ANAIS

I WORKSHOP DO PROJETO TEMÁTICO FAPESP

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BIOPROCESS SYSTEMS ENGINEERING (BSE) APPLIED TO THE PRODUCTION OF BIOETHANOL FROM SUGARCANE BAGASSE

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REALIZAÇÃO
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APRESENTAÇÃO

Este "I Workshop do Projeto Temático" tem como principal objetivo a apresentação de propostas e de resultados obtidos durante o primeiro ano de desenvolvimento do Projeto Temático: **"Bioprocess Systems Engineering (BSE) Applied to the Production of Bioethanol from Sugarcane Bagasse"**, financiado pela Fundação de Amparo à Pesquisa do Estado de São Paulo – FAPESP (Processo 2008/56246-0), no bojo do programa FAPESP/PRONEX/BIOEN, com vigência de junho de 2009 a julho de 2013. O projeto, proposto conjuntamente pelo Departamento de Engenharia Química da UFSCar e pelo grupo de Bioprocessos da Embrapa Instrumentação Agropecuária, incorpora atualmente colaborações com outros laboratórios e instituições como Instituto de Catálisis y Petroleoquimica (Consejo Superior de Investigaciones Científicas, Espanha), Institute of Resource and Energy Technology (Technishe Universität München, Alemanha), Programa de Engenharia Química da COPPE/UFRJ e do Grupo de Intensificação, Modelagem, Simulação, Controle e Otimização de Processos da UFRGS. O projeto é coordenado pelo Prof. Dr. Roberto de Campos Giordano.

O tema do projeto foi subdividido em **cinco subprojetos interligados**, que buscam promover o conhecimento aprofundado do tema e o desenvolvimento de tecnologia para a produção de bioetanol a partir de bagaço da cana-de-açúcar:

a) Desenvolvimento, implementação e validação de um ambiente computacional integrado amigável, permitindo simulação, otimização, avaliação econômica, análise de CO_2, análise de dados cinéticos e automação de biorreator para processos de produção de etanol lignocelulósico.

b) Cultivos de microrganismos a partir do banco da Embrapa (*Aspergillus sp.*), para a produção de celulases e xilanases usando reatores trifásicos não convencionais, incluindo bagaço pré-tratado no meio.

c) Pré-tratamento físico-químico do bagaço: explosão a vapor, remoção da hemicelulose e deslignificação. Produção de substratos para rotas de produção de bioetanol via fermentação de hexoses.

d) Determinação das condições (sub-)ótimas para a produção de etanol a partir da celulose.

e) Avaliação da produção de etanol a partir da hemicelulose usando enzimas livres e imobilizadas.

OXYGEN TRANSFER IN AIRLIFT REACTOR WITH SUGARCANE BAGASSE SUSPENSIONS

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The high structural complexity of the cellulose implies in the use of a cellulolytic enzyme pool to degrade this carbohydrate. In this context, the filamentous fungus *Aspergillus niger* has been indicated as a promissory alternative to the *Trichoderma reesei* use to obtain the enzymatic complex to decompose cellulose (Kim *et* al., 1997). Aerated and stirred tank bioreactors are largely used in filamentous fungus submerged fermentation (SF). Recently, the importance of pneumatic bioreactors have increased in the biotechnology area, due to theirs higher oxygen transfer and lower shear stress, making them a good option in filamentous fungus fermentations (Kim *et al.*, 1997; Trager *et al.*, 1989). Other characteristics like the mechanical seal absence; lower cost and lower energy consumption when compared to conventional reactors make of the *airlift* a potential reactor for application in bioprocesses (Cerri, 2005). Then, the objective of this work was to study the oxygen transfer in *airlift* reactor, using *in natura* and exploded sugarcane bagasse in water, with different concentrations and sizes. The parameters evaluated were the overall volumetric mass transfer coefficient (k_La) and the global gas hold-up (ε_G).

In this study, *in natura* and exploded sugarcane bagasse were used as the solid phase, separated in two particle size ranges. *In natura* sugarcane bagasse was separated in the following average particle diameter (d_P) ranges: $0.21<d_P<0.425$ mm (smaller size) and $0.425<d_P<0.710$ mm (larger size). The exploded sugarcane bagasse particle size ranges were: $0.106<d_p<0.425$mm (smaller size) and $0.425<d_p<1.000$ mm (larger size). Distilled water was used as the liquid phase. Polypropylene glycol antifoam (water solution 30% v/v) was added when foam was observed. Experiments were performed at 32°C in a 2.0L internal-loop *airlift* reactor with temperature control system, dissolved oxygen analyser and data acquisition system.

A central composite design, as detailed in Rodrigues e Iemma (2005), was used to study the influence of the "solids loading" and "air flow rate" and to find the best operational conditions. **Table 1** shows "solids loading" and "air flow rate" real values, relative to the studied levels. Forty four experiments were performed using the combinations that follow: i) exploded bagasse, smaller size; ii) exploded bagasse, larger size; iii) *in natura* bagasse, smaller size e iv) *in natura* bagasse, larger size. The response variables chosen were k_La and ε_G. k_La was determined by the dynamic method (Chisti, 1989), considering the probe-delay response (Aiba *et al.*, 1973). ε_G was determined using the volume expansion technique, which consists in height visual measurements of the aerated and non-aerated systems. From the results, empirical polynomial models were fitted to the experimental data and then submitted to a statistical analysis to determine the meaningful terms, the model validity and to build the response surface. Statistical analysis were made using software Statistica 7.0 and applied to the four type and size bagasse combinations.

Figure 1 shows the k_La response surface relative to larger size *in natura* bagasse. A visual analysis allows to identify the optimum area for solids loading below 1% ($x_1<0$) and air flow rate above 32.1 L/min ($x_2>1$). In this operating conditions, airlift reactor reached k_La values of 0.08 s^{-1}, of the same magnitude order of that obtained with water under same operating conditions. Campesi (2007) obtained results of the same magnitude order utilizing air-water system in a 4.0 L stirred and aerated tank reactor, using a airflow rate of 4 L/min and speed stirrer of 1000 rpm. Thomasi (2009) obtained similar values in 5.0 L concentric-tube and split-cylinder airlift reactors using air-water system at 28°C. The operating conditions were 25 and 35 L/min, respectively.

Similarly, **Figure 2** shows the ε_G response surface relative to larger size *in natura* bagasse. The visual analysis confirms what was observed previously; the optimum region occurs for solids loading below 1% w/v and air flow rates above 32.1 L/min.

Concerning the suspensions containing the exploded bagasse, due to its low density, the analysis of the corresponding response surface plot showed that the particles load barely influenced the k_La values, which depended only of the air flow rate, as it occurs with liquids free of solids (data not shown).

Concluding, it is possible to operate the airlift reactor with sugarcane bagasse, maintaining higher oxygen transfer levels. *In natura* sugarcane bagasse with $0.425>d_p>0.710$ mm showed a good potential to be used as substrate in fermentation process with *Aspergillus niger* for cellulose production utilizing *airlift* reactors. The optimum operating conditions are: solids loading below 1% w/v and air flow rate above 32.1 L/min.

Table 1 – Real and coded values for solids loading and air flow rate factors.

Level / Factor	Solids loading (% $m_{SÓLID}/V_{SUSPENSION}$)	Air flow rate (L/min)
-1.41	0.013	15.0
-1.00	0.30	17.9
0.00	1.0	25.0
1.00	1.7	32.1
1.41	2.0	35.0

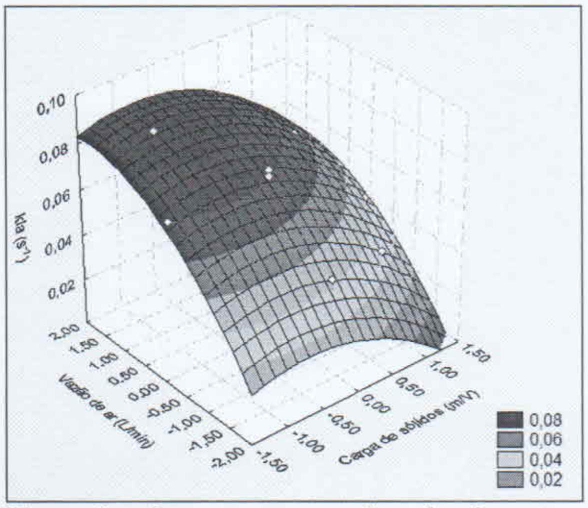

Figure 1 – k_La response surface for *in natura* bagasse ($0.425>d_p>0.710$ mm).

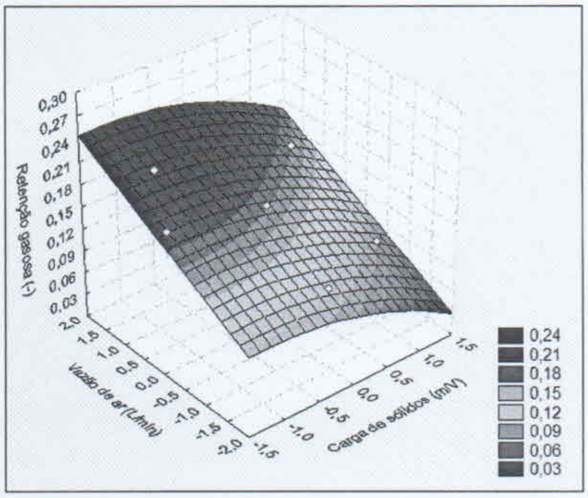

Figure 2 – ε_G response surface for *in natura* bagasse ($0.425>d_p>0.710$ mm).

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