UNIVERSITI SAINS MALAYSIA

Second Semester Examination
Academic Session 2007/2008

April 2008

EKC 471 – Biochemical Engineering
[Kejuruteraan Biokimia]

Duration : 3 hours
[Masa : 3 jam]

Please check that this examination paper consists of EIGHT pages of printed material before you begin the examination.

[Sila pastikan bahawa kertas peperiksaan ini mengandungi LAPAN muka surat yang bercetak sebelum anda memulakan peperiksaan ini.]

Instructions: Answer **FOUR** (4) questions. Answer **TWO** (2) questions from Section A. Answer **TWO** (2) questions from Section B

*[**Arahan:** Jawab **EMPAT** (4) soalan. Jawab **DUA** (2) soalan dari Bahagian A. Jawab **DUA** (2) soalan dari Bahagian B.]*

You may answer your questions either in Bahasa Malaysia or in English.

[Anda dibenarkan menjawab soalan sama ada dalam Bahasa Malaysia atau Bahasa Inggeris.]

<u>Section A</u> : Answer <u>ALL</u> questions.
<u>Bahagian A</u> : Jawab <u>SEMUA</u> soalan.

1. [a] State the differences between plant cells and microbes, and their implications for bioreactor design.

Jelaskan perbezaan di antara sel-sel tumbuhan dan mikrobial, dan implikasinya untuk rekabentuk bioreaktor.

[8 marks/markah]

[b] During the batch sterilization of palm oil mill effluent based-media, normally carried out at 121°C for 10 min, the control system showed a malfunction when the temperature reached 116°C. Due to the malfunction, the temperature remained at 116°C for 15 min before the fault was rectified. What new holding time at 121°C will be required to ensure that the design criterion ∇ is maintained for this batch?

Selalunya semasa pensterilan kelompok media efluen kelapa sawit yang di jalankan pada 121°C selama 10 min, sistem pengawalannya menunjukkan pincang tugas apabila suhunya mencecah 116°C. Disebabkan pincang tugas, suhunya akan tetap pada 116°C selama 15 min sebelum kerosakan dikesan. Apakah masa menahan pada 121°C yang diperlukan untuk memastikan yang kriteria rekabentuknya ∇ dikekalkan bagi kelompok ini?

[5 marks/markah]

[c] Glucose is converted to hyaluronic acid by immobilized *S. zooepidemicus* cells entrapped in Ca-alginate beads in a packed column. The specific rate of hyaluronic acid production is $q_P = 0.2$ g hyaluronic acid/(g cell.h). The average dry weight concentration in the bed is $X = 25$ g/L bed. Assume that growth is negligible (that is, almost all glucose is converted to hyaluronic acid), and the bead size is sufficiently small that $\eta \cong 1$. The feed flow rate is F = 400 L/h, and glucose concentration in the feed is $S_{oi} = 100$ g glucose/L. The diameter of the column is 1 m, and the product yield coefficient is $Y_{P/S} \approx 0.49$ g hyaluronic acid/g glucose.

Glukosa ditukar ke asid hyaluronik oleh sel sekat gerak S. zooepidemicus yang terjerat di dalam manik-manik Ca-alginat di dalam turus terpadat. Kadar pengeluaran spesifik bagi asid hyaluronik ialah $q_P = 0.2$ g asid hyaluronik/ (g sel.jam). Purata kepekatan berat kering di dalam lapisan ialah $X = 25$ g/L lapisan. Andaikan pertumbuhan diabaikan (iaitu, hampir kesemua glukosa ditukar ke asid hyaluronik), dan saiz manik adalah kecil dan $\eta \cong 1$. Kadar aliran masuk ialah $F = 400$ L/h, dan kepekatan glukosa di dalam aliran ialah $S_{oi} = 100$ g glukosa/L. Garis pusat turus ialah 1 m, dan pekali hasil produk ialah $Y_{P/S} \approx 0.49$ g asid hyaluronik/g glukosa.

[i] Write a material balance on the glucose concentration over a differential height of the column and integrate it to determine $S = S(z)$ at steady state.

Tuliskan imbangan bahan bagi kepekatan glukosa pada ketinggian lurus dan kamirkannya untuk menentukan $S = S(z)$ pada keadaan mantap.

[ii] Determine the column height for 98 % glucose conversion at the exit of the column.
Tentukan ketinggian turus bagi 98 % pertukaran glukosa di bahagian keluar turus.

[iii] Determine the hyaluronic acid concentration in the effluent.
Tentukan kepekatan asid hyaluronik di dalam efluen.

[12 marks/markah]

2. [a] With an aid of a diagram, describe the different phases which a bacteria will undergo during its growth.
Dengan berbantukan gambarajah, perihalkan perubahan fasa semasa proses pembiakan bakteria.

[6 marks/markah]

[b] The growth of baker's yeast (*Saccharomyces cerevisiae*) can be carried out in two ways, either aerobic or anaerobic. The two overall reactions for both conditions are given below:
Pembiakan yis baker's (Saccharomyces cerevisiae) boleh dilakukan dengan dua cara, sama ada secara berudara atau tanpa udara. Dua persamaan tindakbalas bagi setiap keadaan diberi di bawah:

Aerobic growth:
Pembiakan secara berudara:

$$C_6H_5COOH + aO_2 + bNH_3 \longrightarrow cC_5H_7NO_2 + dH_2O + eCO_2$$

Anaerobic growth:
Pembiakan secara tanpa udara:

$$C_6H_{12}O_6 + \beta NH_3 \longrightarrow 0.59CH_{1.74}N_{0.2}O_{0.45} + 0.43C_3H_8O_3 + 1.54CO_2 + 1.3C_2H_5OH + 0.036H_2O$$

Determine for the aerobic growth:
Tentukan bagi pembiakan secara berudara:

[i] the coefficients a, b, c, d and e, given that the respiratory quotient RQ is 0.9.
pekali-pekali a, b, c, d dan e, diberi bahawa pembahagi pernafasan RQ adalah 0.9.

[10 marks/markah]

[ii] the biomass yield coefficient, $Y_{X/S}^{Aerobic}$ and the oxygen yield coefficient, $Y_{X/O}^{Aerobic}$.
pekali penghasilan biomas, $Y_{X/S}^{Berudara}$ *dan pekali penghasilan oksigen,* $Y_{X/O}^{Berudara}$.

[4 marks/markah]

For the anaerobic growth condition of yeast, determine the yield coefficient, $Y_{X/S}^{Anaerobic}$ and the coefficient, β.
Untuk keadaan pembiakan secara aerobik bagi yis, tentukan pekali penghasilan, $Y_{X/S}^{Tanpa\ udara}$ *dan juga pekali,* β.

[5 marks/markah]

Section B : Answer any TWO questions.
Bahagian B : Jawab mana-mana DUA soalan.

3. [a] Write short notes on the following:
Tuliskan nota ringkas mengenai perkara-perkara berikut:

[i] Effects of sterilization on mixing in a batch bioreactor.
Kesan pensterilan ke atas percampuran bioreaktor kelompok.

[ii] Traditional stirred tank bioreactor is more flexible and can better handle broths that become highly viscous compared to bubble column systems.
Bioreaktor tangki teraduk tradisional adalah lebih boleh suai dan boleh mengendalikan sup yang sangat pekat berbanding dengan sistem turus gelembung.

[12 marks/markah]

[b] 10,000 L of glucose-based medium is sterilized in a bioreactor at a temperature of 120 °C. The time/temperature profile of sterilizing process, from 100 °C is given in Table Q.2. [b].
10,000 L media berglukosa disterilkan di dalam bioreaktor pada suhu 120 °C. Profil masa/suhu bagi proses pensterilan dari 100 °C ditunjukkan di dalam Jadual S.2. [b].

Table Q.2. [b]
Jadual S.2.,[b]

Temperature (°C) *Suhu (°C)*	Time (min) *Masa (min)*	k k
100	54	0.0143
105	61	0.0477
110	69	0.1540
115	79	0.4830
120	91	1.4700
120	101	1.4700
115	104	0.4830
110	107	0.1540
100	114	0.0143

Assume that the contaminating species is *Streptococcus zooepidemicus.*
Andaikan spesis tercemar ialah 'Streptococcus zooepidemicus'.

[i] Calculate the design criterion ∇ for the process
Kirakan kriteria rekabentuk ∇ bagi proses ini

[ii] What will be the destruction ratio N_o/N ?
Apakah nisbah kemusnahan N_o/N ?

[13 marks/markah]

4. [a] A fluidized bed immobilized cell bioreactor is used for the conversion of glucose to ethanol by *Z. mobilis* cells immobilized in *k*-carageenan gel beads. The dimensions of the bed are 10 cm (diameter) by 200 cm. Since the reactor is fed from the bottom of the column and because of CO_2 gas evolution, substrate and cell concentrations decrease with the height of the column. The average cell concentration at the bottom of the column is X_o= 45 g/L, and the average cell concentration decreases with the column height according to the following equation:

Bioreaktor sekat gerak lapisan terbendalir digunakan untuk penukaran glukosa ke etanol oleh sel 'Z. mobilis' yang disekat gerak di dalam manik-manik 'k-carageenan'. Garis pusat lapisan ialah 10 sm dan 200 sm. Oleh kerana reaktor disuap di bawah turus dan gas CO_2 terkeluar, kepekatan substrat dan sel mengurang dengan ketinggian turus. Purata garis pusat kepekatan sel di bawah turus ialah X_o= 45 g/L, dan purata kepekatan sel menurun dengan ketinggian turus berdasarkan persamaan di bawah:

$$X = X_o(1\text{-}0.005\ Z)$$

where Z is the column height (cm). The specific rate of substrate consumption is q_s = 2 g glucose/(g cells.h). The feed flow rate and glucose concentration in the feed are 5 L/h and 160 g glucose/L, respectively.

di mana Z ialah ketinggian turus (sm). Kadar tentu penggunaan substrat ialah q_s = 2 g glukosa/(g sel.jam). Kadar aliran masuk dan kepekatan glukosa dalam aliran ialah 5 L/jam dan 160 g glukosa/L, masing-masing.

[i] Determine the substrate (glucose) concentration in the effluent.

Tentukan kepekatan-kepekatan substrat di dalam efluen.

[ii] Determine the ethanol concentration in the effluent and ethanol productivity (g/L.h) if $Y_{P/S}$ = 0.48 g glucose.

Tentukan kepekatan etanol di dalam efluen dan penghasilan etanol (g/L.jam) jika $Y_{P/S}$ = 0.48 g glukosa.

[15 marks/markah]

[b] List the potential advantages of immobilized cell cultures over suspension cultures.

Senaraikan kebaikan bagi sel sekat gerak berbanding sel bebas.

[10 marks/markah]

5. Consider a 1000 L continuous-stirred-tank reactor (CSTR) in which biomass is being produced with glucose as the substrate. The microbial system follows a Monod model with μ_{max} = 0.4 h^{-1}, K_S = 1.5 g/L and $Y_{X/S}$ = 0.5 $g_{biomass}/g_{substrate}$. If the normal operation with a sterile feed containing 10 g/L glucose at a rate of 100 L/h,

Pertimbangkan sebuah reaktor pengaduk berterusan (CSTR) berukuran 1000 L yang menghasilkan biomas dengan menggunakan glukosa sebagai substrat. Sistem mikrobial tersebut menuruti model Monod dengan μ_{mak} = 0.4 jam^{-1}, K_S = 1.5 g/L dan $Y_{X/S}$ = 0.5 $g_{biomas}/g_{substrat}$. Jika ia beroperasi secara normal dengan suapan yang steril mengandungi 10 g/L glukosa pada kadar 100 L/jam,

...6/-

[a] What is the specific biomass production rate in g/(L·h) at steady-state?

Apakah kadar tentu penghasilan biomas dalam g/(L·jam) pada tahap mantap?

[5 marks/markah]

[b] Show that for a CSTR system with a recycle stream, the external dilution rate, D_{ex} is given by;

$$D_{ex} = \frac{\mu}{1-\alpha(c-1)}$$

with the recycle ratio, α is given by;

$$\alpha = \frac{\text{Recycle flowrate}}{\text{Flowrate leaving the stream}}$$

and c is defined as the ratio of the recycled cell and the amount of cell within the reactor. If recycle is used with a recycle stream of 10 L/h and a recycle biomass concentration five times that in the reactor exit, what would be the new specific biomass production rate?

Tunjukkan untuk suatu sistem CSTR dengan aliran guna semula, kadar pencairan luaran, D_{luaran} diberi oleh;

$$D_{luaran} = \frac{\mu}{1-\alpha(c-1)}$$

dengan nisbah guna-semula, α diberi oleh;

$$\alpha = \frac{\textit{Kadar aliran guna - semula}}{\textit{Kadar aliran yang meninggalkan arus}}$$

dan c didefinasikan sebagai nisbah sel yang diguna semula dan sel yang terdapat di dalam reaktor. Jika penggunaan-semula digunakan dengan aliran sebanyak 10 L/jam dan kepekatan penggunaan semula biomas adalah lima kali berbanding dengan pengeluaran reaktor, apakah kadar tentu penghasilan biomas yang terbaru?

[18 marks/markah]

[c] Explain the differences between the values found in parts [a] and [b] above.

Terangkan perbezaan di antara nilai yang didapati pada bahagian [a] dan [b] di atas.

[2 marks/markah]

6. The data shown in Table Q.6 were obtained from the growth of *E. aerogenes* on a glycerol-limited growth medium using a continuous-stirred-tank reactor CSTR. For a given system, estimate;

Data yang diberikan di dalam Jadual S.6 telah didapati daripada pembiakan 'E. aerogenes' di dalam media pertumbuhan gliserol-terbatas menggunakan reaktor pengaduk berterusan CSTR. Bagi sistem yang diberi, anggarkan;

[a] K_S (mg$_{glycerol}$/mL)
K_S (mg$_{gliserol}$/mL)

[9 marks/markah]

[b] μ_{max} (h^{-1})
μ_{mak} (jam^{-1})

[10 marks/markah]

Given that for a CSTR mass balance with cell death;

$$\frac{dx}{dt} = Dx_o + (\mu - k_d - D)x$$

With the growth rate, μ, described by the normal Monod model and k_d is defined by;

$$k_d = m_s \cdot Y_{X/S}$$

where m_s refers to the maintenance coefficient which is related by;

$$\frac{1}{Y_{X/S}^{apparent}} = \frac{1}{Y_{X/S}} - \frac{m_s}{D}$$

Diberi bahawa untuk suatu CSTR, imbangan jisim dengan kematian sel;

$$\frac{dx}{dt} = Dx_o + (\mu - k_d - D)x$$

Dengan kadar pembiakan, μ, perihalkan oleh model Monod normal dan k_d diertikan sebagai;

$$k_d = m_s \cdot Y_{X/S}$$

di mana m_s menunjukkan pekali pengekalan dihubungkan oleh;

$$\frac{1}{Y_{X/S}^{jelas}} = \frac{1}{Y_{X/S}} - \frac{m_s}{D}$$

Table Q.6.
Jadual S.6.

Dilution rate, D (h^{-1}) *Kadar pencairan, D (jam^{-1})*	$1/D$ *1/D*	Substrate, $[S]$ (mg/ml) *Substrat, [S] (mg/ml)*	$1/[S]$ *1/[S]*	Cell concentration, X (mg/ml) *Kepekatan sel, X (mg/ml)*	$\Delta[S]$ *Δ[S]*	$\Delta[S]/X$ *Δ[S]/X*	$\Delta[S]/X \cdot D$ *Δ[S]/X·D*
0.05	20	0.012	83.3	3.2	9.988	3.12	0.156
0.10	10	0.028	35.7	3.7	9.972	2.70	0.270
0.20	5.0	0.05	20	4.0	9.950	2.49	0.498
0.40	2.5	0.10	10	4.4	9.90	2.25	0.90
0.60	1.67	0.15	6.67	4.75	9.85	2.075	1.245
0.70	1.43	0.176	5.68	4.9	9.824	2.005	1.405
0.80	1.25	0.80	1.25	4.5	9.20	2.045	1.635
0.84	1.19	9.00	0.11	0.5	-	-	-

[c] From the list of downstream processes below, write short notes on any of **two (2)** processes.

*Berdasarkan senarai proses-proses aliran-bawah di bawah, tuliskan nota-nota ringkas **dua (2)** daripada proses-proses tersebut.*

[i] Filtration
Penapisan

[ii] Centrifugation
Pengemparan

[iii] Chromatography
Kromatografi

[iv] Crystallisation
Penghabluran

[6 marks/markah]

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