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

Part II: Fermentation, downstream and waste recycling upstream

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Introduction

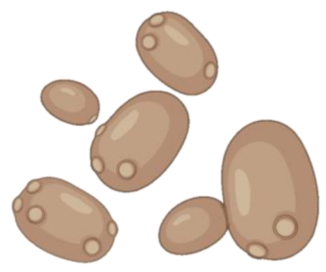

Figure 1. Rendering of *Saccharomyces cerevisiae*.

The most commonly used yeast for beer fermentation is ***Saccharomyces cerevisiae***. As we produce a *Session IPA* beer, we carry out a top fermentation employing ***SafAle^{TM} US-05*** strain at **20-25ºC**. This microorganism has an alcohol tolerance of a 9.2% and an attenuation of 81%.

The inoculum is previously prepared in an agitate bioreactor at 0.8 g/L. We administrate **oxygen** at the beginning of the bioreaction for the yeast to grow more efficiently.

Fermentation

This process is divided in three different stages and it occurs in a 5 800 L fermenter. The fermentation begins with the **adaptation phase** when the yeast consumes all the oxygen and replicates, realised at 18ºC.

Afterwards, in the **attenuation phase** most of the sugars are consumed and converted into alcohol. It is also when the production of esters occurs and is carried out at 20ºC.

Finally, the **maturation phase** takes place at 25ºC and consists of the reduction of aldehydes to alcohols, the enzymatic degradation of diacetyl and the absorption of undesired flavours.

As a result, we obtain 3.10 g/L, 11.14 g/L and 24.61 g/L of substrate, biomass and ethanol, respectively.

$$C_6H_{12}O_6 + 0.019\,NH_4^+ \rightarrow 0.126\,CH_{1.83}O_{0.56}N_{0.17} + 0.391\,C_2H_5OH + 0.079\,C_3H_8O_3 + 0.403\,CO_2 + 0.02\,H_2O$$

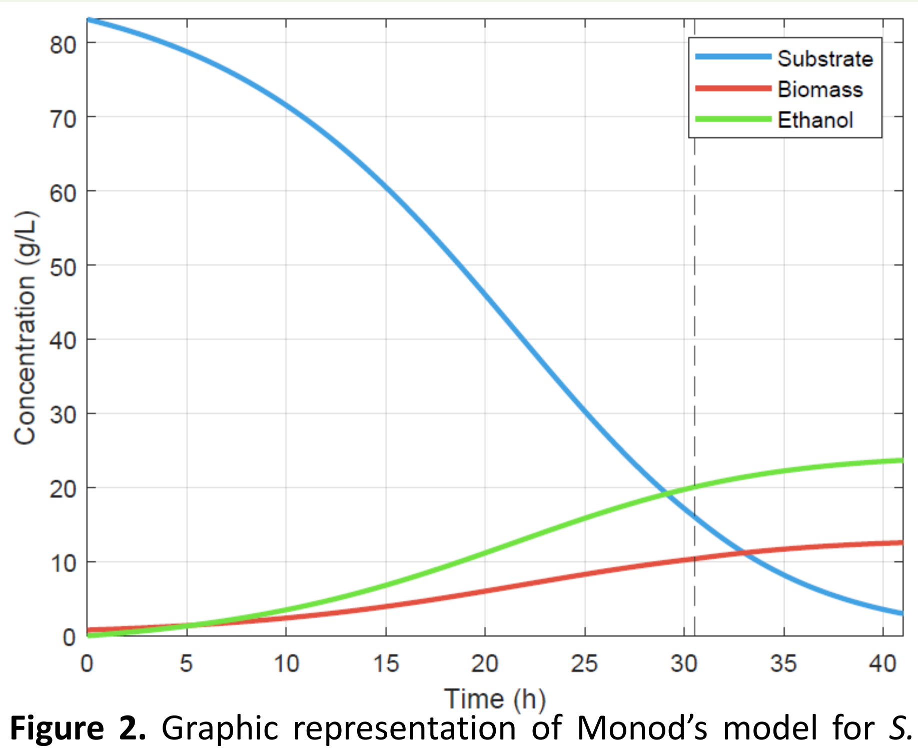

Figure 2. Graphic representation of Monod's model for *S. cerevisiae* primary and secondary fermentations.

Process flowsheet

After the main step, the content is transferred to a **maturation tank** removing the sediment, but retaining some of the microorganisms.

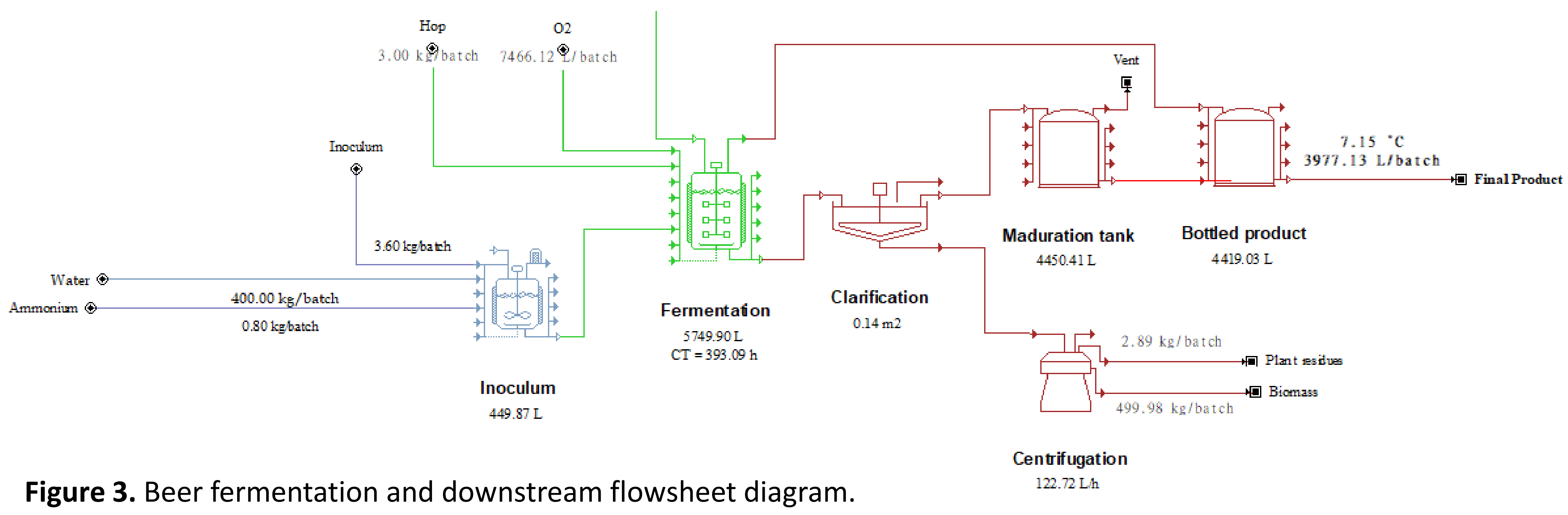

Figure 3. Beer fermentation and downstream flowsheet diagram.

Recycling

Brewer's Spent Grain and **yeast** are conditioned to produce **lactic acid**.

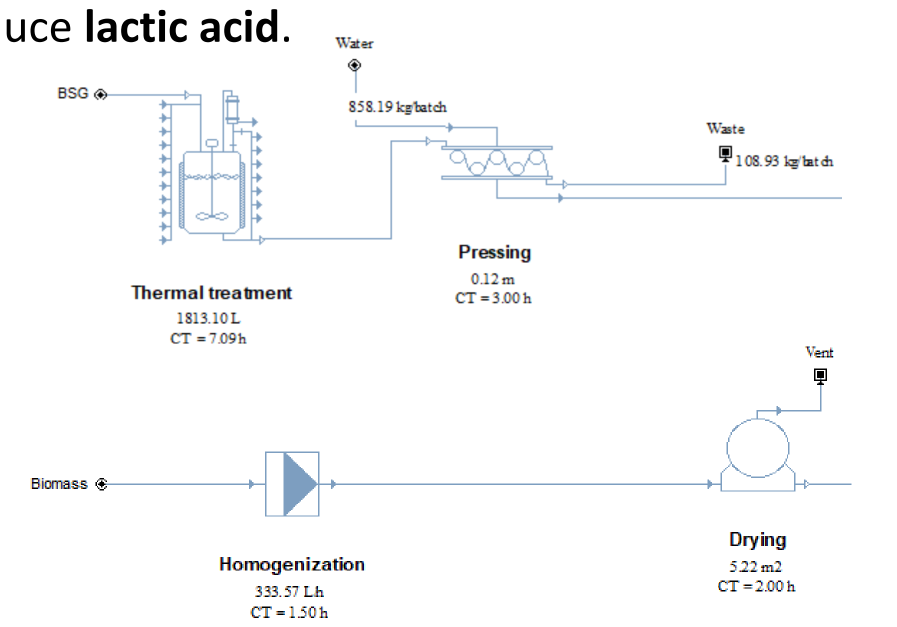

Figure 4. Lactic acid production upstream flowsheet diagram.

Conclusions

To summarize, our microbrewery produces 152 240 L of beer per year, filling up **461 330 bottles** of 0.33 L that are distributed around Catalonia. Furthermore, 1 655 kg of **BSG** and 512 kg of ***S. cerevisiae*** are profited to produce lactic acid and yeast extract.

The obtained product has an **ABV** (Alcohol By Volume) of **3.2%**, falling below the established range. However, glucose, sucrose and glycerol concentrations are in between the reference values. Our beverage presents **fruity flavour** and a **pronounced bitterness**.

Figure 5. Product representation.

Selected literature

1. Palmer, J. J. (2017). How To Brew: Everything You Need to Know to Brew Great Beer Every Time (Fourth ed.). *Brewers Publications*| **2. Parcunev, I., Naydenova, V., Kostov, G., Yanakiev, Y., Popova, Z., Kaneva, M., & Ignatov, I.** (2012). Modeling Of Alcohol Fermentation In Brewing - Some Practical Approaches. *26th European Conference on Modelling and Simulation (ECMS)*| **3. Mussatto, S. I.** (2014). Brewer's spent grain: a valuable feedstock for industrial applications. *Journal of the Science of Food and Agriculture*, 94(7), 1264–1275.

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