

National Exams - May 2003
98-Agric-B9 Food Process Engineering (Part 2)

3 hours duration

Notes:

1. If doubt exists as to the interpretation of any question, the candidate is urged to submit with the answer paper, a clear statement of any assumptions made.
2. Any non-communicating calculator is permitted. This is an Open book exam. Note to candidates you must indicate the type of calculator being used, i.e. write the name and model designation of the calculator, on the first left hand sheet, of the exam work book.
3. Complete the questions as indicated on the paper. Some choices are provided.
4. Marks for each question are given at the end of the question.

Food dehydration

1. A product enters a tunnel dryer with 56% moisture content (wet basis) at a rate of 10 kg/h. The dryer is supplied with 1500 kg dry air/h at 50°C and 10% relative humidity, and air leaves at 25°C and 50% relative humidity. Determine the moisture content (wet basis) of the dried product leaving the dryer. (15 marks)

OR

2. A wet solid is dried from 35% to 10% moisture under constant drying conditions in 5 h. If the equilibrium moisture content is 4% and critical moisture content is 14%, how long will it take to dry to 6% moisture under the same conditions? All moisture contents are dry basis, and consider only one falling drying rate period. (15 marks)

3. A granular material containing 40% moisture is fed to a countercurrent rotary dryer at a temperature of 295 K and is withdrawn at 305 K containing 5% moisture. The air supplied, which contains 0.006 kg water vapour/kg dry air, enters at 385 K and leaves at 310 K. The dryer handles 0.125 kg/s wet stock. Assuming that radiation losses amount to 20 kJ/kg dry air used, determine the mass flow of dry air supplied to the dryer and the humidity of the exit air. Latent heat of water vapour at 295 K = 2449 kJ/kg, specific heat of dried material = 0.88 kJ/(kg.K), specific heat of dry air = 1.00 kJ/(kg K), specific heat of water vapour = 2.01 kJ/(kg K), and specific heat of liquid water = 4.18 kJ/(kg K). Assume that evaporation of water takes place at 295 K. Use mass and energy balances. (20 marks)

OR

4. Calculate the time required to dry a sliced food product from an initial moisture content of 580% (dry basis) to a final moisture content of 80% (dry basis). The wet product has a bulk density of 120 kg dry matter/m³, and it is dried in layers of 0.05 m thick. Constant drying rate = 40 kg water/(h.m²) from 580% to 250% moisture content dry basis. In first falling rate period the drying rate decreases from 40 to 15 kg/(h.m²) when moisture content (dry basis) decreased from 250 to 50%. (20 marks)

Filtration

5. A suspension of *Bacillus subtilis* cells is filtered under constant pressure for recovery of protease. A pilot scale filter is first used to measure filtration properties. For this experiment, the filter area is 0.25 m², the pressure drop is 47988 Pa, and filtrate viscosity is 0.004 Pa.s. The cell suspension deposits 22 g cake per litre of filtrate. The following data are measured:

Time (t)	2	3	6	10	15	20
Filtrate volume, L (V)	0.8	12.1	18	21.8	28.4	32

The plot of t/V vs. V gives slope = $1.18E6$ s/m⁶ and intercept = $-363 \sim 0$ s/m³ since it is relatively small negative number. Determine specific cake resistance (α , m/kg) and filter medium resistance (R_m , 1/m). What size filter is needed to process 4000 L cell suspension in 30 min at a pressure drop of 47988 Pa? Watch dimensions carefully. (20 marks)

Centrifugation

6. A dispersion of oil in water is to be separated by a centrifuge. Calculate the velocity at which the

particles will be separated if the following particulars are known: diameter of oil particles = 0.1 mm, oil density = 920 kg/m³, number of revolutions = 2000 rpm, fluid viscosity = 0.8 cP, radius of centrifuge = 30 mm and density of water = 1000 kg/m³. (15 marks)

OR

7a. What are the differences between electro dialysis, pervaporation, electrophoresis and reverse osmosis? (10 marks)

And

7b. How you will increase the rate of separation in a centrifuge? (5 marks)

Membrane processes

8. We wish to concentrate a protein solution by ultrafiltration (UF) in a batch system. The permeability of the membrane (Q) is 3.5 L/(m² h. Atm.), and total membrane area is 100 cm². The initial volume of the solution is 1 L and the amount of protein present is 0.01 (10⁻³) moles. The pressure drop is 9.867 Atm., and the temperature of the operation is 25°C. Assume that the membrane completely rejects the solute and that concentration polarization is negligible. Calculate the time required to reduce the volume of solution from 1 L to 10 mL. Consider average volume to calculate osmotic pressure ($\Delta\pi$). Gas constant (R) = 82.06 Atm.cm³/(mol.K). (15 marks)

OR

9. A reverse osmosis unit is to demineralize 760 m³/day of a tertiary treated effluent. Mass transfer coefficient (permeability) = 0.207 L/(day.m².kPa) at 25°C, pressure difference between the feed and product water = 2400 kPa, osmotic pressure difference between the feed and product water = 310 kPa, lowest operating temperature = 10°C, membrane area at 10°C = 1.58 times membrane area at 25°C, and membrane area per unit volume of the equipment = 2500 m²/m³. Determine (a) the membrane area required, and (b) the space required for the equipment in m³. (15 marks)

Sedimentation

10. Yeast cells are to be separated from a fermentation broth. Assume that the cells are spherical with diameter 5 μ m and density 1.06 g/cm³. The viscosity of the culture broth is 1.36(10⁻³) Pa.s. At the temperature of separation, the density of suspending fluid is 0.997 g/cm³. 500 L broth is required to be treated per hour. (a) If the Σ (sigma factor) = $q/(2u_t)$, where q is volumetric flow rate and u_t is the terminal velocity of the particles in a gravitational field, calculate Σ , and (b) if instead of yeast, quartz particles of diameter 0.1 mm and specific gravity of 2.0 are separated from the culture liquid, by how much is Σ is reduced? (15 marks)

OR

Extrusion

11. For a screw extruder, the following data are given: Inside diameter of the housing or screw (D) = 90 cm, channel depth in the screw (H) = 6 mm, apparent viscosity (μ) = 500 Pa.s, screw length (L) = 63 cm, rotational rotor speed (N) = 60 rpm, $\tan \phi = 0.318$ (where ϕ is screw channel angle), density (ρ) = 750 kg/m³, specific heat (c_p) = 2200 J/(kg.K), height of the leakage gap (δ) = 0.5 mm, friction coefficient on the screw channel geometry (K) = 0.842, and pressure difference generated by the extruder (ΔP) = 15 MPa. Calculate volumetric flow rate in the extruder (Q_v), mechanical efficiency (η) and temperature increase (ΔT). (15 marks)

OR

Cleaning and sanitation

12. How you will establish a successful sanitation program in a food plant? How centralized clean-in-place (CIP) system will be implemented in the plant during its design. (15 marks)

