ENVIRONMENTAL
SCIENCE & TECHNOLOGY
INNOVATION

Biorreator airlift: estudo sobre suas aplicações

Airlift bioreactor: study about its applications

Gabrielly Magalhães de Assis[1]; *Gabriela Berbel Belini*[1].

[1]*Centro Universitário Sagrado Coração, Bauru/SP, Brasil.*

E-mail (autores principais): *gabrielly.magalhes@yahoo.com; gabi.belini2017@gmail.com*

RESUMO

Os biorreatores são determinados como equipamentos nos quais ocorrem conversões bioquímicas usando enzimas, células ou microrganismos como catalisadores. Pela especificidade, existem inúmeros tipos de biorreatores disponíveis que se adequam às necessidades dessas reações, destacando-se os biorreatores pneumáticos não convencionais, dentre eles, os do tipo airlift, cuja utilização vem se expandindo significativamente na indústria de biotecnologia, devido à princípio de injeção de gás, capaz de promover a agitação e homogeneização do meio de cultura, sem a necessidade de componentes mecânicos. Diante do exposto, o presente estudo, por meio de pesquisa bibliográfica, teve como objetivo reunir uma contribuição teórica sobre as aplicações em biorreatores airlift, destacando as vantagens de sua utilização. Ao final do estudo, foi possível constatar que a utilização de biorreatores airlift credita um grande potencial na área de biotecnologia, despontando como uma ferramenta versátil e promissora, capaz de oferecer eficiência e viabilidade, mesmo quando comparada a outros tipos de biorreatores.

Palavras-chave: Biotecnologia. Bioquímica. Catalisadores. Pneumático.

ABSTRACT

Bioreactors are determined as equipment in which biochemical conversions occur using enzymes, cells, or microorganisms as catalysts. Due to the specificity, thereare numerous types of bioreactors available that fit the needs of these reactions, highlighting the non-conventional pneumatic bioreactors, among them, the airlift type,whose use has been expanding significantly in the biotechnology industry, due to the pneumatic principle of gas injection, capable of promoting the agitation and homogenization of the culture medium, without the need for mechanical components. Given the above, the present study, by means of bibliographical research, had the objective of gathering a theoretical contribution about the applications in airlift bioreactors, highlighting the advantages of their use. At the end of the study, it was possible to verify that the use of airlift bioreactors credits a great potential in the area of biotechnology, emerging as a versatile and promising tool, capable of offering efficiency and viability, even when compared to other types of bioreactors.

Keywords: *Biotechnology. Biochemistry. Catalysts. Pneumatic.*

INTRODUCTION

In a biotechnological process, the most relevant stage refers to the biochemicalreaction that results in the product of interest (CLARK; PAZDERNICK, 2015). This stage of the bioprocess is conducted in equipment named bioreactors, and the entire design and development of the bioprocess, from the separation steps, utilities systems and process control, are performed by virtue of these devices (CHISTI, 1989).

Bioreactors, often called biochemical reactors or fermenters, are equipment thatallow the conversion of raw materials into bioproducts, through reactions that are indispensably catalyzed by microorganisms, enzymes, animal or plant cells, and even subcellular structures such as chloroplasts and mitochondria (ERICKSON, 2011; CHISTI; MOO-YOUNG, 2002; CHISTI, 1989; LEVEAU; BOUIX, 1985).

Such equipment was used years ago to produce food and beverages,such as soy sauce, potable alcohol, cheese, and so on. Research was then accentuated from the 1940s, during World War II, in accordance with the demand for antibiotics(MCNEIL; HARVEY, 2008).

The function of a bioreactor, according to Zhong (2011), is to provide suitable conditions for the physiology and cellular metabolism, regulating the chemical and physical factors present in the system, to obtain the desired product. The choiceof the type and design of each bioreactor is unique, but there are some fundamental criteria for the choice, such as considering adequate oxygen transfer, low shear stress and good homogenization (ZHONG, 2011; MANDENIUS, 2016). However, despite the variety of types, the main examples of bioreactors are pneumatic bioreactors, renowned for being vessels where both agitation and homogenization of the culture medium are carried out only by gas injection (CHISTI, 1989; SIEGEL; ROBINSON, 1992).

An unconventional type of pneumatic bioreactors, which present quite interesting instrumental and operating characteristics are the *airlift* (CHISTI, 1989; SIEGEL; ROBINSON, 1992; ONKEN; WEILAND, 1983).

Airlift bioreactors comprise four distinct zones, each with a distinct flow pattern, which divide the reactor between two flow zones (one directed upward and one downward). The zones or channels allow for large-scale circulation of liquid around the reactor body (SIEGEL; ROBINSON, 1992). They are generally divided intotwo types based on their physical structure: those with internal circulation and those with external circulation (CHISTI, 1989). The difference between them concerns the liquid gas separator. In the internal circulation *airlift*, the gas-liquid separator is usuallysimple with an extension over the *riser* and *downcomer*, allowing a small gas release. In the external circulation *airlift* the liquid gas separator has a horizontal flow region, which allows more gas release and a higher circulation speed (SIEGEL & ROBINSON,1992; CHISTI, 1989).

Thus, they are considered an important class of modified bubble column bioreactors (VIAL; PONCIN; WILD; MIDOUX; 2002). They have received attentionbecause of their simplicity of design and construction, versatility, easy operation, lowerpossibility of contamination, low energy consumption, and high mass and heat transferrates (YUGUO; ZHAO; XIAOLONG, 2000; VIAL; PONCIN; WILD; MIDOUX; 2002). Besides enabling easy and cheap maintenance (SIEGEL; ROBINSON, 1992).

In view of this, many are the works presented in the literature regarding the useof these bioreactors, both for the characterization of cultures and metabolites, and to establish kinematic and hydrodynamic parameters, referring to the bioreactors and theforms of cultivation (MOLINA; CONTRERAS; CHISTI, 1999; CHISTI; JAUREGUI-HAZA, 2002). Given the exposed, the present article aims to gather a theoretical contributionabout the applications in *airlift* bioreactors evidencing the advantages of its use.

METHODOLOGY

The study was guided by the study of *airlift* bioreactor applications.

According to the classifications of Gil (2002), a qualitative study was conducted for a bibliographical survey, in order to generate more knowledge of the theme, from books, theses, scientific articles, newspapers, periodicals, and magazines. The research was explanatory, deepening greater knowledge with the compound studied.

After this survey, basic research was carried out, with no practical application to prove its functionality, only relevant references.

As to procedures, the article is classified as bibliographical research, developed through documental and bibliographical research data.

RESULTS AND DISCUSSIONS

A modified *airlift* bioreactor was proposed by Wu and Wu (1991) for fed-batchcultivation of *Saccharomyces cerevisiae*. In this study, a higher oxygen transfer was obtained when compared to that obtained in a conventional airlift reactor and, as a consequence, a higher cell mass concentration was also obtained.

Pollard *et al*., (1996) also achieved an improved performance of a pilot-scale concentric-tube *airlift* bioreactor in *Saccharomyces cerevisiae* production by using a gas disperser in the central tube instead of placing it in the reactor annulus. Accordingto the authors, this result was obtained through the ratio of the cross-sectional areas ofthe *riser* and *downcomer* (Ad/Ar) together with the effect of the liquid velocity in the riser. Frohlich *et al*., (1991) studied *Saccharomyces cerevisiae* in *airlift* bioreactors bytesting various physical configurations, where they were able to significantly improvetheir performance.

In their studies, Bonnarme *et al*., (1993) found the superiority of the *airlift* andbubble column bioreactor over the stirred tank bioreactor in the production of metabolites by microorganisms sensitive to the shear caused by mechanical stirrers (STR). The authors successfully used the *airlift* bioreactor for production of the peptide lignin, manganese peroxidases and extracellular protein from the fungus *Phanerochaete chrysosporium*.

Yuguo *et al*., (1999) presented the advantage of the externally circulated *airlift*bioreactor in the production of citric acid by mixing dehydrated sweet potato with *Aspergillus niger* pellets. In the following year, the same authors, tested another type ofmicroorganism successfully in the *airlift* bioreactor with external circulation, producing α-amylase from *Bacillus subtilis*.

Klein *et al*., (2002) found that the biotransformation system of glucose into gluconic acid by *Aspergillus niger* can be very effective if used the determination of theoxygen transfer rate in *airlift* bioreactors. In the same year, Cheng *et al*., (2002) achievedgood results in the cultivation of *Acetobacter xylinum* for cellulose production in a modified airlift bioreactor.

In research by Siedenberg *et al*., (1998), the cultivation of *Aspergillus awamori*in stirred batch reactors and in *airlift* bioreactors with external circulation, using a complex culture medium consisting of wheat and soybean meal, was compared. In the*airlift*, mycelium filaments were formed due to the low amount of energy supplied. Despite the high medium viscosity, good xylanase productivity was obtained.

Aleksieva and Peeva (2000) compared the production of acid proteinase by thefilamentous fungus *Humicola lutea* in an *airlift* bioreactor under continuous and batchconditions with the production of proteinase using cells of the fungus, grown in a stirredtank bioreactor. In the study, it was found that the productivity achieved in the airlift under continuous conditions was 3 times higher than in the batch system.

Pedroso (2003) used an externally circulating *airlift* bioreactor for the productionof apple vinegar. Four cultures were performed in the *airlift* bioreactor and, in parallel,four control cultures in a classic bioreactor. The study proved that the *airlift* bioreactorshowed superiority in acetic acid production when compared to the classical bioreactor.The average maximum acetic acid production obtained during the quanta culture was 4.2g.L.d^{-1} for the *airlift* bioreactor and 1.6 g.L.d^{-1} for the classic bioreactor. Also using anexternal circulation *airlift* bioreactor, but in the pre-fermentation of grape must,Scartazzini (2001) verified that the equipment meets the microbiological needs of the yeasts, increasing their growth rate.

Shamlou *et al*., (1994) suggested a model for the prediction of the volumetric mass transfer coefficient (KLa) in an *airlift* bioreactor with concentric tubes. The resultsobtained point out that the KLa is directly influenced by the gas velocity, the gas rise (*hold-up*), the gas circulation velocity, the bubble diameter, and the velocity of the bubbles in the *riser*. By fermentation of *Saccharomyces cerevisiae*, measurements of the mass transfer coefficient as a function of gas surface velocity resulted and comparedto the data achieved in the proposed model.

In the studies by Allen and Robinson (1991), the shear rate was established in *airlift* and bubble bioreactors because of the importance of this parameter in cell destruction and correlation of hydrodynamic parameters in non-Newtonian fluids. This rate can be used to evaluate the effective viscosity of the non-Newtonian fluids, which in turn is used to futurize the rheological behavior of the fluids. This approach, applied in a bubble bioreactor, can also be applied in *airlift* bioreactors with external circulation, by changing the surface gas velocity by the gas velocity in the *riser*.

Freitas *et al*., (2000) verified the influence of the effect of gas disperser orificediameter, airflow rate, amount of suspended solids and solids density on the hydrodynamiccharacteristics - gas holdup (upward gas flow) circulation time and liquid velocity - in athree-phase *airlift* bioreactor with external circulation. It was found that the gas distributorhas a small effect on gas holdup in the *raiser*, circulation time, and liquid velocity in the*downcomer*. In contrast, the airflow rate, the number of suspended solids and the density ofthe solids have a significant influence on the hydrodynamic characteristics of the bioreactor.A described model was used to calculate the upward gas flow through the *riser* and theliquid velocity in the *downcomer* in parallel, showing satisfactory results.

Inward, some authors have studied the *airlift* as a potential bioreactor for the treatment of various wastes. Huppe *et al*., (1990) used a two-stage pilot plant to biologically treat coal refinery effluent. The first stage consisted of an *airlift* of concentric tubes, where coal dust entered the process. The effluent of the first stage passed through the sedimentation and filtration units before entering the second stage. On the other hand, the second stage consisted of a 0.160 m^3 external circulation *airlift* with biomass immobilized on small sand particles. The aromatic substances circulating through the first stage were successively eliminated by the immobilized biomass in the second stage.

Tyagi *et al*., (1990) used a 0.023m^3 laboratory-scale externally circulated *airlift* anda 1.15m^3 pilot-scale externally circulated *airlift* to investigate mesophilic and thermophilicaerobic digestion of primary and secondary municipal sludge. The pilot *airlift*, using air foraeration, achieved results comparable to conventional aerobic sludge digestion systems usingpure oxygen for aeration. In addition, it was able to exhibit thermophilic temperatures,meaning autothermal heating. A cost analysis showed that the self-heated digester can symbolize significant help in both capital and operating costs when compared to aconventional two-stage aerobic digester using pure oxygen.

CONCLUSION

However, the *airlift* bioreactor is a promising technology which offers a variety of applications in the areas of biotechnology and process engineering. The study in this paper explored some of these applications and highlighted the effectiveness of the *airlift* bioreactor in the cultivation of microorganisms, characterization of cultures and metabolites, production of various products, environmental treatment, as well as in establishing kinematic and hydrodynamic parameters.

The *airlift* bioreactor has a number of advantages over other culture systems and biotechnological processes, such as the efficient transfer of mass and energy, promoting an environment conducive to cell growth, the absence of mechanical energy for agitation facilitating the operation of the system and reducing energy consumption and operating costs, the ease of laboratory or industrial scale, and is also highly versatile and adaptable, being able to use different types of cultures and processes.

Furthermore, this type of bioreactor stands out as a promising solution to address environmental challenges such as chemical contamination and waste treatment. Its ability to degrade organic compounds, combined with the efficiency in mass and energy transfer and energy transfer efficiency, makes it a viable option for the removal of contaminants in wastewater and contaminated soil.

Consequently, as technology advances and the demand for sustainable and efficient solutions continues to grow, the *airlift* bioreactor emerges with significant potential to play a key role in the development of more effective and environmentally friendly processes. Therefore, these findings highlight the potential of this bioreactor as a valuable tool in various industries, driving significant advances in research and development of more efficient and sustainable processes.

REFERENCES

ALLE N, GRANT; ROBINSON, CAMPBEL - On The Calculation of Shear Rate andApparent Viscosity in Airlift and Bubble Column Bioreactors. **Biotechnology and Bioengineering**, v. 38, p. 212- 216, 1991.

ALEKSIEVA, P.; PEEVA, L. Investigation of acid proteinase biosynthesis by thefungus *Humicola lutea* 120-5 in an airlift bioreactor. **Enzyme and Microbial Technology**. v.26, n.5-6, p. 402-405, 2000.

BONNARME, P.; DELATTRE, M.; DROUET, H.; CORRIEU, G.; ASTHER, M.
Toward a control of lignin and manganese peroxidases hypersecretion by *Phanerochaete chrysosporium* in agited vessels: evidence of the superiority of pneumatic bioreactors on mechanically agitated bioreactors. **Biotechnology andBioengineering**, v. 41, pp. 440-450, 1993.

CHENG, H.P.; WANG, P.M.; CHEN, J.W.; WU, W.T. Cultivation of *Acetobacter xylinum* for bacterial cellulose production in a modified airlift reactor. **Biotechnologyand Applied Biochemistry**, v. 35, pp. 125-132, 2002.

CHISTI, Y. **Airlift Bioreactors**. Elsevier Applied Sciences, London, 345 p, 1989.

CHISTI, Y.; MOO-YOUNG, 2002, M. Bioreactors. **Encyclopedia of physical scienceand technology**. 2: 247-271; 2002.

CHISTI, Y; JAUREGUI-HAZA, U.J. Oxygen transfer and mixing in mechanically-agitated airlift bioreactors, **Eng.J**, 10, p.43-153, 2002.

CLARK, D.P; PAZDERNIK, N.J. **Biotechnology**. Second Edition, Newnes: 2015

ERICKSON, L. E. Bioreactors for Commodity Products. **ComprehensiveBiotechnology**. 3:653-658; 2011.

FREITAS, CARLA; FIALOVÁ, MARIA; ZAHRADNIK, JINDRICH; TEIXEIRA, JOSÉ A. - Hydrodynamics of a Three-phase External-loop Airlift Bioreactor - **Chemical Engineering Science,** v.55, p. 4961 a 4972, 2000.

FRÖHLICH, S., LOTZ, M., KÖRTE, T,, LÜBBERT, A., SCHÜGERL, K., SEEKAMP, M. "Characterisation of a Pilot Plant Airlift Tower Loop Bioreactor. I". **Biotechnologyand Bioengineering**, v. 38, pp 43-55, 1991.

GIL, Antônio Carlos. **Como elaborar projeto de pesquisa**. 4ºed.São Paulo. EditoraAtlas S.A.2002.

HUPE, P.; HÖKE, H.; HEMPEL, D.C. Biological treatment of effluents from coal tarrefinery using immobilized biomass. **Chemical Engineering Technology**, v,13, pp.3-79, 1990.

KLEIN, J.; ROSENBERG, M.; MARKOS, J.; DOLGOS, O.; KROSLÁK, M.; KRISTOFIKOVÁ, L. Biotransformation of glucose to gluconic acid by *Aspergillusniger* – study of mass transfer in an airlift bioreactor. **Biochemical Engineering Journal**, v. 10, pp. 197-205, 2002.

LEVEAU, J. BOUIX, M. **Bioengenharia**. Ed. Manole, São Paulo, pp.124-175, SãoPaulo, 1985.
MANDENIUS, C.F. **Bioreactors**: Design, Operation and Novel Applications.Weinheim: John Wiley e Sons, 2008.

MCNEIL, B.; HARVEY, L. Practical fermentation technology. Southern Gate,Chichester, **John Wiley & Sons**, 2008.

MOLINA, E; CONTRERAS, A; CHISTI, Y. Gas holdup, liquid circulation and mixingbehaviour of viscous Newtonian media in split-cylinder airlift bioreactor. **Food and Bioproducts Processing**, v.77, n.1, p.27- 32, 1999.

PEDROSO, P.R.F. **Produção de vinagre de maçã em biorreator airlift**. Dissertação(Mestrado em Engenharia Química), 85p, Universidade Federal de Santa Catarina, Centro Tecnológico, Florianópolis-SC, 2003.

POLLARD, D. J„ AYAZI SHANLOU, P., LILLY, M. D„ ISON, A. P. *Saccharomyces cerevisiae* Fermentations in a Pilot Scale Airlift Bioreactor: Comparison of Air SpargerConfigurations. **Bioprocess Engineering**, v.15, n.5, pp. 279-290, 1996.

SHAMLOU, P. AYAZI; POLLARD, D.J.; ISON, A.P.; LILLY, M.D. - Gas holdup and liquid circulation rate in concentric-tube airlift bioreactors, **Chemical EngineeringScience**, v.49, p. 303 a 312, 1994.

SCARTAZZINI, L.S. **Utilização do biorreator airlift na pré-fermentação do mostode uva**. Dissertação (Mestrado em Engenharia Química), 86p, Universidade Federal deSanta Catarina, Centro Tecnológico, Florianópolis-SC, 2003.
SIEDENBERG, D.; GERLACH, S.R.; SCHUGERL, K.; GIUSEPPIN, M.L.F.; HUNIK, J. Production of xylanase by *Aspergillus awamori* on synthetic medium in shake flaskcultures. **Process Biochemistry**, v.33, n.4, pp.429-433, 1998.

TYAGY, Z.R.D.; TRAN, F.T.; AGBEBAVI, T.J. Mesophilic e thermofilic digestion of municipal sludge in an airlift U-shape bioreactor. **Biol. Wastes**, v.31, pp.251-266, 1990.

VIAL, C., PONCIN, S., WILD, G., MIDOUX, N. Experimental and theorical analysisof the hydrodynamics in the riser of an external loop ailrlift reactor. **Chemical Engineering** Science, 57, p. 4745 – 4762, 2002.

WU, J.Y., WU, W. T. "Fed-Batch Culture of *Saccharomyces cerevisiae* in an AirliftReactor with Net Draft Tube". **Bioproducts Processing**, v. 2, pp. 230-233.1991.

YUGUO, Z., ZHAO, W., XIAOLONG, C. α-Amilase production by *Bacillus subtilis* with dregs in an external-loop airlift bioreactor. **Biochemical Engineering Journal**, 5,p.115-121, 2000.

YUGUO, Z., ZHAO, W., XIAOLONG, C. Citric acid production from the mash ofdried sweet potato with its dregs by *Aspergillus niger* in an external-loop airlift bioreactor. **Process Biochemistry**, v. 35, pp. 237-242, 1999.

ZHONG, J. J. Bioreactor Engineering. **Comprehensive Biotechnology**. v.3, pp. 653-658; 2011.