UP-FLOW VELOCITY INFLUENCE ON STRUVITE PARTICLE SIZE DISTRIBUTION

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INTRODUCTION

European cows and pigs jointly produce **1.27 billion ton of manure every year.** Its high nutrient content could favor its recovery as **struvite ($MgNH_4PO_4 \cdot 6H_2O$)**, a slow-release fertilizer. **Particle size** is an important characteristic in fertilizers, as bigger particles will have longer effects on soil, increasing the nutrient uptake of plants/crops.
Few attempts have been made to increase particle size in lab-scale, only by adding seeding crystals/materials or by increasing the reaction time. The **up-flow velocity** as a controlling parameter for particle size has not been yet studied.

OBJECTIVES

This study evaluates the influence of **up-flow velocity** on struvite particles size and in struvite production and quality.
Thus, the up-flow velocity will be assessed as a controlling parameter, and a hydrodynamic model will be used to determine the minimum theoretical equivalent diameter that can be obtained.

MATERIALS AND METHODS

EXPERIMENTAL SET-UP

In Figure 1, an scheme of the crystallizer is presented, showing the 3 different zones: **RISER**, **COLLECTOR** and **EFFLUENT ZONE.**

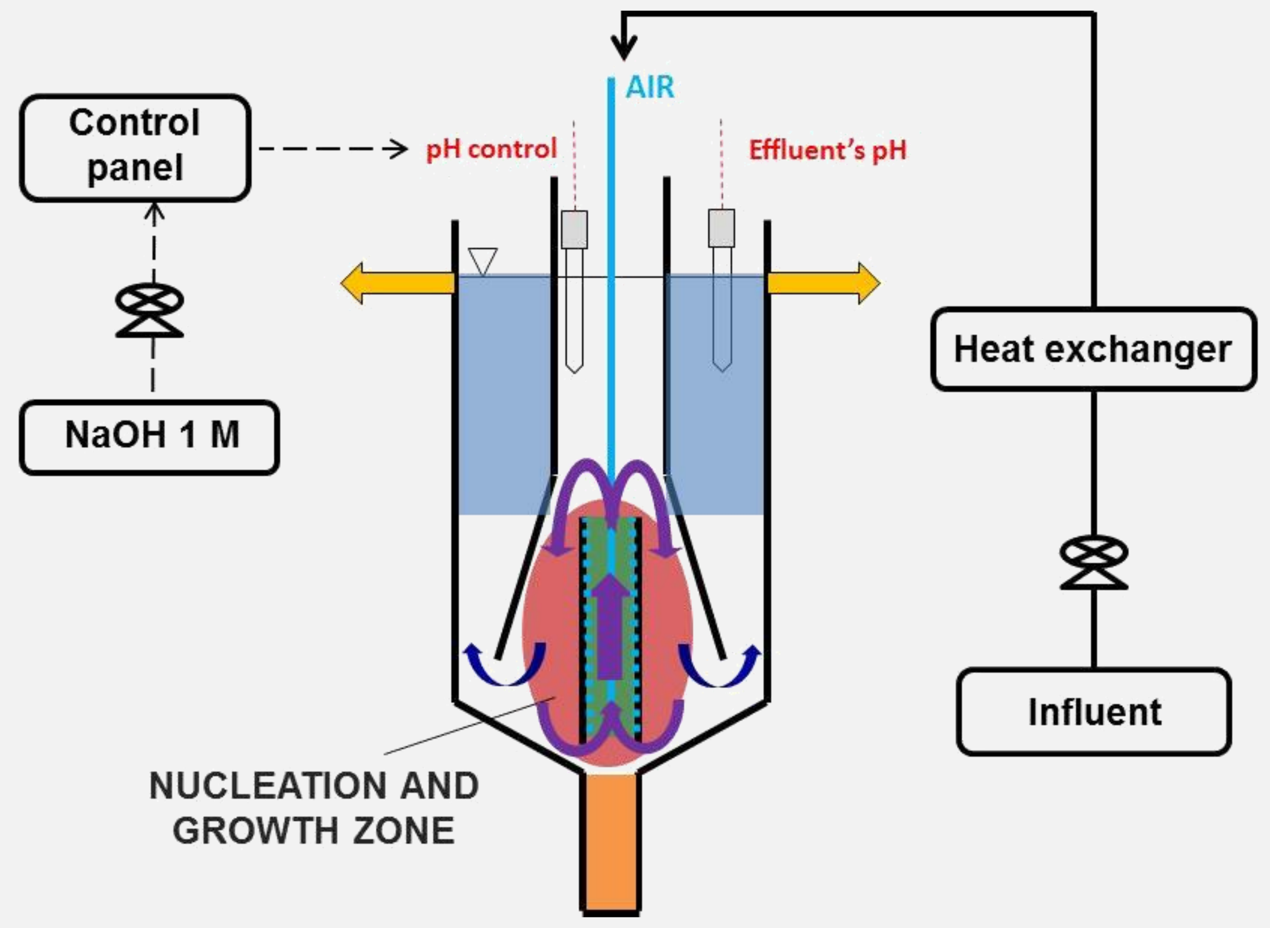

Figure 1. Scheme of the crystallizer designed for struvite recovery.

Struvite was recovered from an effluent of wastewater treatment plant, in which the concentrations of magnesium, ammonium and phosphate were increased (200 mg Mg^{2+} L^{-1}, 1000 mg NH_4^+ L^{-1} and 500 mg PO_4^{3-} L^{-1}) to have similar concentrations as swine manure.

THEORETICAL APPROACH

By applying **AIR**, a recirculation flow in the riser is induced, which can be calculated according to Merchuk and Gluz (1999)[1]. Then, from the recirculation and the influent flow, the up-flow velocity can be calculated.
Therefore, adjusting the settling and the up-flow velocity, and with the hydrodynamic model:

- The up-flow velocity determines the **particle size** of the particles that settle in the collector.
- The recirculation flow induced favours **growth** due to recirculation and fluidization of formed nuclei.
- **MINIMUM THEORETICAL EQUIVALENT DIAMETER,** considering spherical particles (0,1 mm), that can be obtained can be calculated (Figure 2).

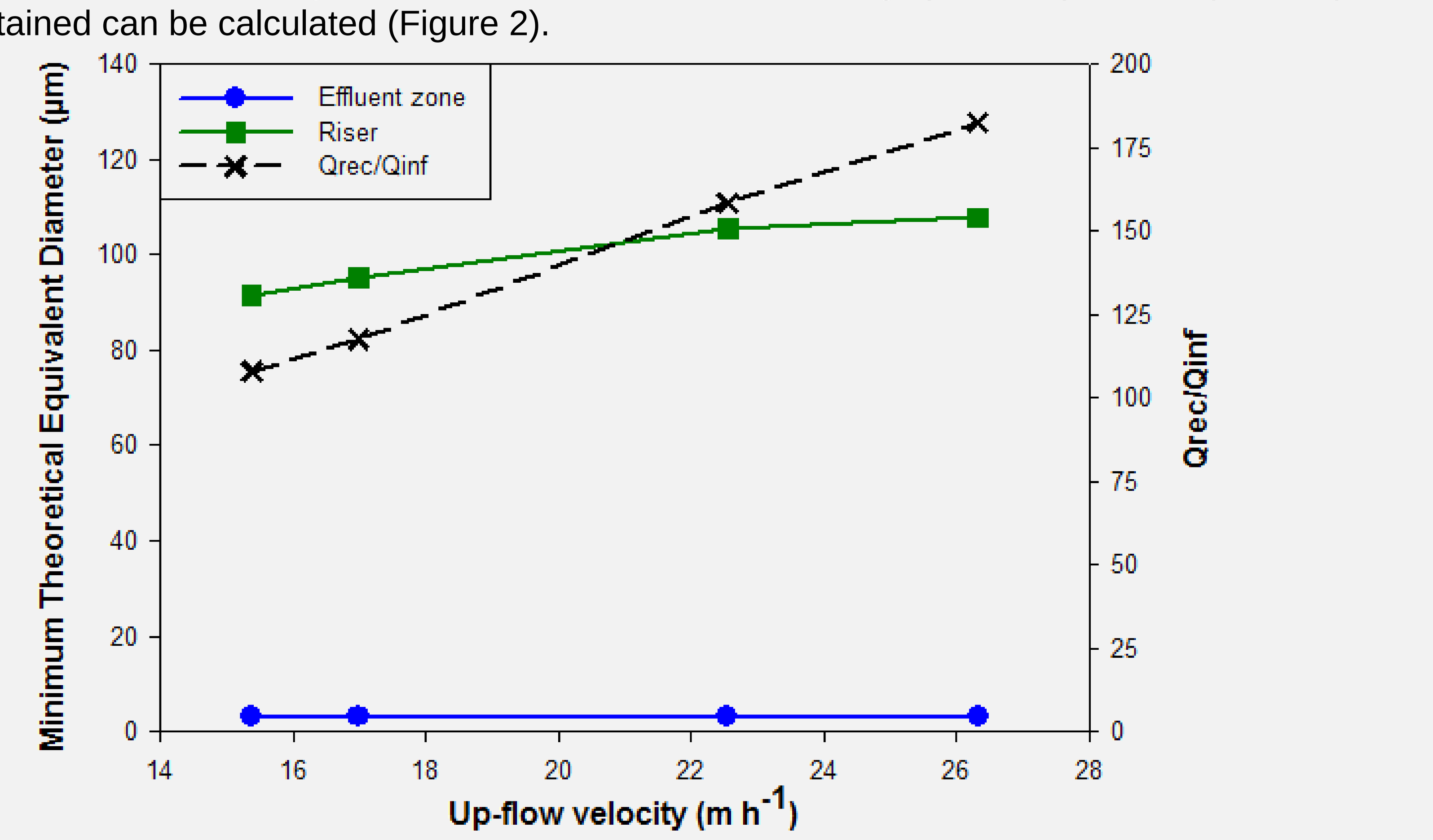

Figure 2. Minimum theoretical equivalent diameter (µm) for each up-flow velocity (m h^{-1}) in the effluent zone and in the riser, as well as the ratio between the recirculation and the influent flow (Qrec/Qinf).

RESULTS

Four different up-flow velocities (15.37; 16.99; 22.55 and 26.33 m h^{-1}) were studied to determine the influence of this parameter in struvite PARTICLE SIZE, PRODUCTION and QUALITY of the product.

PARTICLE SIZE of the product recovered in each study was determined by a particle size distribution analysis (Figure 3).

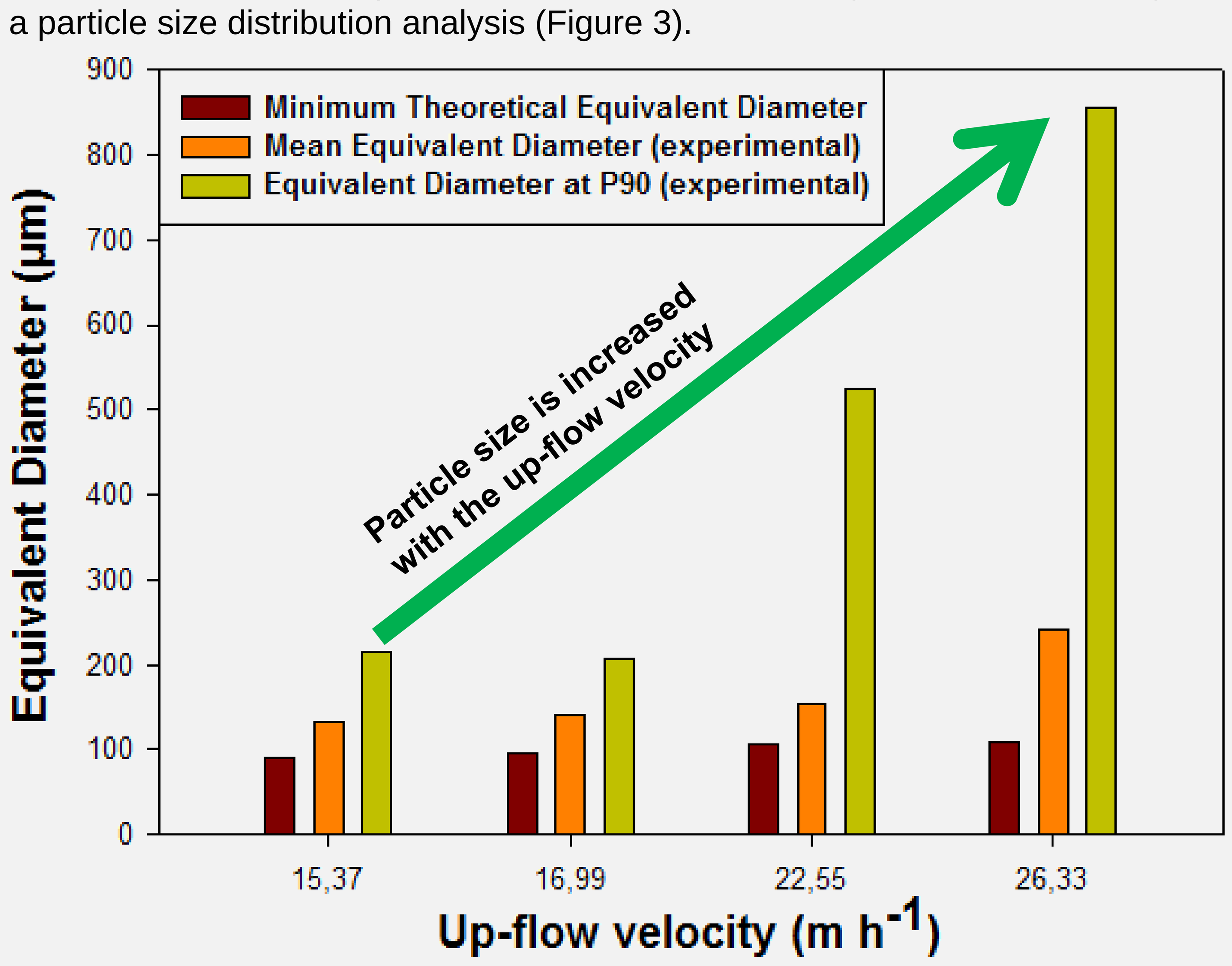

Figure 3. Particles' equivalent diameter for each up-flow velocity studied, expressed as the mean equivalent diameter recovered and the equivalent diameter at percentile 90. Also, the minimum theoretical equivalent diameter is represented.

By comparing theoretical (minimum theoretical equivalent diameter) and experimental (mean equivalent diameter) particle size, the theoretical approach is confirmed.
A higher increase in particle size was noticed by using the equivalent diameter at percentile 90, increasing from less than 300 µm at lower up-flow velocities to **525-855 µm** at 22.55-26.33 m h^{-1}, respectively.

Struvite **PRODUCTION** was assessed, varying from 1.45 g L^{-1} treated at lower up-flow velocities, to **1.80 g L^{-1} treated** at the highest. Also, optic microscope images were taken (Figure 4).
The designed crystallizer favoured particles growth due to particles fluidization and recirculation of formed nuclei.

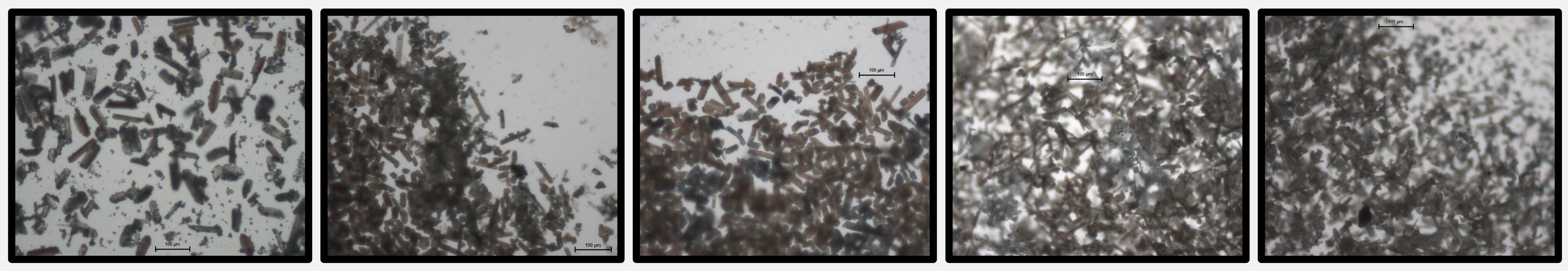

Figure 4. Optic microscope pictures at 10x for each up-flow velocity studied (13.29; 15.37;16.99; 22.55 and 26.33 m h^{-1}, respectively.

– **STRUVITE PRODUCTION (g L^{-1} treated)** +

The **QUALITY** of the product settled (Figure 5) in the **collector** was analyzed by XRD (Figure 6), recovering **pure struvite** in all the up-flow velocities studied.

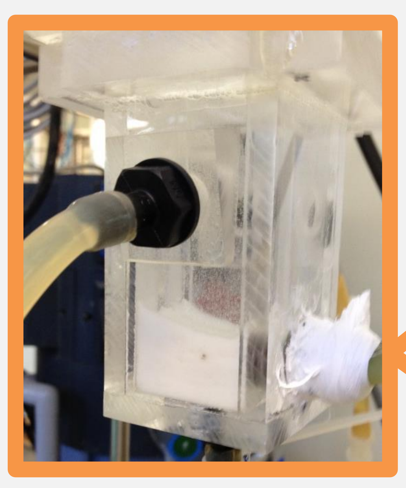

Figure 5. Product settled in the collector.

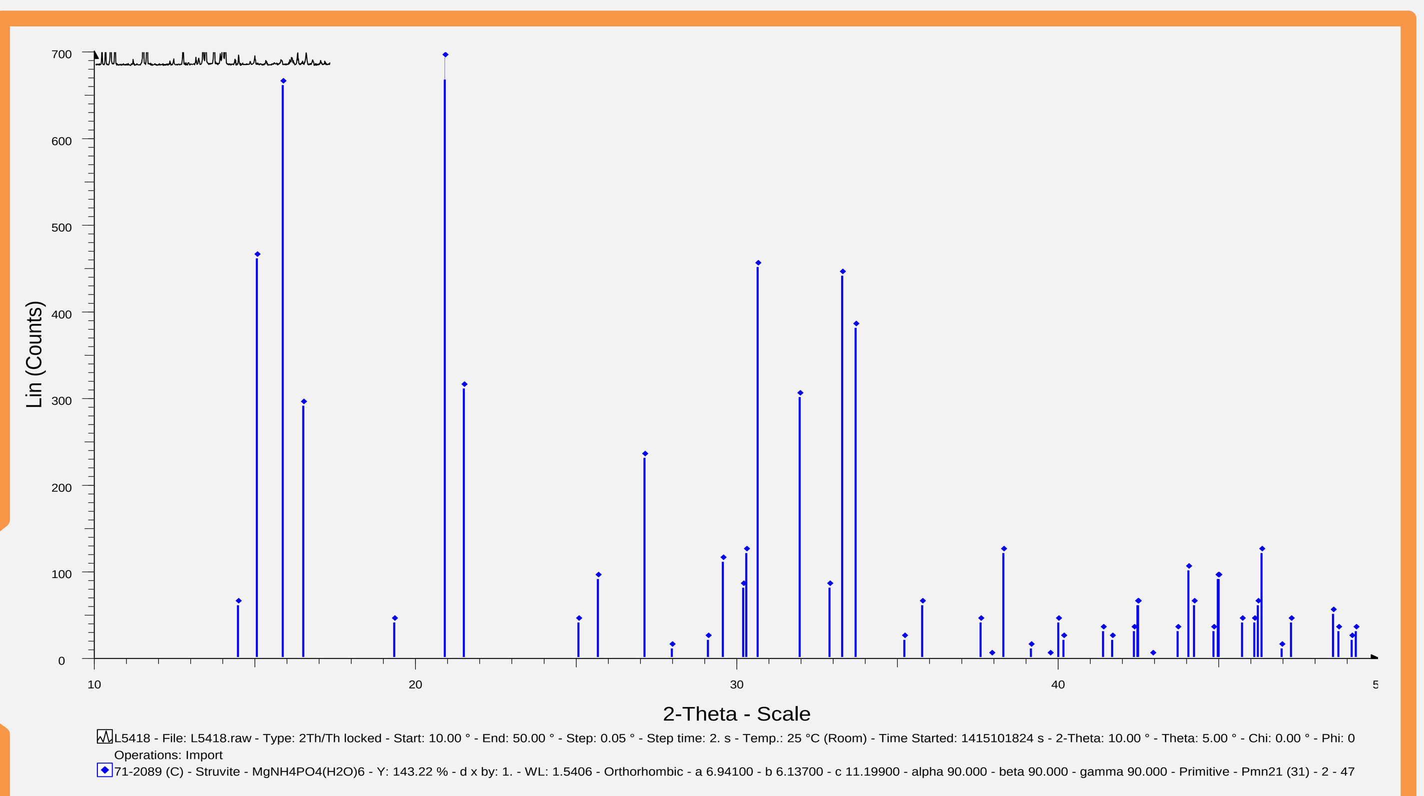

Figure 6. XRD diffractograms of the precipitates at the up-flow velocity of 26,33 m h^{-1}.

CONCLUSIONS

- **Bigger particles** could be obtained by **increasing the up-flow velocity** in the nucleation zone varying the air-flow applied, without affecting recovery efficiency.
- The system performance, both in terms of **production** and **quality** of the harvested product (pure struvite), showed great results, increasing the production at higher up-flow velocities.
- The crystallizer designed (air-lift reactor plus a settler) favoured particles growth due to particles fluidization and recirculation of formed nuclei, promoting **secondary nucleation**.
- The **'model-predicted'** equivalent diameters matched with experimental analysis, confirming the theoretical approach done.

[1] Merchuk, J. C. and Gluz, M. Bioreactors, air-lift reactors, in Encyclopedia of Bioprocess Technology (pp. 320-353). M. C. Flickinger and S. W. Drew, eds. John Wiley & Sons, New York, 1999.

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