Freeze-Drying Control by taking into account Environmental Considerations

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Micro-organisms are biological agents which present a large scale of applications in food domain (e.g. ferments), medical domain (e.g. probiotics) or non-food domain (e.g. active molecule production). Freeze-drying is a dehydration method widely used to preserve highly sensitive bio-products such as micro-organisms. Life cycle assessment of freeze-dried lactic acid bacteria showed that freeze-drying was a hotspot of the system, together with fermentation and subsequent storage of freeze-dried bacteria.[1] Environmental improvement could significantly be obtained by reducing energy required by the freeze-drying process.

The freeze-drying process is based on three successive steps: freezing of the water, sublimation of the ice (primary drying) and desorption of unfrozen or sorbed water (secondary drying). We have previously developed a software able to predict a freeze-drying cycle by taking into account product quality and able to optimize process duration while preserving the highest quality of the freeze-dried bacteria.[2] The optimal process results in fluctuation of the shelf temperature during the sublimation step, what can represent a strong energy request.

In this work, the objective was to investigate component-by-component the energy consumptions of a freeze-drier pilot plant as a function of the applied process variables (shelf temperature profile and product load).

Wi-LEM energy sensors were used to measure energy consumptions of the main components of freeze-dryer: compressors, heating resistance, vacuum pump, shelf fluid circulation pump. Different shelf temperature profiles were applied during the three steps of the process. Experiments were performed on a model solution (15% w/w of maltodextrin). The energy consumptions were correlated to the shelf temperature profile and the product quantity. Primary drying was the most consuming step and the step duration was the main parameter allowing energy savings.

Simulations were then performed by using the software previously developed and the corresponding energy consumptions were calculated. It was found that an optimal cycle could save 16% of energy. Shelf temperature fluctuation in primary drying could finally save energy by shortening cycle duration, while maintaining the product quality.

Further work will consist in developing on-line and real-time optimization tool making able to minimize energy consumption of the process while maintaining an acceptable product quality.

References

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2. Trelea, Passot, Fonseca & Marin. 2007. An interactive tool for the optimization of freeze-drying cycles based on quality criteria. Drying Technology, 25, 741-751.