Baker’s yeast filtration through mixed beds of filtration aids and large glass beads

Manuel Mota[*], **José A. Teixeira, Alexander Yelshin**
Centro de Eng. Biológica, University of Minho, Campus de Gualtar, 4710-057 Braga, Portugal

Keywords: Yeast, Cake filtration, Mixed bed, Filter aids, Regeneration
Topic: Engineering Sciences and Fundamentals.

Abstract

Filtration of baker´s yeast through a mixed particulate bed of filter aid and glass beads was investigated. Glass beads form the large size particle fraction in the mixture, whereas the small size particle fraction was made by the following filter aids: kieselgel, kieselguhr-G, and industrial kieselguhr of different grades. Investigated particle size ratio of beads and filter aids was in the range around 20 – 100. Obtained results show that the large size particles do not influence the cake filtration performance up to a volume fraction of large particles in the layer of 0.8 ÷ 0.85. Bench filtration through a composite layer was performed, being the mixed layer built by filtering a kieselguhr suspension through the glass beads packing formed on a support. Regeneration of the glass beads by fluidization allows its use as a non-disposal fraction of the filter bed. Obtained results clearly demonstrate that the amount of filter aid used is less than required in conventional processes, showing advantages in what concerns saving of filter aid and reduction of pollution levels. From the tested filter aids, the coarse grade kieselguhr proved to be the most adequate as it was the component that allowed for the higher initial filtration velocity in the large size particle volume fraction in the mixture of 0.82 – 0.85.

1 Introduction

Filtration for solid liquid separation is widely applied in biotechnology, brewing and food industry. In filtration processes, prevention of filter medium fouling is usually done by using a filter aid in the form of a precoat layer (Freeman et al. (1995); Rushton et al. (1996); Wolthuis and Dichiaria, 1997), the advantages being: the precoat with contaminants can be easily removed and a new layer may be build-up.

One of the demands concerning the use of filter aids is low cost with a high output, Yoon et al. (1992), Freeman et al. (1995), Freeman (1995). The smaller the particle size and the narrower the particle size distribution the higher the filter aid cost. In the precoat filtration, according to (Heidenreich and Tittel, 1983), the filter aid costs account for 50-80% of the total filtration expenditure. Often commercial filter aids are subject of an additional pre-treatment or particle re-fractionation with the purpose of improving their filtration properties, Freeman (1995).

Among the available powdered filter aids, kieselguhr has a wide application, Gautier (1984). The effectiveness of the recovery of this type of filter aid is small as it has a low settling velocity close to the settling velocity of the filtered solids, Brown (1974).

It has been previously shown that the introduction of coarse particles in the kieselguhr layer up to a volume fraction of 0.8 does not affect the quality of the filtrate of a yeast suspension, Mota et al. (1998). Therefore, the objective of this work is to analyse the effect of the addition of large size particles to kieselguhr on the performance of yeast filtration with the purpose of reducing the consumption of filter aids.

---

[*] Corresponding author. Tel + 351-253-601191. E-mail: MMota@reitoria.uminho.pt

2 Materials and Experimental Procedure

Glass beads were used as large particles added to kieselguhrs. The application of spherical particles as a model presents the following advantages: well-known shape and possibility of a more precise definition of the properties of the mixed layers.

Glass beads of *Potters-Ballotini, s. a.*, mean size D = $337.5\cdot10^{-6}$ m were used for the investigation of permeability and porosity of kieselguhr/glass beads mixtures at different fractional contents; glass beads with (1 – 1.25)$\cdot10^{-3}$ mm diameter (average $1.125\cdot10^{-3}$ m) were applied for the analysis of the composite filter layer behaviour in yeast filtration.

As filter aids the following ones were used: (1) kieselgel, *Merck*, which is a silica gel for thin layer chromatography, d = $14.48\cdot10^{-6}$ m, corresponding to D/d = 23.3; (2) kieselguhr-G, *Merck*, for thin layer chromatography, d = $12.33\cdot10^{-6}$ m (D/d = 27.4); and different grade kieselguhrs commercially used in the brewery industry (3) fine, d = $12.26\cdot10^{-6}$ m (D/d = 91), (4) middle, d = $11.64\cdot10^{-6}$ m (D/d = 96) and (5) coarse grade kieselguhr, d = $30\cdot10^{-6}$ m, (D/d = 37.5).

The shape of the kieselgel particles and some types of kieselguhr is shown in Fig. 1, as obtained by image treatment. All samples have plate and rod shaped forms being disc shaped particles observed in fine and middle grade kieselguhrs.

Kieselgel and kieselguhr particle size distributions were measured by Particle Size Analyses using the GALAI-CSI-100 with Computerised Inspection System. The particles size distributions are presented in the work Mota et al. (2003) as well as the values of mixed filter layer porosity ε and permeability k.

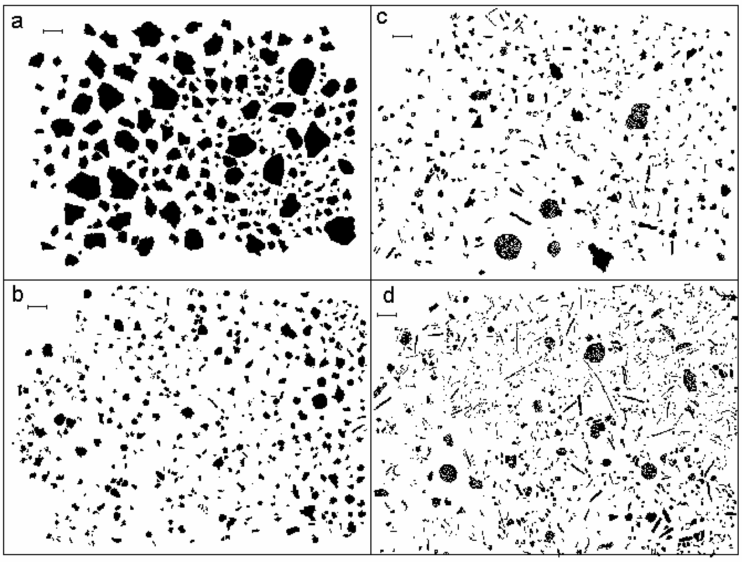


Figure 1. Particles shape as the mean projection area. (a) – Kieselgel; (b) – Kieselguhr-G; (c) – Kieselguhr of middle grade, and (d) – Kieselguhr of fine grade. Bar corresponds to 50 microns.

Yeast suspension was modelled by commercially available *Saccharomyces serevisiae* cells re-suspended in a NaCl isotonic solution. The yeast has a narrow size distribution (average cell size 5.8 microns) and a spheroid shape. Assayed yeast slurry concentrations were c = 1 and 6 g (dry weight) per litre of isotonic solution and were selected based on the operating range of yeast suspensions filtration in biotechnological processes (Arora and Davis (1993); Shimizu et al. (1993); Schluep and Widmer (1996); Park et al., 1997).

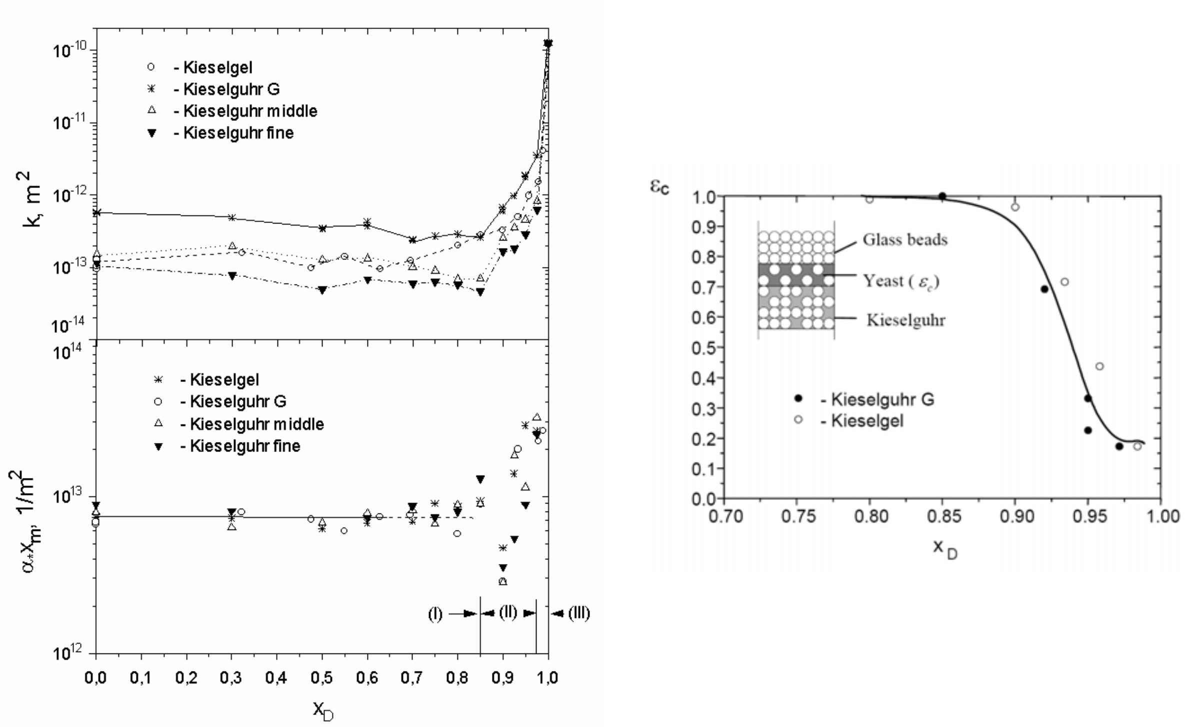
Yeast filtration was performed under a constant pressure of 80 kPa. With the obtained experimental data, the specific mass cake resistance α [m/kg] for yeast filtration was determined Rushton et al. (1996): $t/q = Aq + B$, where $A = \mu\cdot\alpha\cdot x_m/(2\Delta p)$; $B = \mu R_m/\Delta p$; R_m is the filter media resistance (supported filter-paper with binary mixed bed), 1/m; t is the filtration time, s; q is a specific filtrate volume per 1 m^2 of filtration area, m^3/m^2; α is the specific mass cake resistance, m/kg: x_m is the ratio of solid mass in the cake to the filtrate volume, kg/m^3. The mass of solid in the cake was calculated as the ratio of the mass of the dry cake (dried at 104°C) to the yeast density, Shimizu et al. (1993).

The characterization of the fouling potential of the suspension was done by the application of a Modified Fouling Index, $\alpha \cdot x_m$ (Rautenbach and Albrecht, 1989). As the slurry concentration is fixed, a constant value for $\alpha \cdot x_m$ confirms the occurrence of cake filtration.

3 Results and discussion

The first part of this work was made on binary mixtures of glass beads (D = 337.5·10^{-6} m) and filter aids - kieselgel, kieselguhr-G, fine and middle grade kieselguhrs - for comparison with the porosity and permeability data presented in Mota et al. (2003). Yeast slurry concentration was 6 g/l.

The effect of the glass beads fraction in the mixture x_D on the layer permeability and filtration parameters is shown in Fig. 2, making possible to conclude that the large size particles do not have a significant effect on the permeability of the mixed layer of glass and beads up to x_D ~ 0.8 – 0.85. For larger values of x_D, the permeability increases exponentially.



(a) (b)

Figure 2. (a). Dependence of the permeability k and $\alpha \cdot x_m$ on x_D. Three regions on the dependence of $\alpha \cdot x_m$ on x_D are identified: I – the region of cake filtration law; II – the intermediate filtration region; III – the region where layers segregation occurs due to the displacement of kieselguhr to the bottom of the mixed bed.

Fig. 2. (b). Dependence of the porosity of the yeast sediment ε_c in the void space of the mixed bed occupied by cells on x_D.

According to Mota et al. (2003), the minimum porosity of a mixed bed ε occurs in the region of x_D = 0.85 - 0.9, where the skeleton of large particles is built with a porosity close to the porosity of the monosized glass beads packing. Because of the large size ratio of glass beads and filter aid particles, there is enough space within the skeleton void to have fragments of porous medium with a structure similar to the pure filter aid packing.

The filtration performs as cake filtration up to x_D = 0.7 ÷ 0.75 as $\alpha \cdot x_m$ is constant for all types of mixtures. Although the total porosity decreases (Mota et al. (2003)), a slight increase in the average equivalent pore diameter $d_e = (2/3)d_{av}\varepsilon/(1-\varepsilon)$, where $1/d_{av} = x_D/D + (1-x_D)/d$, compensates the reduction in porosity. Then, up to x_D ~ 0.85, the permeability is kept constant as tortuosity and d_e increases are compensated by a decrease in ε, Mota et al. (2000).

When packing passes through the minimum porosity region towards higher values of x_D, zone II in Fig. 2a, the filter aid amount becomes insufficient to fill all the skeleton void and the filtration performance shifts to the intermediate filtration law. The initial filtration period performs as a gradual pores blocking process and part of the yeast deposits inside the upper part of the filter aid. The density $(1-\varepsilon_c)$, where ε_c is the yeast deposit porosity inside the layer, increases from zero (cake filtration and absence of the deposit inside filter aids pores) up to 0.8 (ε_c = 0.2), Fig. 2b.

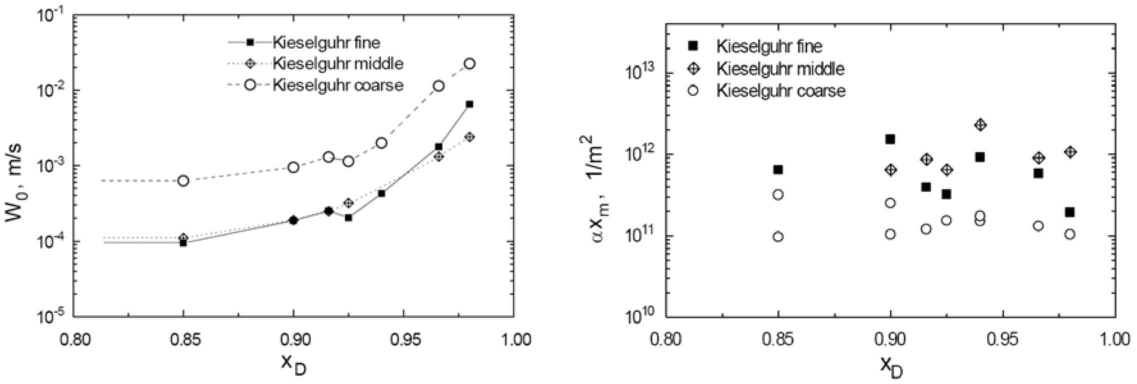
Yeast sediment porosity in zone (III), x_D > 0.9, is close to the cake porosity formed on a microfiltration membrane. Yeast cake porosity measurement on a *Gelman* microporous membrane with pore size 0.45 microns gave a value of 0.22, Mota et al. (2004). The filtration behaves as cake filtration with cake building inside the mixed bed on the border of filled by the filter aid and unfilled glass beads matrix.

Obtained results demonstrate that for filtration processes where a cake is built on a precoat, as is the case of cells separation, the introduction in the filter aid of a specific amount of large particles may reduce the process costs by decreasing the amount of used filter aid and by making easier the recycling of the particles (large) being used. This fact suggests that the less expensive kieselguhr (coarse grade kieselguhr with a wider particle size distribution) may present advantages when being used in the preparation of a composite bed. Therefore, in the second part of the work, the filtration properties of mixed beds formed by fine and middle grades kieselguhr and coarse grade kieselguhr were compared.

Glass beads with $1.25 \cdot 10^{-3}$ m diameter (average D = $1.125 \cdot 10^{-3}$ m) were used as the large size particle fraction in the composite filter layer, allowing for size ratios of D/d = 91.76, 96.6, and 37 for fine, middle and coarse grades, respectively. The yeast slurry concentration was chosen as c = 1 g/l (Schluep and Widmer, 1996; Park et al., 1997).

The composite filter layer was prepared into a cylindrical filter unit with a support formed by two wires and a cloth between them. The support does not create obstacles for yeast passage throughout and the filtrate quality depends on the mixed layer filterability only. As the regeneration procedure was based on the fluidisation of the layer, the glass beads, before the first filtration, were also fluidized using water. In all the experiments, the layer thickness was 4.2 – 4.5 cm. Kieselguhr was introduced into the glass beads layer by filtration of a 0.1% (mass percentage) kieselguhr suspension and the filtrate was re-circulated during binary mixed layer formation. Yeast concentration in the filtrate was measured by spectrophotometry. The same glass beads fraction was used in all the experiments and no beads damage or surface obliteration was observed. The region of minimum porosity was investigated.

Filtration performs as cake filtration up to x_D = 0.82 – 0.85. For x_D > 0.88 the kieselguhr fraction was not enough to fill all void space between glass particles. The initial flow velocity W_0 and parameter $\alpha \cdot x_m$ are presented in Fig. 3, being observed that the use of coarse grade kieselguhr allows for the highest initial filtration velocity, Fig. 3a, as well as it lowers the cake resistance, Fig. 3b.



(a) (b)

Figure 3. Dependence of W_0 (a) and $\alpha \cdot x_m$ (b) on x_D.

The filtrate quality up to x_D ~ 0.98 was characterised by the absence yeast cells in the filtrate for all types of kieselguhr. This clearly shows that the proposed method for filter medium preparation can be applied as kieselguhr saving process in the beverage industry.

4 Conclusion

Yeast cells filtration thorough mixed layers of glass beads and kieselguhr with a size particle ratio in the range 20 – 100 occurs as cake filtration up to a volume fraction of glass beads in the mixture of 0.85. The mixed layer is built by filtration of a kieselguhr suspension through the primary glass beads packing.

In the range of the glass beads volume fraction in the mixture of 0.82 – 0.85, the mixed layer is characterized by the complete filling of the glass beads void space by kieselguhr and may be recommended as the composite filter for yeast removal.

Coarse grade kieselguhr may form the basis for creating not expensive filters. Moreover, glass beads or other rigid large particles may act as a rigid skeleton preventing the compression of the compressible filter aids.

The regeneration of glass beads by fluidization allows its use as non-disposable fraction of the filter layer. The proposed method needs less kieselguhr (about 4 times) than usual, with evident advantages in terms of filter aid saving and reduction of pollution levels.

Acknowledgement

The authors wish to thank Fundação para a Ciência e Tecnologia (FCT) for having provided the funds to perform this work through the project POCTI/EQU/37500/2001, as well as for the grant accorded to A. Yelshin. This project was partially funded by FEDER.

References

Arora, N., Davis, R.H. (1993). Deadend microfiltration of bovine serum albumin suspension through yeast cake layers and asymmetric polymeric membranes. *Advances in Filtration and Separation Technology*, AFS, Kingwood (USA), 353-356.

Brown, J.G. (1974). Reusable precoat filtration. *Filtr. and Sep.*, 11, 505-508.

Freeman, G. J. (1995). Getting the best from your filters - filter optimisation. *Brewers´ Guardian*, May, 33-37.

Freeman, G. J., Mckechnie, M. T., Smedley, S. M., Hammond, R. V., et al. (1995). Determination and use of process characteristics for optimization of the beer filtration operation. *Trans. IChemE.*, 73, 157-164.

Gautier, B. (1984). *Aspects Pratiques de la Filtration des Vins*, Bourgogne-Publications, France.

Heidenreich, E., Tittel, R. (1983). Fortschritte bei der Auschwemmfilteration. *Österreichische Chemie-Zeitschrift*, 84, 339-347.

Mota, M., Teixeira, J.A., Bowen, R., Yelshin, A. (2000). Effect of tortuosity on transport properties of mixed granular beds. *Proceedings of 8-th World Filtration Congress, 3-7 April 2000*, Filtration Society, Brighton (UK), 57-60.

Mota, M., Teixeira, J. A., Yelshin, A. (2004). Dependence of *Saccharomyces cerevisiae* filtration through membrane on yeast concentration. *Proceedings of 9th World Filtration Congress, April 18 - 22, 2004*, Paper 125-2, AFS, Louisiana (USA), 1-20.

Mota, M., Teixeira, J.A., Yelshin, A. (1998). Tortuosity in bioseparations and its application to food processes. *Proceedings of 2nd European Symposium on Biochemical Engineering Science, Porto, 16-19 Sept. 1998*, Porto (Portugal), 93-98.

Mota, M., Teixeira, J.A., Yelshin, A., Bowen, W.R. (2003). Interfering of coarse particles with finest of different shape in cake model. *Minerals Engineering*, 16, 135-144.

Park, B.G., Lee, W.G., Chang, Y.K., Chang, H.N. (1997). Effects of periodic backflushing with filtrate on filtration performance in an internal-filtration bioreactor. *Bioprocess Eng.*, 16, 253-256.

Rautenbach, R., Albrecht, R. (1989). *Membrane Processes*, Wiley, UK.

Rushton, A., Ward, A.S., Holdich, R.G. (1996). *Solid-Liquid Filtration and Separation Technology*, VCH, Germany.

Schluep, T., Widmer, F. (1996). Initial transient effects during cross flow microfiltration of yeast suspensions. *Journal of Membrane Science*, 115, 133-145.

Shimizu, Y., Shimodera, K.-I., Watanabe, A. (1993). Cross-flow microfiltration of bacterial cells. *J. Fermentation and Bioengineering*, 76, 493-500.

Wolthuis, R., Dichiaria,V.C.F. (1997). Conventional filtration. *Handbook of Downstream Processing*, Blackie Academic and Professional, London, 20-47.

Yoon, S.-H., Murase, T., Iritani, E. (1992). Filtration with different kinds of diatomaceous precoating. *Int. Chem. Eng.*, 32, 172-180.