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Process integration and optimisation of the Wits Microbrewery Plant using artificial neural networks.

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ABSTRACT

Beer brewing is one of the most widely practiced processes in the world. The brewing technology is associated with huge business opportunities because of high demand of the final product. Due to worldwide competition and increasing costs of resources and input costs, businesses have to consider innovative ways of brewing beer optimally. Optimisation of the brewing process is a challenging task that relies on understanding the complex effects of processing inputs on productivity and quality outputs, whose relationship exhibits non-linear behaviour. In this study, various optimisation methods aimed at reducing feed and energy costs are introduced. The proposed methods use Response Surface Methodology and neural networks for optimisation of significant inputs. Process integration is used for increased energy recovery and to minimize waste energy; and the prospects of using fed-batch fermentation in brewing are evaluated.

There is a need for more advanced optimisation tools that can handle complex behavior of biological processes such as brewing process. The importance of this study is reflected in the novel use of Artificial Neural Networks with Genetic Algorithms (ANN) as an optimisation tool for biological systems. Because of its great potential to circumvent the limitations associated with the traditional optimisation methods, it can serve as a basis of discernment in improving the brewing process.

Increasing energy costs as well as inefficiencies optimisation of batch brewing processes as compared to continuous processes make it necessary to save energy through other strategies such as process integration; and possible switch to fed-batch fermentation. The thesis makes significant contributions to current debates on switching to fed-batch fermentation in the

brewing industry. It also extends the existing focus on batch process integration for sustainable industries.

Artificial Neural Network models proved superior and more accurate than Response Surface Methodology model when tested against various experimental results. The optimal values of temperature, sugar concentration and yeast concentration were found to be 19.0^{o}C, 163.9 g/l and 0.42 g/l, respectively. The optimal values from the Genetic Algorithm were then inserted as inputs to the neural network to yield an optimal ethanol concentration of 63.49 g/l.

Fed-batch fermentations produced higher ethanol yields than batch, although the differences were not major to justify the switch to fed-batch fermentation. After heat integration of process units was deployed to the Wits Microbrewery plant, heat loss and energy demand were reduced by 19.5% and 23.0%, respectively. It was observed that besides time and temperature constraints, energy load mismatch is one of the critical variables that restrict maximum energy recovery in batch process integration.

It was thus concluded that ANN is suitable for prediction and optimisation of complex and non-linear processes like brewing fermentation. It was also concluded that opportunities exists for energy savings and costs reduction through implementation of heat integration strategies and use of fed-batch fermentation in brewing process.