

The influence of non-Newtonian fluids in the hydrodynamic behaviour of an airlift reactor with an enlarged degassing zone

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Introduction

Since the mid-eighties increasing attention has been given to the airlift bioreactor. Besides single-cell protein production, now in decline, it has been used for processes as diverse as waste water biological treatment, antibiotics, animal and vegetable cell production [1], [2], [3], [4].

One of its most attractive characteristics is the fact that relatively low and constant shear stresses are generated in the liquid phase. This renders airlift reactors particularly adapted for sensitive cell cultures [5], [6], [7]. Other advantages are their simpler design (easier to build and less prone to contamination), their ease of operation and the need for smaller investments and lower maintenance costs [3], [8], [9].

The presence of an enlarged degassing zone in the top of an airlift reactor strongly affects its hydrodynamic performance [10], being e.g. extremely useful not only to enhance gas disengagement at the top but also to improve the settling of solids eventually present (e.g. as in high cell density systems). Studies have been made in such a reactor with Newtonian fluids and in the presence of a third (solid) phase [11, 12]. The present work deals with the hydrodynamic characterisation of a two-phase (air-liquid) airlift reactor with an enlarged degassing zone, in the presence of water and non-Newtonian (pseudo-plastic) fluids.

Materials and Methods

A 60 L capacity internal circulation airlift reactor with an enlarged degassing zone was used, in the presence of two phases: air / non-Newtonian fluids or water.

Experiments were made for several pseudo-plastic fluids (carboxymethyl-cellulose – CMC – aqueous solutions with several concentrations: 0.125 %, 0.250 % and 0.375 % in weight) and a Newtonian fluid (water), at several aeration rates (from 5 to 24 standard litres per minute – slpm).

The determination of mixing and circulation times was based on the salt pulse method, where a pulse of a saturated solution of NaCl was injected near the top of the internal tube of the reactor, measuring the alteration of the conductivity of the fluid by means of a conductivity cell connected to a data acquisition system.

The circulation velocities in the riser and downcomer tubes were measured using a solid flow follower. The density of the particle was adjusted to be equal to that of the circulating liquid phase.

The total gas hold-up was determined measuring the volume of the fluid displaced with each aeration rate.

Results and discussion

Figures 1 and 2 show the correlations obtained between the circulation velocity (v) and the aeration rate (G) for each CMC solution for the riser and downcomer sections, respectively. The correlations presented (in the form of $v = k.e^{(\alpha.G)}$) show that, in general, the values of k and α follow a regular trend. The former decreases with the increase in the CMC concentration, while for the latter increases with the increase in the CMC.

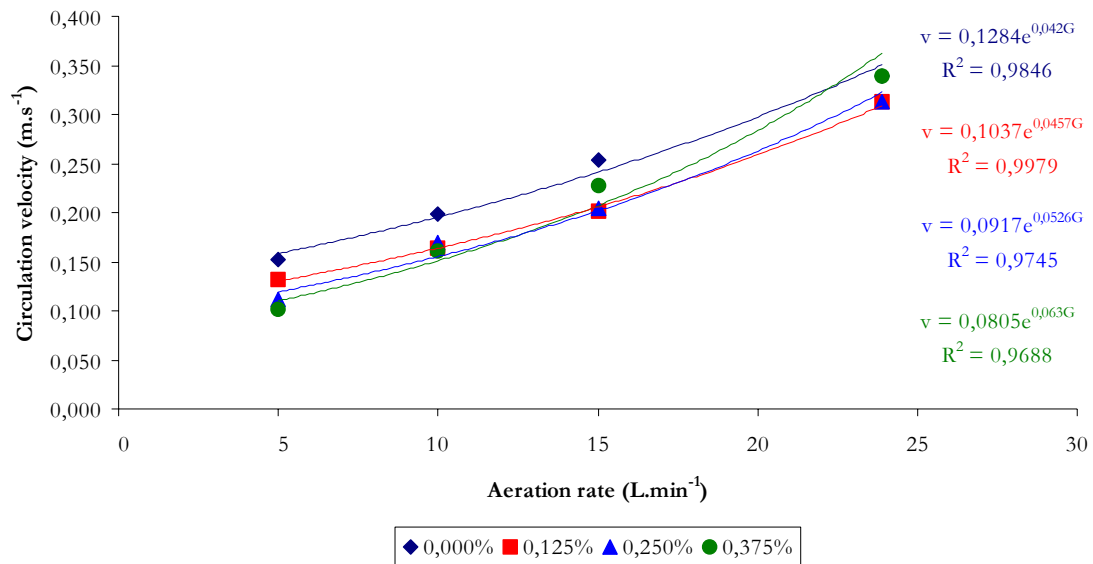


Figure 1: Circulation velocities, v ($m.s^{-1}$), versus aeration rate, G ($L.min^{-1}$), for the riser section and the correlation expressions obtained for water and each CMC solution (from top to bottom, corresponding to water and 0.125 %, 0.250 % and 0.375 % CMC solution).

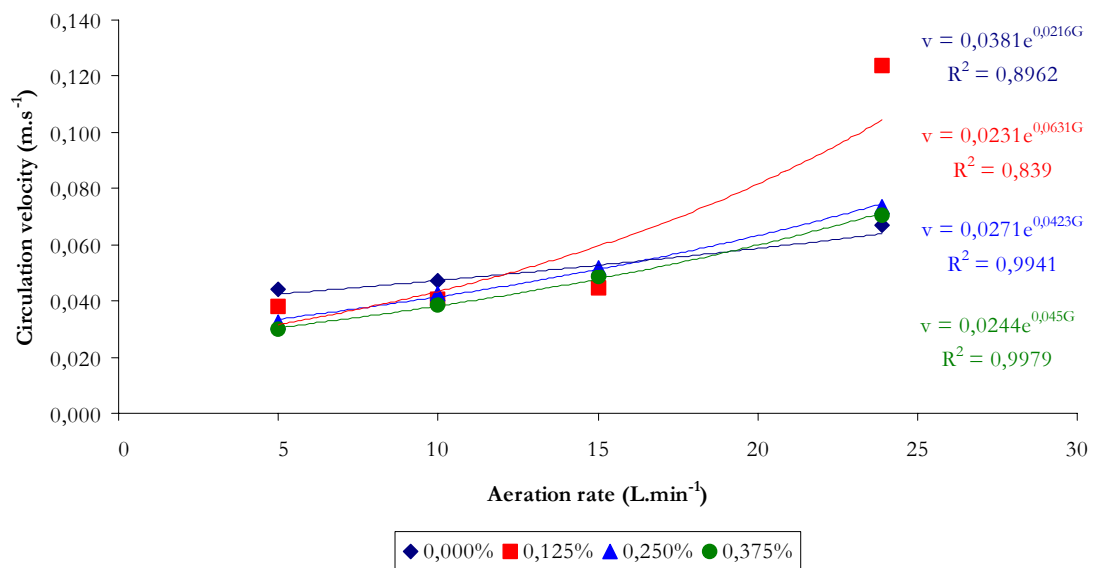


Figure 2: Circulation velocities, v ($m.s^{-1}$), versus aeration rate, G ($L.min^{-1}$), for the downcomer section and the correlation expressions obtained for water and for each CMC solution (from top to bottom, corresponding to water and 0.125 %, 0.250 % and 0.375 % CMC solution).

This means that there is an inverse relationship between liquid circulation velocity and liquid (apparent) viscosity (there is an increase of the apparent viscosity with the increase of CMC concentration – data not shown), k being the parameter reflecting that relationship. Further, there is a more than proportional increase of the circulation velocity with the increase of the aeration rate, becoming more significant as the viscosity of the solution increases (higher values of α). This can be caused by the bigger air bubbles formed in higher viscosity solutions: the gas holdup increases (see Figure 5), increasing the driving force that is responsible for the circulation inside the reactor.

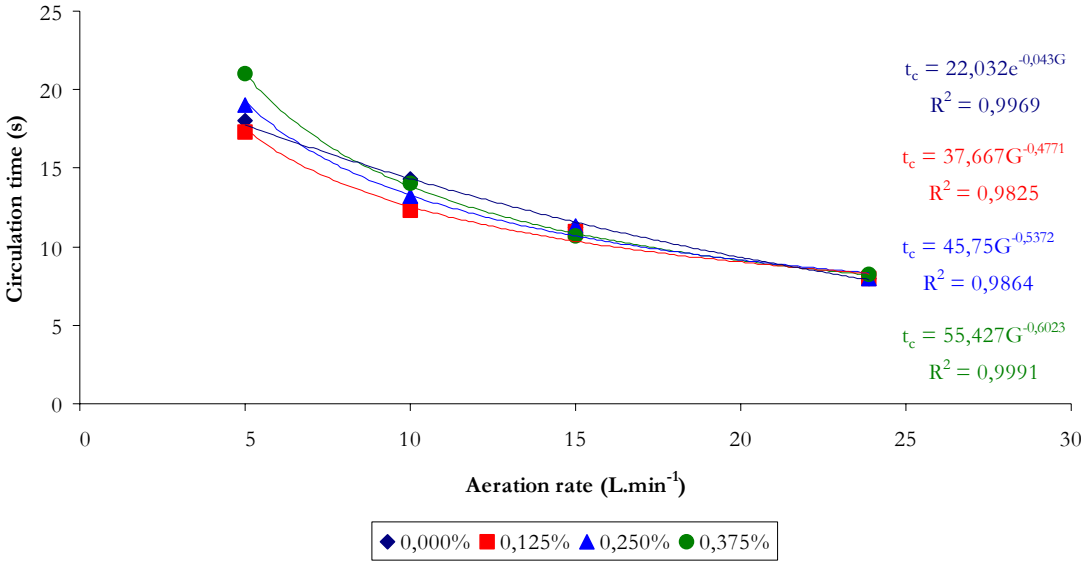


Figure 3: Circulation time, t_c , as a function of the aeration rate, G , for water and for each CMC solution. The correlations obtained are also presented (from top to bottom, corresponding to water and 0.125 %, 0.250 % and 0.375 % CMC solution).

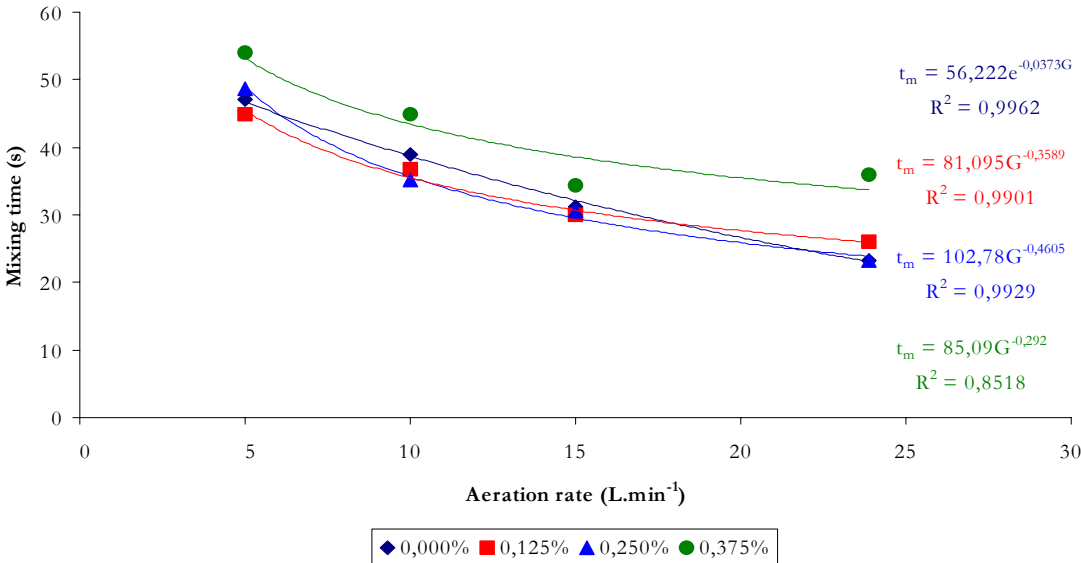


Figure 4: Mixing time, t_m , as a function of the aeration rate, G , for water and for each of the CMC solutions. The correlations obtained can also be seen (from top to bottom, corresponding to water and 0.125 %, 0.250 % and 0.375 % CMC solution).

Figure 3 shows that the circulation time decreases with the increase in the aeration rate for all of the CMC solutions used. The concentrations of the CMC solutions also play a role, though having a less significant effect: circulation time increases with the solution's concentration. It can also be observed that with the increase in the aeration rate the behaviour of the solutions approaches that of water, that is, of a Newtonian fluid. The variation of the circulation time with the aeration rate is not linear; in the case of water, however, the closeness to the linearity is noteworthy.

Mixing time shows the same trend of the circulation time, as displayed in Figure 4. For CMC solutions with a concentration of 0,275% or less, mixing time approaches that of water. The solution with a concentration of 0,375% CMC shows higher mixing times, which is in agreement with the solution's more marked non-Newtonian behaviour as compared to the other solutions used in this study.

The trends of mixing and circulation times were expected, given the results obtained for the circulation velocity, reflecting the dependence of the former parameters from the latter.

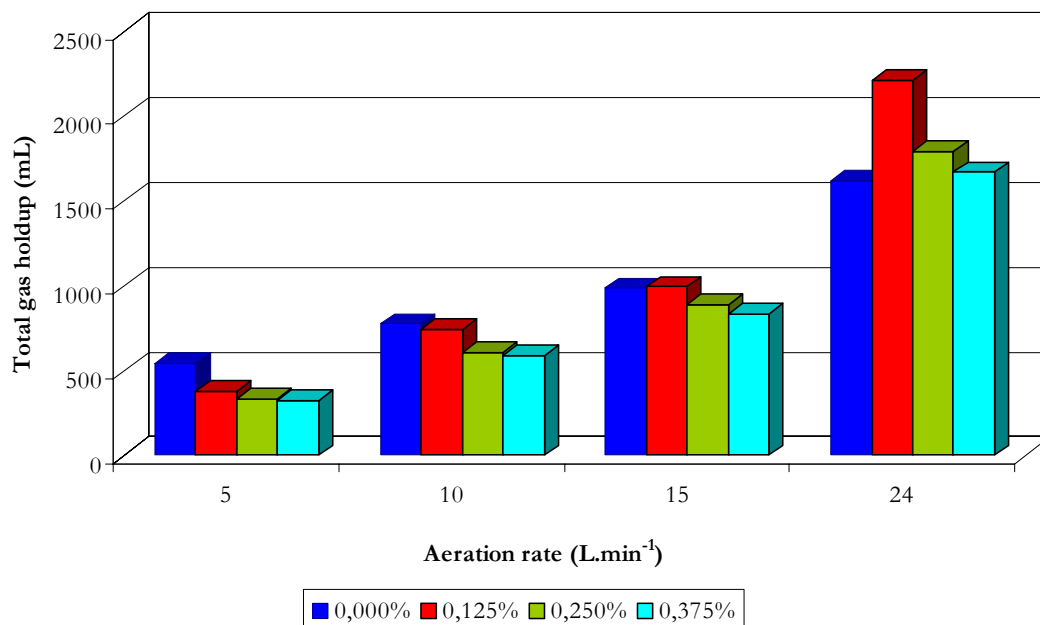


Figure 5: Total gas hold-up *versus* aeration rate, for the various CMC solutions.

Figure 5 shows that for all CMC solutions and for water the total gas hold-up increases with the increase of the aeration rate. That increase is greater for CMC solutions than for water due to the higher viscosity of the former. In fact, more viscous fluids make the air bubbles' disengagement more difficult at the top section, leading to a higher air recirculation into the downcomer and therefore increasing total gas hold-up. This effect is less pronounced for water owing to its lower viscosity.

From the results shown in Figure 5, it may also be observed that there is a decrease in the total gas hold-up with the increase of the CMC concentration for each aeration rate. This observation may be explained by the lower fluid velocity inside the reactor causing less air being dragged into the downcomer section, on one hand, and the formation of bigger bubbles (which have higher rising velocities) in the solutions having a higher CMC concentration, leading to a more efficient gas release in the top section, on the other hand.

In the present work correlations were obtained for the mixing and circulation times and for the circulation velocity in the riser and downcomer sections as a function of the aeration rate for the various fluids in study. Further, the influence of the aeration rate on the total gas hold-up was also determined.

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