REPITCHING OF YEAST IN BEER FERMENTATIONS: INDIVIDUAL-BASED MODEL SIMULATIONS

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INTRODUCTION

The yeast *Saccharomyces cerevisae* has a limited replicative lifespan. **Replicative ageing** depends on the number of divisions experienced by each cell, and can be determined by counting the number of bud scars on the wall of the mother cell.

The industrial production of beer reuses yeast cropped at the end of fermentation in subsequent fermentation, a process unique to brewery fermentations called **«serial repitching»**. Depending on the mechanism used for extract and reuse the yeast, **populations of different features** can be obtained [1, 2].

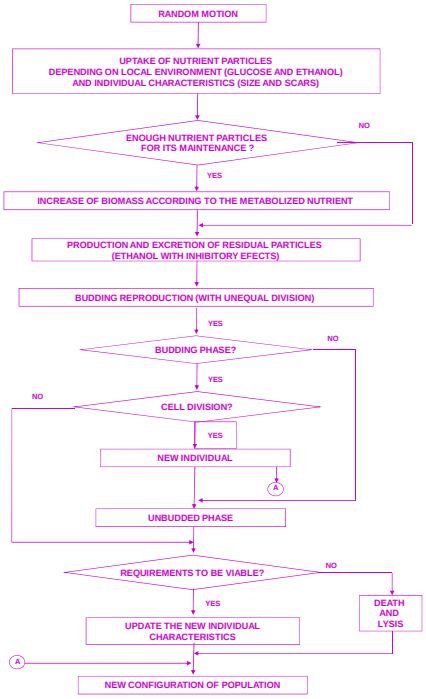
http://blog.peltarion.com/2007/06/13/the-self-organized-gene-part-2/

Individual based Modelling (IbM) approach can be a useful tool to improve our comprehension of the consequences of serial repitching. This modelling methodology has already been used to study bacterial cultures, developing the basic simulator **INDISIM** (**INDi**vidual **DIS**crete **SIM**ulations) [3] and yeast cultures by means of **INDISIM-YEAST** simulator [4, 5].

The aim of this study is to present the preliminary simulation results derived from exploring the influence of cell ageing on the fermentation process, carried out with this individual-based simulator INDISIM-YEAST.

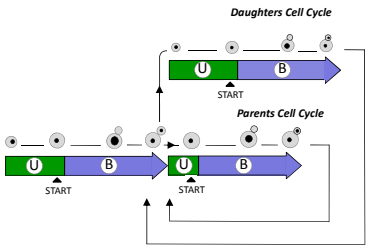
THE SIMULATOR INDISIM-YEAST

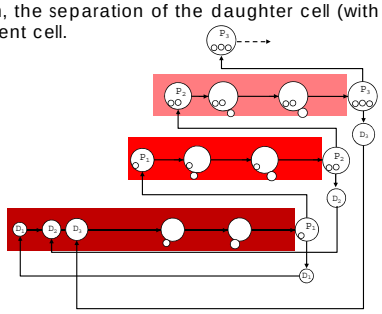
ACTIONS ON EACH INDIVIDUAL



The reproduction model involves two phases in the cellular cycle: Unbudded phase (U) and Budding phase (B). The change into the B phase takes place only if at the end of U phase the cell has attained a minimum stochastic cellular mass (the start mass) and a minimum growth of its biomass. The completion of the B phase requires both growth and temporal checks: a minimum growth of biomass and a minimum time interval. This B phase is completed with the cell division, the separation of the daughter cell (with a fraction of the mass achieved during this phase) and the parent cell.

The cell population exhibits a distribution of sizes, ages and duration over several cycles.





The set of N(t) virtual yeast cells conforms the population, defined by

$$P(t) = \{Y_i(v_1(t), v_2(t), \ldots, v_{10}(t)\}_{i=1,2,\ldots,N(t)}$$

Y_i is a yeast cell with the individual characteristics:

- v_1 : cell biomass
- v_2 : genealogical age, number of bud scars on the cellular membrane
- (v_3, v_4, v_5) : position in the spatial domain
- v_6 : the reproduction phase in the cellular cycle (U or B phase)
- v_7 : "start mass" (mass required to change from U to B phase)
- v_8: minimum bud biomass to complete budding reproduction
- v_9: minimum time required to complete the B phase
- v_{10}: survival time without satisfying the metabolic requirements

The set of Q^3 spatial cubic cells configures the grid, defined by :

$$G(t)=\{S_{xyz}[s_1(t), s_2(t)]\}_{x,y,z=1,\ldots Q}$$

S_{xyz} is a spatial cell, being $s_1(t)$ and $s_2(t)$ the number of glucose and ethanol particles respectively.

The web page **https://aneto.upc.es/simulacio/hoja-portada** presents a basic version of INDISIM-YEAST which permits carrying out the simulation of fermentation processes, and represents graphically a few of the variables controlled by the simulator [5].

RESULTS AND DISCUSSION

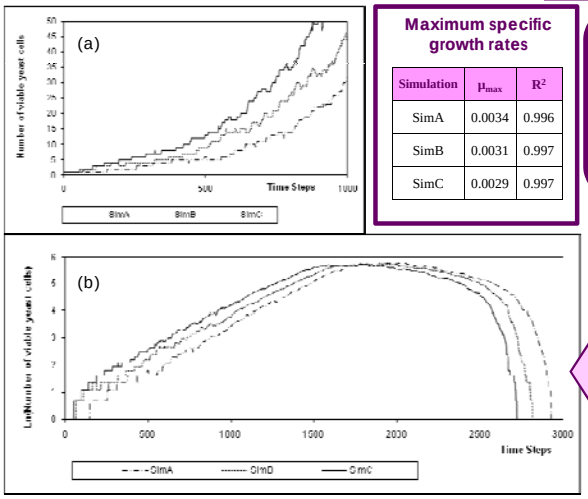


Figure 1. Time evolution of the number of viable yeast cells from the virtual yeast fermentations obtained in the INDISIM-YEAST simulations. Initial cell with genealogical age: 0 for SimA, 3 for SimB, and 10 for SimC. (a) Initial growth; (b) Full evolution (natural logarithm).

Maximum specific growth rates

Simulation	μ_{max}	R^2
SimA	0.0034	0.996
SimB	0.0031	0.997
SimC	0.0029	0.997

We have performed several simulations using INDISIM-YEAST, in which the only parameter that was changed was the genealogical age of the cells, the initial inoculums

The initial age of the seed yeast cell not only influences the population growth, but also the rate of nutrient uptake and ethanol production.

Our findings are in broad agreement with the experimental results of Powell and co-authors [1, 2] and support their views.

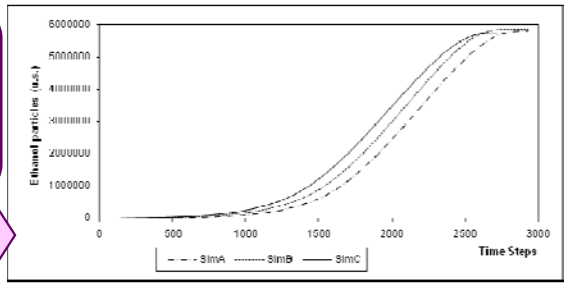


Figure 2. Time evolution of the number of ethanol particles produced by the virtual yeast fermentations obtained in the INDISIM-YEAST simulations. Initial cell with genealogical age: 0 for SimA, 3 for SimB, and 10 for SimC.

INDISIM-YEAST OFFERS DIVERSE AND ATTRACTIVE POSSIBILITIES TO CONTINUE TO EXPLORE THE FERMENTATION PROCESS, AND SPECIFICALLY ALL THE PROTOCOL RELATED WITH THE "REPITCHING" OF YEAST IN THE BREWING INDUSTRY.

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