitrogen	7,94 % ± 0,03
	Phosphor	0,887 % ± 0,003
Heat of Combustion		18,949 kJ/g

With the analyzes above validated, the next step is the performance of two cultivations in bioreactor: the first under anaerobiosis and in batch and the second under aerobiose and fed batch with specific speed of growth (μ) controlled. Each sample will be submitted to the analyzes previewsly described, allowing to evaluate the variation of the composition of yeast cells throughout the cultivations.

Conclusions

By means of the test of the proposed hypothesis, it will be possible to broaden the understanding of the metabolism of yeast *Saccharomyces cerevisiae*, which is essential to allow new proposals regarding the increase of its energetic efficiency.

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