Design of a sustainable microbrewery for artisanal *Session IPA* production

Part I: Upstream, enzymatic and chemical processes

Hulsbus Andreu, P. | Ortiz de Orruño Cuesta, G. | Salas Gómez, M.

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Introduction and objectives

Beer is the most consumed alcoholic beverage worldwide. Its industry generates more than 66 M€/year only in Spain, and this value is expected to increase in the coming years. In the project at hand, we describe the design of a small-scale brewery for the production of *Session India Pale Ale*. Our main objective is to achieve an annual production of about 150,000L, which can be translated to about 450,000 bottles per year. Moreover, we want to transform organic waste from the microbrewery into lactic acid. As a result of computer-aided design using *SuperPro Designer ®*, we will attain a reasonable theoretical yield while supporting sustainable industrial processes.

Main components of beer

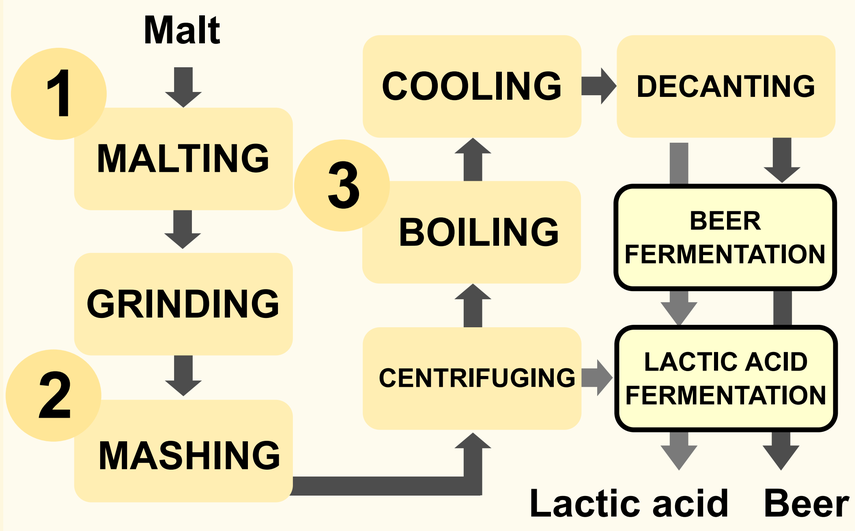
H. vulgare, commonly known as barley, is a cereal that provides sugars to the wort as well as colour and flavour.

H. lupulus, or hops, contribute to aroma and bitterness because of their high content in α-acids and terpenes.

Water can be a decisive factor in the final flavour depending on its ionisation. The most important ions are Ca^{2+}, Mg^{2+} and HCO_3^-.

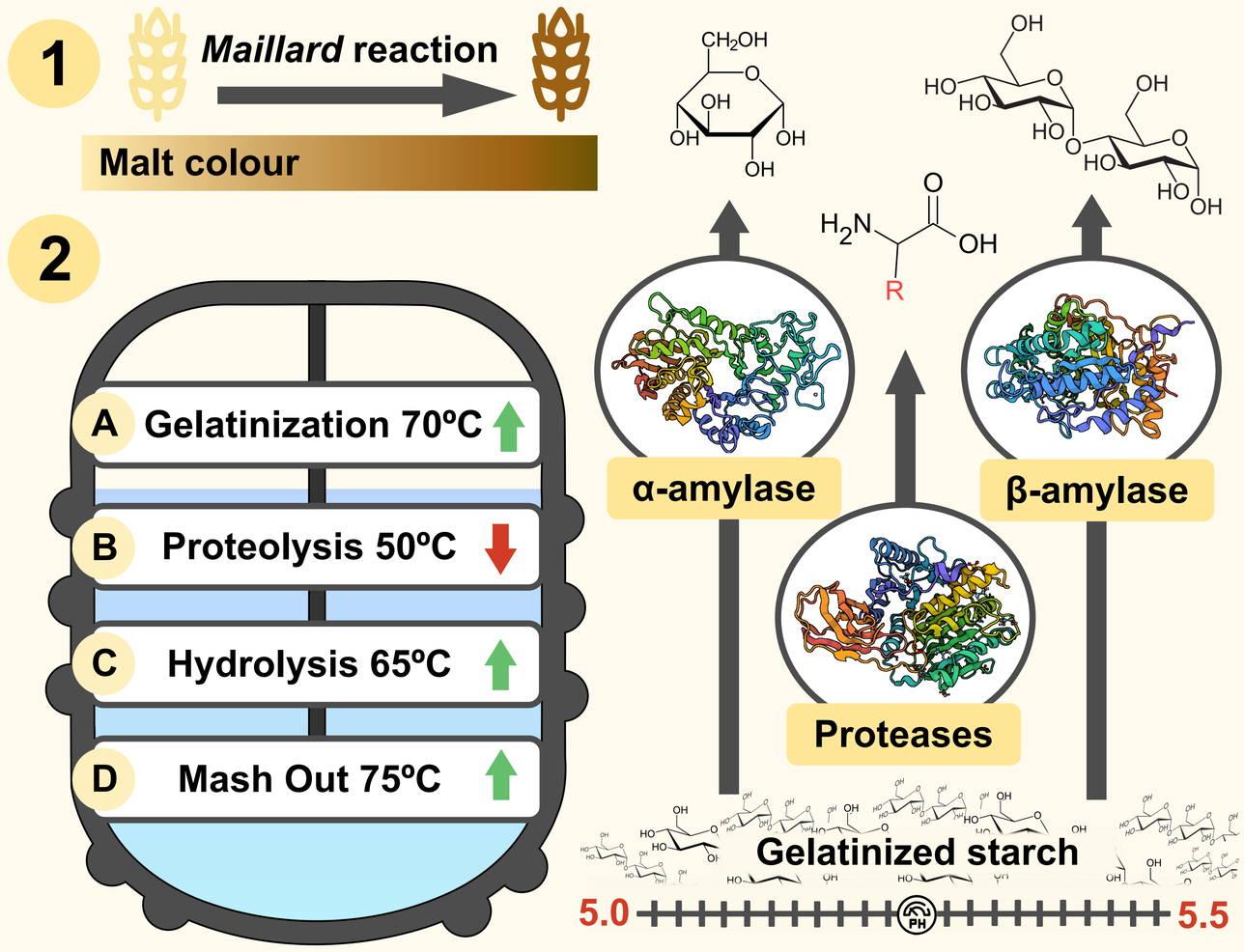
S. cerevisiae is a unicellular yeast used since ancient Mesopotamia. This fungus sequentially converts sugars to ethanol, glycerol, and CO_2.

Process description

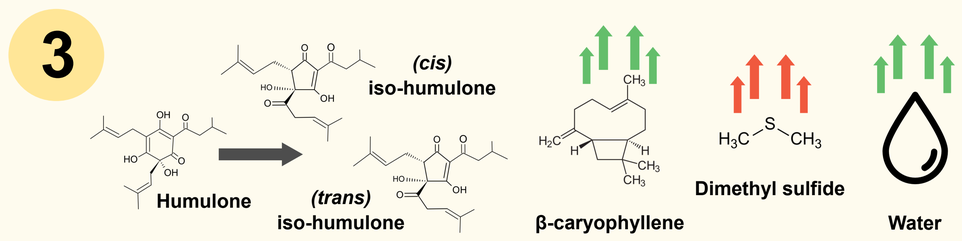


Malting and mashing

Barley is modified through a 3-step process called **malting**. After germination is induced, the grains are dried and roasted in a kiln. At this moment, the malted barley can undergo a series of enzymatic processes collectively known as **mashing**. Enzymatic efficiency is greatly affected by **temperature and pH**. Three main enzymes were taken into consideration in order to simplify the simulation in *SuperPro Designer* ®.

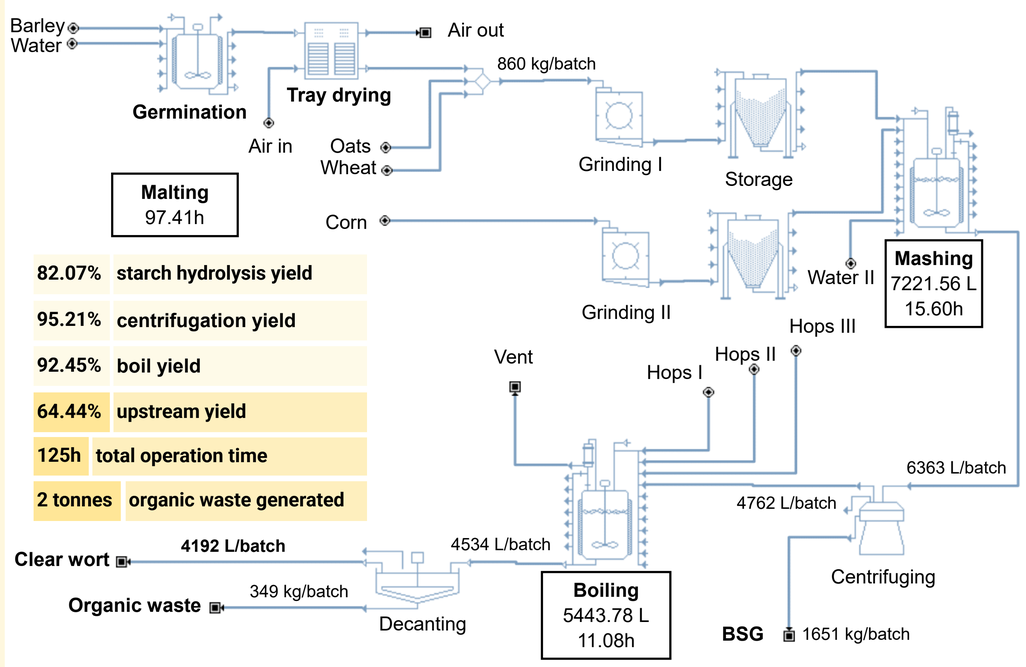


Boiling the wort



During the boiling step, **α-acids** are isomerized to their bitter forms. Due to the high temperature, volatile compounds as well as ~10% water volume can be lost.

Process flow diagram



82.07%	starch hydrolysis yield
95.21%	centrifugation yield
92.45%	boil yield
64.44%	upstream yield
125h	total operation time
2 tonnes	organic waste generated

Process Flow Diagram of the upstream section. The contents of each stream are calculated for a single batch. Each batch takes 125h (5.2 days), achieves a yield of 64.44% (in weight) and generates a total of 2 metric tonnes of waste.

Selected literature

1. Palmer JJ. How To Brew: Everything You Need to Know to Brew Great Beer Every Time. 4th ed. Brewers Publications; 2017. 612 p. | **2. Mussatto SI.** Brewer's spent grain: a valuable feedstock for industrial applications. 2014;(November 2013). | **3. Eyres G, Dufour JP.** Hop essential oil: Analysis, chemical composition and odor characteristics [Internet]. Beer in Health and Disease Prevention. Elsevier Inc.; 2008. 239–254 p. Available from: http://dx.doi.org/10.1016/B978-0-12-373891-2.00022-5 | **4. Brandam, C., Meyer, X., Proth, J., Strehaiano, P., & Pingaud, H.** (2003). An original kinetic model for the enzymatic hydrolysis of starch during mashing. *Biochemical Engineering Journal*, *13*(1), 43–52. https://doi.org/10.1016/s1369-703x(02)00100-6