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AN AIRLIFT FERMENTER FOR CONTINUOUS CULTURES AT ELEVATED PRESSURES

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Summary

For continuous cultures at elevated pressures an airlift fermenter (10 l) has been developed. It has been tested by cultivating the yeast Candida utilis at aerobic conditions. With higher pressure (from 1.5 bars to 7.0 bars absolute) the consumption of substrate per unit biomass is increased.

Introduction and experimental set-up

In industrial fermenters pressure may reach values distinctly higher than one atmosphere because of the increase of hydrostatic pressure with reactor height. This is especially true for high airlift fermenters used for single cell protein production. For example, the airlift fermenter of the ICI SCP process has a height of 65 m, which is equivalent to a hydrostatic pressure of 6.5 bars or 7.5 bars absolute (Hines, 1978).

In order to investigate the effect of increased pressure on microbial growth, we constructed a stainless steel airlift fermenter (Fig. 1). Its total volume is about 20 l, but it is operated with a liquid hold-up of about 10 l, to ensure efficient degassing and to prevent fermentation liquid from entering the off-gas line. For the same purpose the upper part of the fermenter is widened. It can be viewed by an inspection window. Aeration is performed via a porous plate (160 ... 250 μm) which is positioned at the lower end of the draught tube. With total fermenter height of 1.1 m and with length of draught tube of 0.72 m, the liquid level is kept at approx. 0.85 m. The outer tube (diameter 0.11 m) is fitted with a jacket for thermostating by heating or cooling. The diameter ratio for draught tube to outer tube is 0.67. For further details see Kiese (1982).

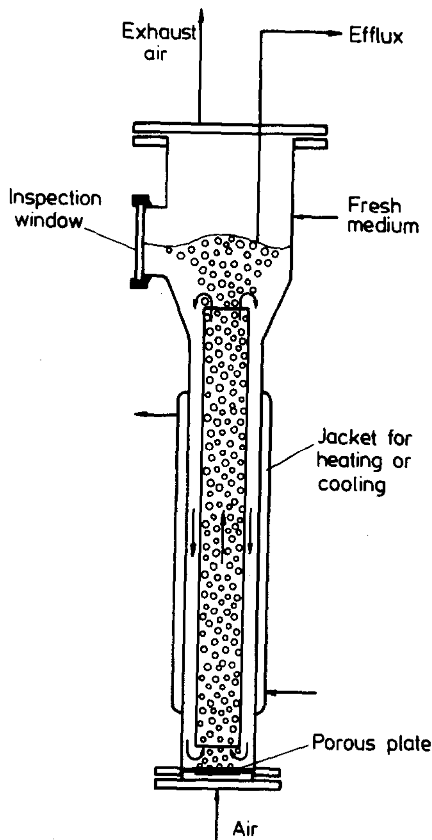

Fig. 1: Stainless steel airlift fermenter

Because preliminary experiments with batch cultures in pressurized shake bottles showed too much scatter in results to allow for clear identification of pressure effects on microbial growth and oxygen transfer, we decided to use the method of continuous fermentation for our investigation. For this purpose we built up the installation shown in Fig. 2. It is equipped with various control devices (for temperature, pressure, pH, defoaming) which ensure operation at sterile conditions for several weeks. Before start-up the whole set-up is sterilized by steam. Fresh medium to be fed into the fermenter is sterilized by pumping it continuously through a short time sterilizer (4.5 s at 150°C), before it enters the storage tank (Kiese, 1982).

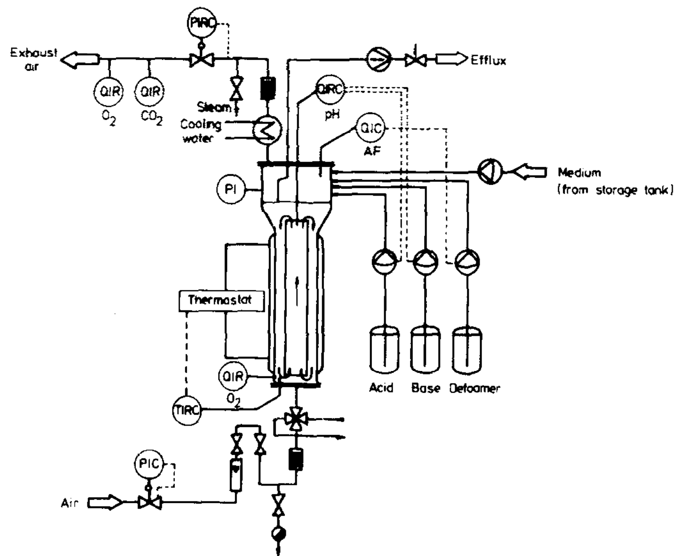

Fig. 2: Experimental set-up for continuous fermentation

Microorganism and medium

For the continuous fermentations we used the yeast Candida utilis (CBS 621). The synthetic medium consisted of inorganic components as suggested by Pirt (Pirt, 1975) and of the vitamines biotin and thiamin; besides, 0.2 g/l polypropyleneglycol (Fluka PPG 2000) were added as defoaming agent. As substrates saccharose and glycerol were used.

Results (Kiese, 1982)

a) Reactor behaviour of the fermenter

Liquid phase mixing in the fermenter was determined by measuring the time necessary for reaching a degree of inhomogeneity of less than 5% after adding a tracer (Onken and Weiland, 1983). At superficial gas velocities (related to draught tube cross section) of 2.5 resp. 5.0 cm/s, mixing times of 20 resp. 15 s were found. This means, compared to average residence times of at least 1 h for continuous fermentations, perfect mixing. This conclusion was confirmed by continuous flow experiments with pulsed tracer yielding the residence time distribution of an ideally mixed tank.

For measuring maximum oxygen transfer rates, glycerol was

used as substrate. As can be seen from Fig. 3, at increased pressure (from 1.5 to 7.0 bars) much higher oxygen transfer rates can be obtained. The reason is that because of the lower specific volume of the air at higher pressures, higher gas loads (mass flow of air per reactor volume) are possible.

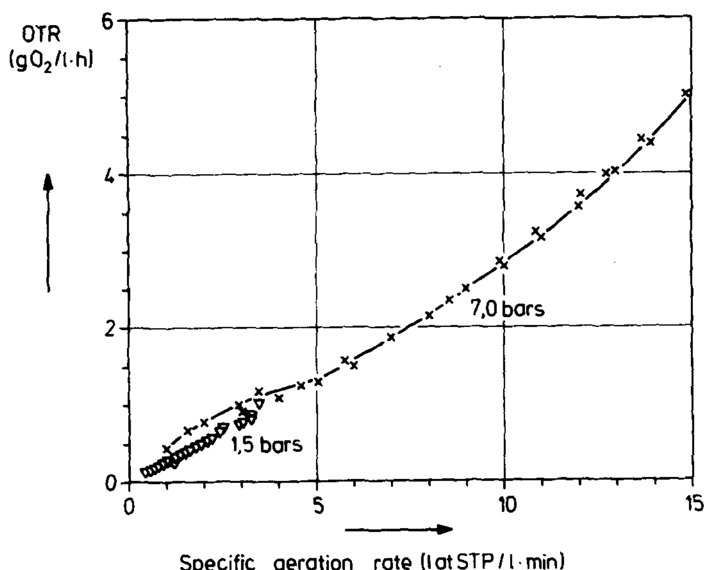

Fig. 3: Maximum oxygen transfer rate (OTR) for C. utilis on *glycerol* (100 g/l) in airlift fermenter. Temperature: 30 °C, pH: 4.0

b) Continuous fermentation of C. utilis

These experiments were performed with saccharose as substrate. We found, that the consumption of substrate per unit of dry cell mass increases markedly with pressure, as is evident from Fig. 4, where the reciprocal yield coefficient for saccharose is given versus reciprocal dilution rate. This result would mean that higher pressures are unfavourable for the utilization of the carbon source in the production of yeast. On the other hand, in aerobic biological effluent treatment higher pressures should lead to increased degradation of dissolved organics with higher production of CO_2 and to decreased formation of sludge. Therefore, the employment of rather high reactors for aerating should make biological effluent treatment more efficient. In fact, this is apparently done already (e.g. ICI deep shaft (Hines et al., 1975), Hoechst/Uhde (Leistner et al., 1979), Bayer Tower Biology (Zlokarnik, 1982).

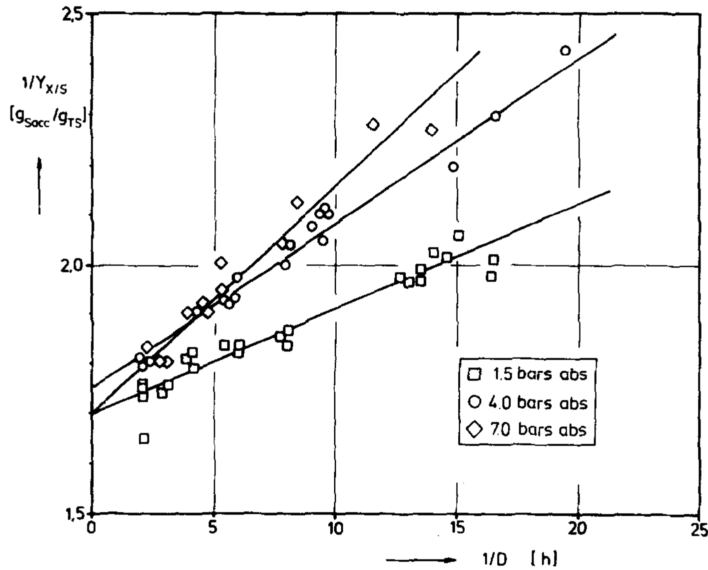

Fig. 4: Reciprocal yield coefficient (g saccharose consumed per g biomass) versus reciprocal dilution rate for C. utilis at different pressures; saccharose concentration in feed: 7 g/l, temperature: 30 °C, pH: 4.0

Another result of our experiments with C. utilis is shown in Table 1. The data for μ_{max} in the first column have been obtained by keeping the pressure constant during the full length of the wash-out experiment. At these conditions there is apparently no significant effect of pressure on μ_{max}. If however about 100 min. after starting the wash-out the pressure was changed (practically within three min.), μ_{max} showed a significant response, i.e. higher μ_{max} with pressure decrease and lower μ_{max} with pressure increase. This behaviour should be due to a hysteresis effect in cell metabolism, because after stopping the feed stream before total wash-out, μ_{max} appeared to come near again to the value of 0.50 h^{-1} which had been determined before the pressure shift. Since stopping the feed stream means operating in batch, these last data (batch cultures after wash-out) show a wider scatter ($\pm$ 0.04 h^{-1}).

Table 1: Effect of pressure shift during wash-out

Pressure	(bars)	7.0 →	1.5
μ_{max}	(1/h)	0.50 ($\pm$ 0.02)	0.60 ($\pm$ 0.02)
Pressure	(bars)	1.5 →	7.0
μ_{max}	(1/h)	0.50 ($\pm$ 0.02)	0.43 ($\pm$ 0.02)

Conclusion

Bench-scale airlift fermenters are well suited for studying cell growth in continuous cultures. Increased total pressure produces a decrease in biomass yield and an increase in formation of CO_2.

Acknowledgement

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