Bioprocess Engineering 19 (1998) 351–353 © Springer-Verlag 1998

Biosorption of heavy metals by distillery-derived biomass

M. Bustard, A.P. McHale

Abstract Biomass derived from the Old Bushmill's Distillery Co. Ltd., Northern Ireland was harvested and examined for its ability to function as a biosorbent for metals such as Cu, Zn, Fe, Pb and Ag. Binding studies were carried out using biosorption isotherm analysis. Although the material had previously been shown to be capable of efficient U biosorption, its affinity for Cu, Zn, Fe was lower. However, binding studies with Pb demonstrated that it had a maximum biosorption capacity for that metal of 189 mg/g dry weight of the biomass. In addition, the biomass exhibited a maximum biosorption capacity of 59 mg/g dry weight for Ag and this compared very favourably with previously quoted values for other industrial sources of *Saccharomyces cerevisiae.* On the basis of the biosorption isotherm analyses carried out in this study, preference for this series of metals by the biomass was found to be Pb > U > Ag > Zn ≥ Fe > Cu.

1 Introduction

It has been known for some time that microbial biomass is capable of binding heavy metals and radionuclides to varying degrees and it has been suggested that certain forms of biomass might find wide application in processes concerned with the bioremediation of heavy metal-bearing waste-water streams [1]. It has also been shown that both living and non-living sources of biomass exhibit this phenomenon although many more recent studies have been concerned with studying biosorptive processes exhibited by the latter [2, 3, 4]. Since commercial biotechnological processes such as brewing and distillation result in the production of large quantities of biomass and since this material is currently viewed as a low-value by-product, these industries represent an ideal source of non-living material for use as metal biosorbents. In addition, since metal biosorption by non-living biomass is a metabolism-independent process, constraints placed upon the biosorption process by metal-induced toxicities become irrelevant [5]. General acceptance of the above in addition to factors relating to public awareness and legislative pressures have led to a renewed interest in biosorptive processes based on the use of non-living microbial biomass.

Recently we have shown that non-living biomass derived from both the brewing and whiskey distillation industries is capable of removing uranium from solution, although the mechanisms of removal in both cases differ [6, 7]. In the case of biomass from the brewing industry, it would appear that removal of uranium from solution is dependant on both biosorption and precipitation [6]. In the case of removal of uranium from solution by distillery-derived biomass, direct interaction between the biosorbent and the uranium (true biosorption) appears to be responsible [7]. It has been demonstrated that other forms of *Saccharomyces* biomass are also capable of biosorption of heavy metals such as Co, Cd [8], Cu, Ni and Mn [9] and indeed it has been found that a commercial source of that microorganism is capable of more efficient Sr uptake than the corresponding laboratory strain [10].

Since our results relating to U uptake by distillery-derived biomass were very positive and since it had shown that industrial strains of *Saccharomyces cerevisiae* accumulated various metal species, it was of interest to determine whether or not the former might serve as a general biosorptive agent [7]. Here we have studied biosorption of Ag, Pb, Zn, Fe and Cu by distillery-derived biomass and suggest that this material might find application in bioremediative processes concerned with the removal of heavy metals from waste-water streams.

2 Materials and methods

2.1 Preparation of distillery-derived biomass

Whiskey distillery spent wash was obtained from the Old Bushmill's Distillery Co. Ltd., Bushmills, Co. Antrim, Northern Ireland. The residual solid material (3–5% [w/v] dry weight) was recovered and washed with distilled water by centrifugation as described previously [7]. The resulting pellets were lyophilized and the dried material was stored at −20 °C.

Received: 27 October 1997

M. Bustard, A.P. McHale
Biotechnology Research Group,
School of Applied Biological and Chemical Sciences,
University of Ulster, Coleraine, Co.
Londonderry, BT52 1SA, Northern Ireland
e-mail: ap.mchale@ulst.ac.uk

Correspondence to: A.P. McHale

M.B. was funded under the CAST (Cooperative Award in Science and Technology) which was administered by the Dept. of Education, Northern Ireland.

2.2
Biosorption assays

Assays were carried out by placing biomass (final conc. = 1 g biomass dry weight/l) in contact with solutions of $FeSO_4$, $CuSO_4$ and $ZnSO_4$ at concentrations ranging from 0–200 mg/l. In the case of Pb and Ag the nitrate salts were employed at similar concentrations. The biomass was placed in contact with each solution for 2 h and subsequently removed by either centrifugation or filtration through 0.2 μm filtration units. The residual concentration of each metal was determined using a Schimadzu 6701 Flame Emission Atomic Absorption Spectrophotometer. Metal uptake (q, mg metal/g dry weight biomass) was determined as described previously [11].

3
Results and discussion

Spent wash is the liquid remaining following recovery of ethanol by distillation in the production of whiskey and the effluent from the Old Bushmill's Distillery Co. Ltd., contains approximately 3–5% (w/v) suspended solids. This residual biomass in the spent wash is subjected to the rather harsh conditions during the distillation process and its value to the industry is very limited. Suggested treatments for the spent wash include its concentration by evaporation and subsequent use as an animal feed additive [12]. Although the biomass is treated in a harsh manner during distillation, direct microscopic examination of that biomass indicated that the cell walls remained relatively intact [13]. It has previously been demonstrated that microbial cell wall structures play an important role in the biosorption of U by non-living microbial biomass [1]. Since these cell walls remain relatively intact in the material from the distillery and since other forms of non-living biomass derived from industry have been used as biosorbents, it was originally decided to examine the possibility of using the distillery-derived residual biomass for U biosorption experiments [7, 13]. The studies demonstrated that the distillery-derived biomass functioned as an efficient biosorbent for U and on this basis it was suggested that this material might by applied to processes concerned with bioremediation of metal-bearing wastewater streams.

In order to confirm the latter it was decided to examine the biosorption characteristics of the distillery-derived biomass for metals such as Ag, Pb, Zn, Cu and Fe. Initially, Zn, Cu and Fe were chosen as sorbates and biosorption isotherm analysis of results obtained from biosorption contact reactions was carried out. The results are shown in Fig. 1 and they show that, of the three metals examined, Cu was taken up least effectively by the biomass. It was interesting to note that in all three cases the maximum biosorption capacities were relatively low with values of 16.8, 16.89 and 5.7 mg/g dry weight biomass for Fe, Zn and Cu, respectively. It has previously been found that other forms of *Saccharomyces* biomass exhibited biosorption capacities ranging from 17–40 mg/g biomass for Cu and 14–40 mg/g biomass for Zn [14] and in comparative terms the values reported here for biosorption maxima using the distillery-derived biomass for both Cu and Zn are relatively low. However, since the distillery-derived biomass is considered a waste or low-value product, its use as a biosorbent for these metals, even with relatively low maximum biosorption capacities, may be positively indicated in economic terms. It was interesting to note that the maximum biosorption capacity for Fe was relatively low and yet it had relatively potent inhibitory effects on U biosorption as reported in one of our earlier studies [7]. This phenomenon is currently under investigation in our laboratories.

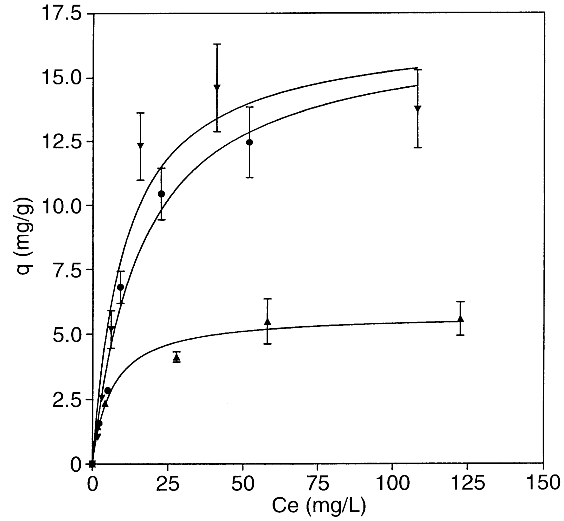

Fig. 1. Biosorption of Cu (▲), Fe (▼) and Zn (●) by distillery-derived biomass. Reactions were incubated at room temperature for 2 h and the residual concentration (Ce) of each metal was determined following removal of the biomass. q = the amount of metal bound per g of biomass

In addition to examining the biomass for its ability to function as a biosorbent for the above described metals it was also decided to use Ag and Pb as sorbates in contact reactions. Again, biosorption isotherm analysis of the results was carried out and the profiles are shown in Fig. 2. It was found that the distillery-derived material had a rela-

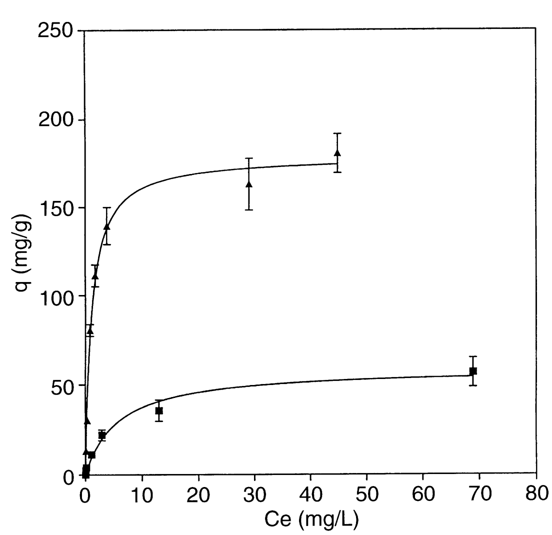

Fig. 2. Biosorption of Ag (■) and Pb (▲) by distillery-derived biomass. Reaction conditions were as described for Fig. 1

tively high biosorption capacity for Pb with a maximum biosorption capacity of 189 mg/g dry weight biomass. This was higher than previously reported values for U (180 g/g biomass) using this form of biomass. It also compares very favourably with reported values for Pb using other forms of *Saccharomyces* biomass (48 mg/g biomass) although it should be stated that the latter had been treated with acetone [15]. In a more recent study from our laboratory it was found that yeast biomass from a local brewery was capable of removing Pb from solution and had an apparent maximum biosorption capacity of 129 mg/g biomass [16]. It should be noted however that this was shown to result from a combination of true biosorption and precipitation and as such comparisons on the basis of biosorption are not entirely valid.

In this study, the biosorptive capacity of the distillery-derived biomass for Ag was also examined and the results obtained using biosorption isotherm analysis are shown in Fig. 2. It was found that the biomass had a maximum biosorption capacity for Ag of 58.7 mg/g dry weight biomass. This compared very favourably with previously reported values of 41 mg/g biomass for laboratory-grown preparations of industrial strains of *S. cerevisiae* [17]. It also compares very favourably with values obtained in our laboratory using residual biomass from a local brewery (unpublished results). The biosorptive capacity of distillery-derived biomass for Ag and the other metals described above demonstrates its potential, not only in detoxification of waste-water streams, but also in the recovery of precious metals which might occur in mining leachates.

References

1. **Gad, G.M.:** Fungi and yeasts for metal accumulation. In: Microbial Mineral Recovery. Eds. Ehrlich, H.L. and Brierly, C.L. McGraw-Hill Inc. U.S.A. 249–275
2. **McHale, A.P.; McHale, S.:** Microbial biosorption of metals: Potential in treatment of metal pollution. Biotech. Adv. 12 (1994) 647–652
3. **Donnellan, N.; Rollan, A.; McHale, L.; McHale, A.P.:** The effect of electric field stimulation on the biosorption of uranium by non-living biomass derived from *Kluyveromyces marxianus* IMB3. Biotech. Letts. 17 (1995) 439–442
4. **Omar, N.B.; Merroun, M.L.; Gonzalez-Munoz, M.T.; Arias, J.M.:** Brewery yeast as a biosorbent for uranium. J. Appl. Bacteriol. 81 (1996) 283–287. Biotech. Letts. 18 (1996) 479–482
5. **Gadd, G.M.; White, C.:** Microbial treatment of metal pollution – a working biotechnology? Trends in Biotechnol. 11 (1993) 353–359
6. **Riordan, C.; Bustard, M.; Putt, R.; McHale, A.P.:** Removal of uranium from solution using residual brewery yeast: combined biosorption and precipitation. Biotechnol. Letts. 19 (1997) 385–387
7. **Bustard, M.; Higgins, D.; McHardy, F.; McKerr, G.; McHale, A.P.:** Biosorption of uranium by residual biomass from distillery spent wash. Elsevier Scientific Publications. (1997) In Press
8. **Norris, P.R.; Kelly, D.P.:** Accumulation of cadmium and cobalt by *Saccharomyces cerevisiae*. J. Gen. Microbiol. 137 (1977) 317–324
9. **Norris, P.R.; Kelly, D.P.:** Accumulation of metals by bacteria and yeasts. Dev. Indust. Microbiol. 20 (1979) 299–308
10. **Avery, S.V.; Tobin, J.M.:** Mechanisms of strontium uptake by laboratory and brewing strains of *Saccharomyces cerevisiae*. Appl. Env. Microbiol. 58 (1992) 3883–3889
11. **Holan, Z.R.; Volesky, B.; Prasetyo, I.:** Biosorption of cadmium bybiomass of marine algae. Biotechnol. Bioeng. 41 (1993) 819–825
12. **Alsaker, J.:** By-Products. In: The Science and Technology of Whiskies. [Eds. Piggott, J.R.; Sharp, R.; Duncan, R.E.B.]. J. Wiley & Sons, Inc. New York. (1989) 360–394
13. **Bustard, M.; McHale, A.P.:** Biosorption of uranium by cross-linked and alginate immobilized residual biomass from distillery spent wash. Bioprocess Eng. 17 (1997) 127–130
14. **Volesky, B.; May-Phillips, H.A.:** Biosorption of heavy metals by *Saccharomyces cerevisiae.* Appl. Microbiol. Biotechnol. 42 (1995) 797–806
15. **Ashkenazy, R.; Gottlieb, L.; Yannai, S.:** Characterization of acetone-washed yeast biomass functional groups involved in lead biosorption. Biotechnol. Bioeng. 55 (1997) 1–10
16. **Riordan, C.; McHale, A.P.:** Removal of lead from solution using non-living residual brewery yeast. Bioprocess Eng. In Press
17. **Simmons, P.; Singleton, I.:** A method to increase silver biosorption by an industrial strain of *Saccharomyces cerevisiae.* Appl. Microbiol. Biotechnol. 45 (1996) 278–285