Biosurfactants: Efficient Production and Applications

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Introduction

Surfactants, surface active amphiphilic molecules, have a broad spectrum of applications, from everyday tasks such as washing the dishes to advanced oil recovery operations. The global market for surfactants is approximately 8 million tonnes per annum with a total value of $ 13.9b[1]. The majority of this demand is met with surfactants obtained from non-renewable oil-based feedstocks. The need for sustainable alternatives to petrochemical surfactants is illustrated by the recent net increase in the price per barrel of crude oil and the global drive to reduce our negative impact on the environment. An alternative route of surfactant production exists in nature in the form of microbes capable of producing surfactants. Microbially produced biosurfactants are characterised by both their chemical composition and microbial origin[2] and can perform many tasks for which traditional petrochemical or oleochemical surfactants are currently used. Biosurfactants have also found utility in fields such as environmental bioremediation , food-processing and pharmaceuticals[3]. An interesting example of a biosurfactant is the heptapeptide surfactin, a metabolite of *Bacillus subtilis* BBK006. Surfactin is highly surface active and exhibits antibacterial, antiviral and antitumor behaviour[4].

The preferential use of biosurfactants has many advantages, primarily due to their low toxicity and biodegradable nature[2]. Also the development of new markets give biosurfactants potential *to increase wealth; to improve well being*. To fully realise this potential technology for the economic production of biosurfactants must be developed. This is a multidisciplinary challenge which must be solved by collaboration between biochemical engineers, microbiologists and the petrochemical and biotechnology industries.

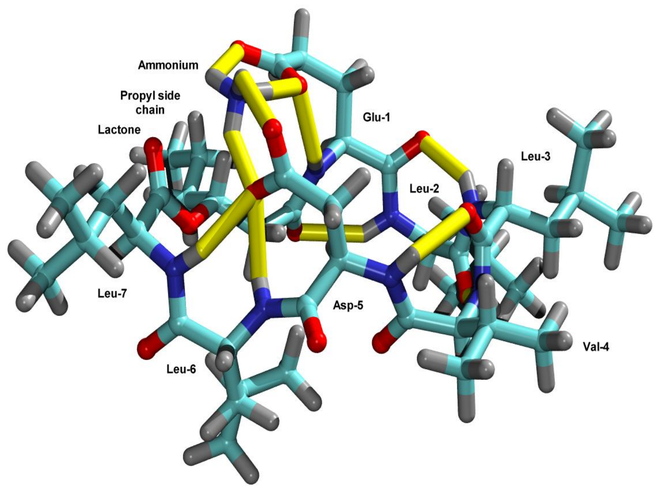

Figure 1 - The structure of surfactin, deduced from energy minimisation.

Biosurfactant Production

The production of biosurfactants by fermentation is often carried out as a batch process in a stirred tank bioreactor. Production yields can be improved by increasing expression of the biosurfactant through genetic modification of the microorganism. Shown below are two examples of alternative fermentation systems which aim to allow for in-situ recovery of product and better control over foaming.

Foam: Foaming is well known to be a nuisance in fermentation systems. Control of foaming is achieved with antifoam chemicals and mechanical foam breaking devices. The use of antifoams adds to production costs and introduces another component which must be removed from the product during downstream processing[5]. The problems caused by foaming during biosurfactant production can be alleviated with the use of improved foam breaking methods or through design of innovative processes. Such innovative processes include integrated foam fractionation for primary product separation.

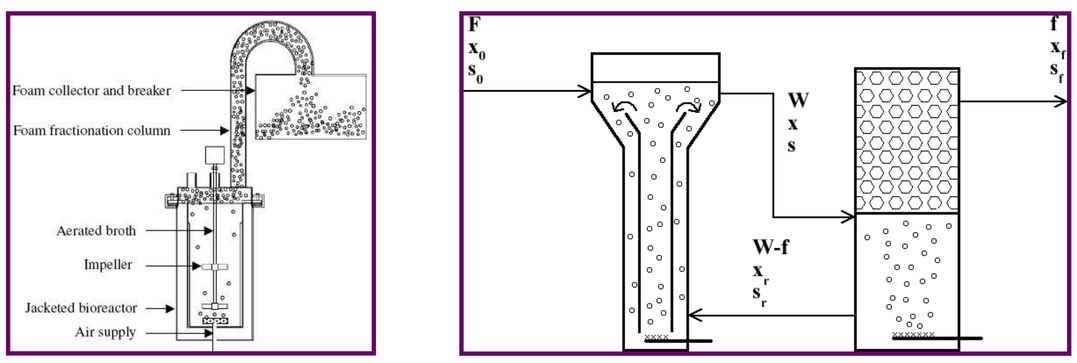

Figure 2 – Biosurfactant production and foam fractionation apparatus. Standard bioreactor [6](LHS).Airlift bioreactor (RHS).

Downstream Processing- Foam Fractionation

A significant proportion of the production costs of biosurfactants are incurred during downstream processing. Standard separation techniques such as microfiltration are costly when applied to typical bioproduct process streams, i.e. large volumes, with a low product concentration. Foam Fractionation is a low cost adsorptive bubble separation method, which is used to enrich and partially separate solutions of surface active species[7]. An analogy can be made between foam fractionation and distillation, and the familiar concept of an equilibrium stage applied to foam column design

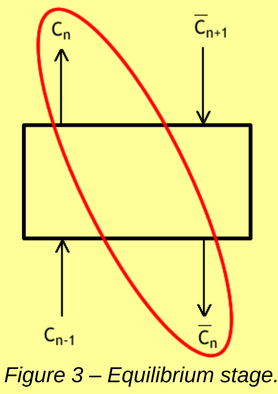

Figure 3 – Equilibrium stage.

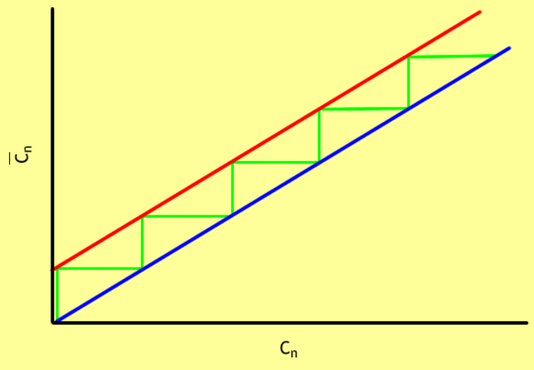

Figure 4 – McCabe-Thiele diagram for fractionation column.

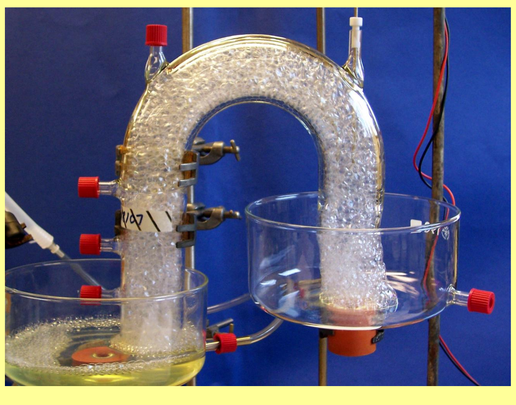

Figure 5 – Foam fractionation apparatus with five equilibrium stages.

Ultrasound Foam Interactions[8]

Having effective control over foaming in a fermentation system is critical if laboratory developed processes are to be scaled-up for bulk biosurfactant production. The use of ultrasound to break foam was investigated by Dorsey[9] who used a ultrasonic air horn to suppress foaming in a bioreactor.

Methods: Experiments were carried out in which a column of detergent based foam were subjected to two different frequencies of low power ultrasound. The variation of foam height and liquid drainage with time were measured.

Results: Figure 6 shows the progression of foam height vs. mean liquid holdup with time for foams with two different initial liquid holdups. The trajectory of the plot is related to the dominant foam collapse mechanism, rupture front breakage (FR) or homogeneous rupture (HR). It was observed that for 40 kHz ultrasound rupture front breakage dominates the foam collapse.

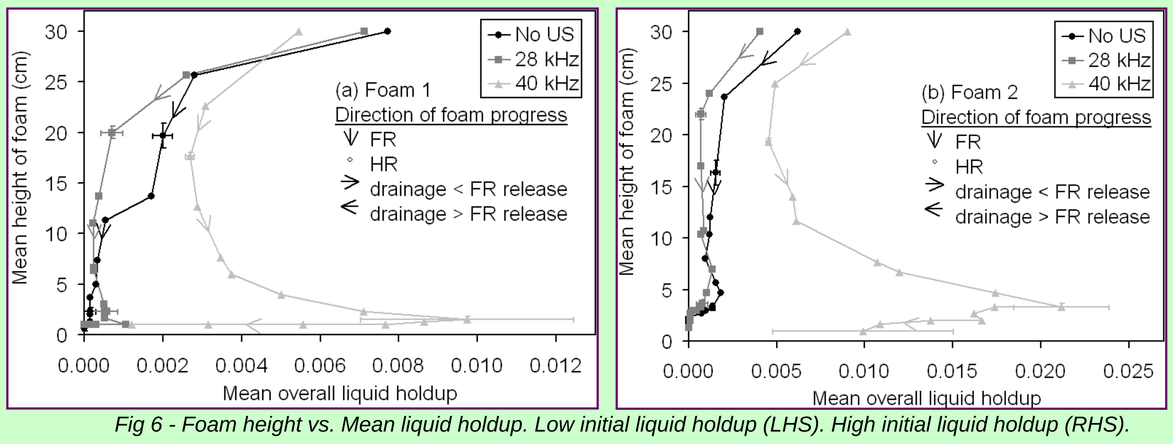

Fig 6 - Foam height vs. Mean liquid holdup. Low initial liquid holdup (LHS). High initial liquid holdup (RHS).

What's New: Low power ultrasound, at power to foam volume ratio of 3 W l^{-1} compared to that used in previous work[10] of 250 W l^{-1}, has a frequency dependent effect on foam collapse behaviour. The possibility of energy efficient ultrasonic foam breakers has been demonstrated through minimising the impedance boundaries between ultrasound and foam.

Conclusions

•Biosurfactants are biodegradable, non-toxic alternatives to petrochemical based surfactants.

•Foam fractionation is a simple, low cost separation technique which can be integrated with biosurfactant production.

•40 kHz ultrasound has a repeatable effect the collapse behaviour of detergent stabilised foam, although more research is required to develop a low power ultrasonic foam breaker.

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