Biological and Agricultural Engineering Department

Modeling and Analysis of Physical and Biological Processes: EBS 270

Homework No. 2

Points: 50 Due Date: May 10, 2019

8 1a) Evaluate the peanut oil concentration in peanut butter cup with time, if peanut butter cup is assumed cylindrical in geometry and has a height of 18 mm with a 12 mm layer of peanut butter in the middle (i.e., develop a MATLAB code). Assume that the diffusivity of the lipid in liquid medium is $5.5\bullet10^{-15}$ m^2/s and the initial concentration of peanut oil in peanut butter layer is 18%.

2 1b) Use the surface[1] plot in MATLAB to produce plot of concentration versus the height of the peanut butter cup and time.

2 1c) Also plot the concentration of peanut oil at times 0, 1, 3, and 5 years on a single 2-D (concentration versus position) plot.

1 1d) What do these results suggest?

2 1e) Discuss the limitation of the model developed – do not simply restate the assumptions as limitations, identify one or two major limitations. How can you overcome these limitations?

20 2a) A completely thawed thin patty is being cooked on a hot plate that is maintained at a temperature of T_H. The ambient temperature is T_∞. Develop a model for the heat transfer through the thickness direction of the patty while properly accounting for the convective heat loss through the circumferential edge. State all your assumptions.

2b) If the diffusion of moisture within the patty and evaporation of moisture at the surface are also considered important, how will the model change?

[1] Use help 'surf' in MATLAB to find details of this built-in function.

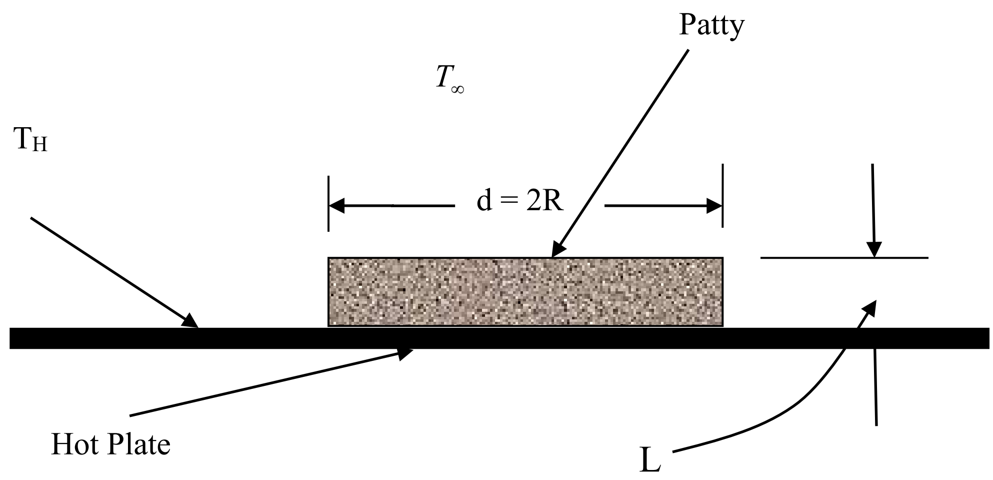

Figure 1. Cooking of a patty on a hot plate

15 3 A 6 cm radius and 35 cm long flexiglass cylinder is loaded with biomass at 50% humidity on a dry basis and inoculated with Aspergillus niger. A water jacket at a constant temperature of 35 °C surrounds the cylindrical face (See Figure 1). Develop a model to describe the temperature variation within the bioreactor. Assume also that the growth of A. niger follows the following growth equation:

$$\frac{dX}{dt} = \mu_{\max} X\left[1 - \frac{X}{X_{\max}}\right] \tag{3a}$$

$$\frac{d[m_{CO2}]}{dt} = \left[a\frac{dX}{dt} + bX\right] \tag{3b}$$

where, μ_{max} = Maximum growth rate that depends on temperature.

X = Mass of the microorganism
X_{max}= Maximum biomass concentration that depends on temperature
a = 0.37 g–CO_2/cc-substrate (S)
b = $0.41 \bullet 10^{-5}$ g-CO_2/(cc-S h)

m_{CO2} = mass of CO_2 per unit volume of substrate.
Moreover, respiration which leads to CO_2 generation is given by:

$$C_6H_{12}O_6 + 6O_2 = 6CO_2 + 6H_2O + Q \qquad (3c)$$

where Q = 674 Kcal/mole of glucose.

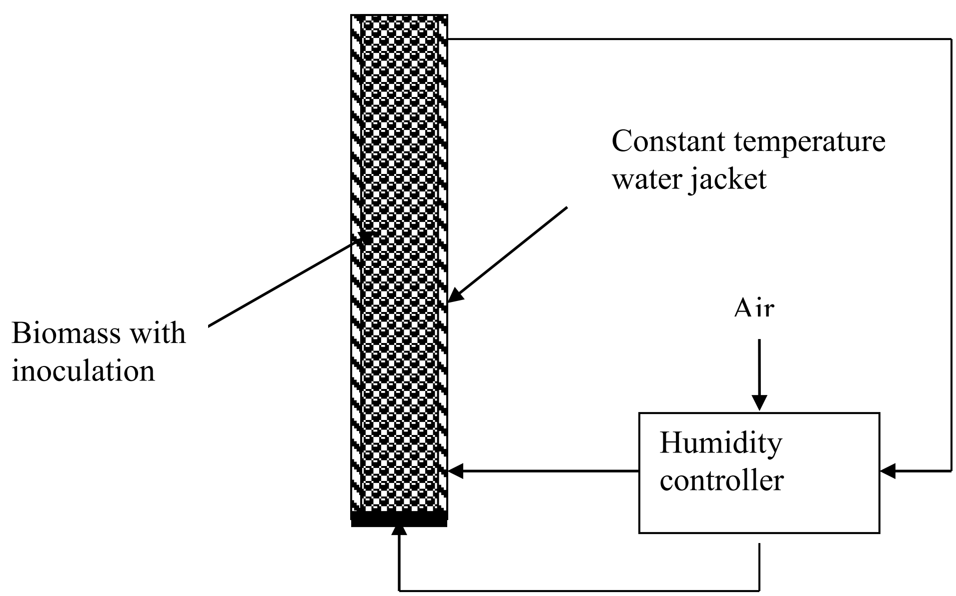

Figure 2. A flexiglass, cylindrical bioreactor of radius 6 cm and height 35 cm with a water jacket that is maintained at 35 ºC.