UNIVERSITY OF GUELPH
SCHOOL OF ENGINEERING

ENGG*2660 Biological Engineering Systems-I, W'2004, 3+1 (0.5)

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Calendar Description (2002-03):
Mathematical description and identification of biological systems; through mass and energy balances; reactions in biological systems; biomedical, food and bioprocessing applications.

Pre-requisites: ENGG*2400, MATH*2270, MICR*1020; Co-requisites: CHEM*2580, STAT*2120

Objectives:
After successfully completion of the course, the student will be able to:

1. Analyse biological processes using the techniques of engineering systems analysis.

2. Develop mathematical models of biological processes based on mass and energy balances and reaction kinetics.

3. Simulate these models using a simulation language.

Text Materials:
Doran, Pauline M. 1995. Bioprocess Engineering Principles. Academic Press, Toronto.

References:
1. Mittal, G.S. 1992. Food Biotechnology--Techniques and Applications. Technomic Pub. Co., Lancaster, PA.

2. Aiba, S., A.E. Humphrey and N.F. Millis. Biochemical Engineering. Academic Press, Toronto.

3. Shuler, M.L. and F. Kargi. 2002 (2nd edition). Bioprocess Engineering -- basic concepts. Prentice Hall, Toronto.

4. Bailey, J.E. and D.F. Ollis. 1986. Biochemical Engineering Fundamentals. McGraw Hills, Inc., Toronto.

5. Mittal, G.S. (Ed.). 1996. Computerized Control Systems in the Food Industry. Marcel Dekker, Inc., New York. System models for a number of biological processes and systems are given. Chapters 3, 6, 15, 16 and 20 are recommended.

Teaching Schedule:
1. Bioprocess development -- chapter 1, p 3-7, sec. 1.1; chap. 3, p43-45, Fig. 3.13-3.15 (ref. 1,

chapter 1).
A typical new product from recombinant DNA, process flow diagrams for typical processes.

2. Chemical composition -- chapter 2, p 16-18, sec. 2.4.5

3. Material balances -- chapter 4, p 51-85, all sections, ref. 3-4.
System and process, steady state and equilibrium, law of conservation of mass, examples, stoichiometry of growth and product formation, elemental balances, electron balances, biomass yield, product stoichiometry, concepts of theoretical oxygen demand and maximum possible yield.

4. Energy balances -- chapter 5, p 86-108, all sections, ref. 3-4.
Energy concept, enthalpy, law of conservation of energy, state properties, change in phase and temperature, mixing and solution, steam tables, energy balance calculations without reaction; enthalpy change due to reaction, heat of combustion; heat of reaction for processes with biomass production, thermodynamics of microbial growth; heat of reaction with and without oxygen as electron acceptor, energy balances for cell culture.

5. Unsteady state material and energy balances -- chapter 6, p 110-124, all sections except 6.3.
Unsteady state examples for various biological processes.

6. Homogeneous reactions -- chapter 11, p 257-294, all sections except 11.8, 11.9.2-3, ref. 2.
Reaction theory, thermodynamics, rate, yield, and kinetics; temperature effect, Arrhenius equation and Eyring's reaction rate theory; kinetics for biological systems; zero, first, second and fraction order kinetics; enzymic reactions including Michaelis-Menten; yields in cell culture, various yields, cell growth kinetics, production kinetics in cell culture, product formation; kinetics of substrate uptake in cell culture, substrate uptake with and without product formation; determining cell kinetics parameters; rates of growth, product formation and substrate uptake; biomass yield from substrate; product yield from biomass and substrate.

7. Engineering principles and modelling of Human circulatory system and muscular system. Other topics based on time available. Some of these topics (not covered in class) will be assigned as projects and their reports will be presented in the class to provide background information.
Examples on biological, food, biomedical, and bioprocessing systems will be given.

Evaluation:

Short tests (quiz type)	30%
Project	20%
Final Exam.	50%

Holy Days: Students must contact the instructors within first two weeks of class if academic consideration is to be requested due to religious reasons.

Projects will be assigned later on. Last class week will be used to present project reports. All short tests will be during tutorial hour based on assignments and tutorial work conducted during the last week. All tests and examination will be open book.

Assignments: Solutions are not required to hand over for grading. However, short tests will cover these assignments. The solutions of assignment problems are available in the library. You are advised to look these solutions only after solving these problems first yourself. If you find these problems difficult to solve, please consult instructors and/or TA. Assignment problems requiring more clarification will be discussed in tutorials.

Assignment 1

1. A vegetable after drying to a moisture content of 5% dry basis (weight basis) is to be packaged containing 0.6 kg of dry matter. It is desired to reduce the moisture content from 5% to 2% by placing a desiccant in each package with the vegetable. The desiccant absorbs moisture from the vegetable and when equilibrium is reached, the desiccant contains 10 times the moisture content of the vegetable. If the desiccant initially has zero moisture, what mass of desiccant is required for each package (m.c.d.b. = mass of water/mass of dry matter)?

2. Orange juice extract containing 11.5% solids is being separated into pulpy juice (20% by weight) and strained juice using a finisher. The strained juice in concentrated to 57% total solids by passing through a vacuum evaporator. The pulpy juice is mixed with the concentrated juice to achieve the desired solids concentration of 42% (Fig. 2.3). Calculate (i) the concentration of solids in (a) pulpy juice and (b) strained juice and (ii) the mass of water evaporated per kg of extracted juice.

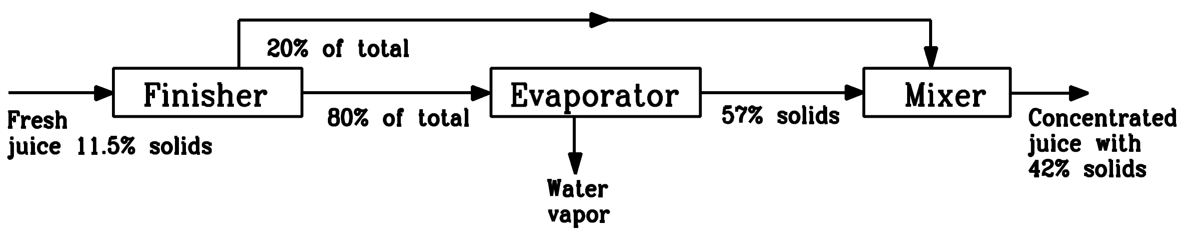

Fig. 2.3 Schematic for Problem 2.9.

3. 1000 kg of soybeans, of composition 18% oil, 35% protein, 27.1% carbohydrate, 9.4% fibre and ash, and 10.5% water, are: (a) crushed and pressed, which reduces oil content in beans to 6%, (b) then extracted with hexane to produce a meal containing 0.5% oil, and (c) finally dried to 8% moisture. Assuming that there is no loss of protein and water with the oil, set out a mass balance for the soybeans constituents, and calculate (i) the amount of expressed oil, (ii) the amount of oil in hexane, (iii) the amount and composition of meal, and (iv) amount of water lost in drying.

4. 500 kg of diced carrots are dehydrated in a parallel flow dryer from 85% to 20% moisture content (wet basis). Air with a moisture content of 0.013 kg water per kg dry air enters the dryer at a rate of 400 kg of dry air per kg of dry solid. Calculate the moisture content of the air leaving the dryer.

5. A membrane separation system is used to concentrate total solids (TS) in a liquid food from 10 to 30%. The concentration is accomplished in two stages with the first stage resulting in release of a low-total-solids liquid stream. The second stage separates the final concentration product from a low-total-stream which is returned to the first stage. Determine the magnitude of the recycle stream (R) when the recycle contains 2% TS, the waste stream (W) contains 0.5% TS, and the stream (B) between stages 1 and 2 contains 25% TS. The process should produce (P) 100 kg/min of 30% TS.

6. If 100 kg of raw sugar containing 95% sucrose, 3% water and 2% soluble uncrystallizable inert solids, is dissolved in 30 kg of hot water and cooled to 20°C, calculate: (a) kg of sucrose that remains in solution. A saturated solution of sucrose at 20°C contains 67% sucrose, b) crystalline sucrose, and c) the purity of the sucrose (in % sucrose) obtained after centrifugation and dehydration to 0% moisture. The solid phase contained 20% water after separation from the liquid phase in the centrifuge.

7. Soybean oil is being extracted from soybeans in a single-stage extraction system. The feed rate for the soybeans is 500 kg/h and the feed contains 18% oil. The extract stream should contain a minimum of 15% oil and solids stream should not contain more than 5% oil. Determine the extract production rate and the rate at which solvent will be required. Assume no solvent in the solids stream, and no oil in solvent stream.

A2: 4.1, 4.2, 4.3, 4.6

A3: 4.7, 4.10, 4.11, 4.14

Assignment 4

1. Pectin enzymes of the tomato pulp are being deactivated by heating with steam mixing. The

initial concentration of total solids in the pulp is 5.7%. The pulp is heated by mixing saturated steam at 105°C, and being heated from 20 to 87°C. Calculate the concentration of total solids. The specific heat of solids is 2.2 kJ/(kg.K) and of water 4.19 kJ/(kg.K).

2. The manufacture of pie filling involves blending of concentrated product with liquid sugar and heating by steam injection. The product being manufactured will contain 25% product solids and 15% sugar solids and will be heated to 115°C. The process has input streams of concentrated product with 40% product solids at 40°C and 10 kg/s and liquid sugar with 60% sugar solids at 50°C. Heating is accomplished using steam at 198.53 kPa Abs. The concentrated product entering the process and the final product have specific heats of 3.6 kJ/(kg.K), whereas the liquid sugar has a specific heat of 3.8 kJ/(kg.K). Determine (a) the rate of product manufacturing, (b) the flow rate of liquid sugar into the process, (c) the steam requirements for the process, and (d) the quality of steam required for the process.

3.Skim milk is being concentrated in a double effect evaporator. Calculate the solids content of the liquid leaving the first effect. The specific heat of the solids is 2.09 kJ/(kg.K). Other data are given on the diagram.

4. The figure below shows the concentration of peach puree. The data are given on the figure. Calculate all the unknowns (m1, m3, m4 and m5). Take specific heat values from question 3.

A5: 5.3, 5.5, 5.9

A6: 6.4, 6.6, 6.9, 6.13

A7: 11.2, 11.4, 11.5, 11.6, 11.8, 11.10