UNIT OPERATIONS IN FOOD PROCESSING

CHAPTER 11

SIZE REDUCTION (cont'd)

SUMMARY

1. Size reduction is accomplished by shearing forces that cause the material to fracture releasing most of the applied energy as heat.

2. A general equation giving the power required for size reduction is:

$$dE/dL = KL^n$$

and from this can be derived

(a) Kick's Law in which n = -1 and which may be integrated to give:

$$E = K_K f_c \log_e(L_1/L_2)$$

(b) Rittinger's Law in which n = - 2, integrated to give:

$$E = K_R f_c(1/L_2 - 1/L_1)$$

(c) Bond's equation in which n = - 3/2, integrated to give:

$$E = E_i\,(100/L_2)^{1/2}(1 - 1/q^{1/2})$$

It appears that Kick's results apply better to coarser particles, Rittinger's to fine ones with Bond's being intermediate.

3. The total surface area of a powder is important and can be estimated from

$$A_t = 6\lambda m/\rho_p D_p$$

4. An emulsion is produced by shearing forces which reduces the size of droplets of the dispersed phase to diameters of the order of 0.1-10 µm, with a large specific surface area. Application of Stokes' Law gives an indication of emulsion stability.

PROBLEMS

1. From measurements on a uniformly sized material from a dryer, it is inferred that the surface area of the material is 1200 m^2. If the density of the material is 1450 kg m^{-3} and the total weight is 360 kg calculate the equivalent diameter of the particles if their value of λ is 1.75.
[2200 microns]

2. Calculate the shape factors ~ for model systems in which the particles are:
(a) cylinders with $L = 2D$,
(b) tetrahedra with their sides being equilateral triangles (the volume of a tetrahedron being the area of the

base multiplied by 1/3 the vertical height)
Estimate the specific surface area of a powder consisting of equal numbers of the above two shapes in which there are 4 x 10^3 particles kg^{-1}. The cylinders have a density of 1330 kg m^{-3} and the tetrahedra a density of 1500 kg m^{-3}.
[(a) 0.83 ; (b) 2.4 ; (c)) 0.81 $m^{2}kg^{-1}$]

3. It is found that the energy required to reduce particles from a mean diameter of 1 cm to 0.3 cm is 11 kJ kg^{-1}. Estimate the energy requirement to reduce the same particles from a diameter of 0.1 cm to 0.01 cm assuming:
(a) Kick's Law,
(b) Rittinger's Law,
(c) Bond's Equation.
[(a) 21 $kJkg^{-1}$; (b) 423 kJkgkg-1 ; (c) 91 kJkg-1]

4. It is suspected that for a product of interest the oxidation reactions, which create off-flavours, are surface reactions which proceed at a rate which is uniform with time, and if the shelf life of the product is directly related to the percentage of the off-flavours that have been produced, estimate the percentage reduction in shelf life consequent upon the size reductions of example 3, that is from 1 cm to 0.3 cm and from 0.1 cm to 0.01 cm in diameter, assuming λ = 1.5.
[(a) 10:1 ; (b) 100:1]

5. If it is desired to reduce the separation time for milk to at least one week (before cream will rise to the top), what maximum diameter of cream droplet would Stokes' Law predict to be necessary for the homogenization to achieve? Assume the depth is 10 cm.
[0.0567 microns]

CHAPTER 12: MIXING

Back to the top