10.542 – Biochemical Engineering
Spring 2005

Problem Set #4
Solutions should be written and submitted on your own paper. All pages should be stapled together.

1) Shuler & Kargi, Problem 6.14

2) Shuler & Kargi, Problem 7.6

3) The following data were obtained for the growth of a strain *Lactobacillus* with glucose as growth-limiting nutrient in the presence of excess nitrogen, and for growth with nitrogen as limiting nutrient in the presence of excess glucose.

Glucose Limitation	**Experiment A**		**Experiment B**		**Experiment C**	
Time (hr)	Cell conc. (g/L)	Glucose (g/L)	Cell conc. (g/L)	Glucose (g/L)	Cell conc. (g/L)	Glucose (g/L)
0	0.100	0.250	0.100	1.000	0.100	5.000
0.5	0.106	0.225	0.110	0.958	0.113	4.950
1.5	0.113	0.200	0.122	0.912	0.127	4.893
2.0	0.119	0.175	0.134	0.862	0.143	4.829
2.5	0.125	0.151	0.148	0.800	0.161	4.757
3.0	0.131	0.128	0.163	0.750	0.181	4.676
3.5	0.136	0.106	0.178	0.686	0.204	4.584
4.0	0.141	0.088	0.195	0.619	0.230	4.482
4.5	0.145	0.071	0.213	0.547	0.258	4.366
5.0	0.149	0.056	0.232	0.474	0.291	4.237

Nitrogen Limitation	**Experiment D**		**Experiment E**		**Experiment F**	
Time (hr)	Cell conc. (g/L)	Nitrogen (g/L)	Cell conc. (g/L)	Nitrogen (g/L)	Cell conc. (g/L)	Nitrogen (g/L)
0	0.300	0.500	0.500	1.000	0.500	5.000
0.5	0.307	0.485	0.516	0.964	0.526	4.942
1.5	0.313	0.470	0.533	0.927	0.554	4.880
2.0	0.320	0.455	0.550	0.890	0.583	4.816
2.5	0.327	0.441	0.567	0.852	0.613	4.748
3.0	0.333	0.426	0.584	0.814	0.645	4.677
3.5	0.340	0.411	0.601	0.776	0.679	4.602
4.0	0.347	0.396	0.618	0.738	0.714	4.524
4.5	0.353	0.381	0.635	0.699	0.751	4.442
5.0	0.360	0.367	0.653	0.661	0.790	4.356

(i) Determine the values of μ_{max}, the yield coefficient ($Y_{X/S}$) and K_s for each substrate.

(over)

(ii) Using Eq (3.43) from the Blanch & Clark handout - Blanch, Harvey W., and D. S. Clark, eds. *Biochemical Engineering*. New York, NY: Marcel Dekker Incorporated, 1997. ISBN: 0824700996. write mass balances for cell mass and each substrate in a batch reactor. Note that the uptake rates of each substrate contains only one of the terms in Eq (3.43e).

4) Anaerobic digestion is the degradation of complex organic matter to gaseous products, CO2 and CH4. Although the complete process involves complex interacting microbial species, the majority of methane formed in an anaerobic digestion is produced by acetate-utilizing methanogens. Yang and Okos (S.T. Yang and M.R. Okos, paper No. 39d presented at the AIChE 1984 Annual Meeting) have studied the kinetics of methanogenesis from acetate for *Methanococcus mazei* and *Methanosarcina barkeri* in batch culture. Significant substrate inhibition was observed for both methanogens grown on acetate. Rate constants estimated from growth data are given below –

Strain	μ_{max} **(h^{-1})**	K_s **(g acetate/L)**	K_i **(g acetate/L)**
M. mazei S6	0.029	1.0	48.7
M. barkeri MS	0.63	100	0.46

Using these data, calculate for each methanogen the optimal acetate concentration and the maximum observable specific growth rate.