SHEKHAWATI INST. OF ENG.& TECHNOLOGY COLLEGE

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Subject Code & Name: **4AG3 FOOD PROCESS ENGINEERING**

MM: 20 Times: 1.5hrs

MODEL ANSWER PAPER

Q.1 Explain batch and continuous process in food engineering. (4)

Processes may be carried-out in batch, continuous or mixed fashion. In *batch processing* , a portion of the materials to be processed is separated from the bulk and treated separately. The conditions such as temperature, pressure, composition etc. usually vary during the process. The batch process has a defi nite duration and, after its completion, a new cycle begins, with a new portion of material. The batch process is usually less capital intensive but may be more costly to operate and involves costly equipment dead-time for loading and unloading between batches. It is easier to control and lends itself to intervention during the process. It is particularly suitable for small-scale production and to frequent changes in product composition and process conditions. A typical example of a batch process would be the mixing of fl our, water, yeast and other ingredients in a bowl mixer to make a bread dough. After having produced one batch of dough for white bread, the same mixer can be cleaned and used to make a batch of dark dough.

In *continuous processing* , the materials pass through the system continuously, without separation of a part of the material from the bulk. The conditions *at a given point of the system* may vary for a while at the beginning of the process, but ideally they remain constant during the best part of the process. In engineering terms, a continuous process is ideally run at *steady state* for most of its duration. Continuous processes are more diffi cult to control, require higher capital investment, but provide better utilization of production capacity, at lower operational cost. They are particularly suitable for lines producing large quantities of one type of product for a relatively long duration. A typical example of a continuous process would be the continuous pasteurization of milk.

Q.2 Explain Principle of conservation of mass and conservation of energy with respect to food processing (4)

The law of conservation of mass states that mass can neither be created nor destroyed. Thus in a processing plant, the total mass of material entering the plant must equal the total mass of material leaving the plant, less any accumulation left in the plant. If there is no accumulation, then the simple rule holds that "what goes in must come out". Similarly all material entering a unit operation must in due course leave.

For example, when milk is being fed into a centrifuge to separate it into skim milk and cream, under the law of conservation of mass the total number of kilograms of material (milk) entering the centrifuge per minute must equal the total number of kilograms of material (skim milk and cream) that leave the centrifuge per minute.

Similarly, the law of conservation of mass applies to each component in the entering materials. For example, considering the butter fat in the milk entering the centrifuge, the weight of butter fat entering the centrifuge per minute must be equal to the weight of butter fat leaving the centrifuge per minute. A similar relationship will hold for the other components, proteins, milk sugars and so on.

The law of conservation of energy states that energy can neither be created nor destroyed. The total energy in the materials entering the processing plant plus the energy added in the plant must equal the total energy leaving the plant.

This is a more complex concept than the conservation of mass, as energy can take various forms such as kinetic energy, potential energy, heat energy, chemical energy, electrical energy and so on.

During processing, some of these forms of energy can be converted from one to another. Mechanical energy in a fluid can be converted through friction into heat energy. Chemical energy in food is converted by the human body into mechanical energy.

Note that it is the sum total of all these forms of energy that is conserved.

For example, consider the pasteurizing process for milk, in which milk is pumped through a heat exchanger and is first heated and then cooled. The energy can be considered either over the whole plant or only as it affects the milk. For total plant energy, the balance must include: the conversion in the pump of electrical energy to kinetic and heat energy, the kinetic and potential energies of the milk entering and leaving the plant and the various kinds of energy in the heating and cooling sections, as well as the exiting heat, kinetic and potential energies. To the food technologist, the energies affecting the product are the most important. In the case of the pasteurizer, the energy affecting the product is the heat energy in the milk. Heat energy is added to the milk by the pump and by the hot water passing through the heat exchanger. Cooling water then removes part of the heat energy and some of the heat energy is also lost to the surroundings.

The heat energy leaving in the milk must equal the heat energy in the milk entering the pasteurizer plus or minus any heat added or taken away in the plant.

Heat energy leaving in milk = initial heat energy
+ heat energy added by pump
+ heat energy added in heating section
- heat energy taken out in cooling section
- heat energy lost to surroundings.

The law of conservation of energy can also apply to part of a process. For example, considering the heating section of the heat exchanger in the pasteurizer, the heat lost by the hot water must be equal to the sum of the heat gained by the milk and the heat lost from the heat exchanger to its surroundings.

From these laws of conservation of mass and energy, a balance sheet for materials and for energy can be drawn up at all times for a unit operation. These are called material balances and energy balances

Q.3 Explain Dimensional consistency with a suitable example

All physical equations must be dimensionally consistent. This means that both sides of the equation must reduce to the same dimensions. For example, if on one side of the equation, the dimensions are $[M] [L]/[T]^2$, the other side of the equation must also be $[M] [L]/[T]^2$ with the same dimensions to the same powers. Dimensions can be handled algebraically and therefore they can be divided, multiplied, or cancelled. By remembering that an equation must be dimensionally consistent, the dimensions of otherwise unknown quantities can sometimes be calculated

In the equation of motion of a particle travelling at a uniform velocity for a time t, the distance travelled is given by $L = vt$. Verify the dimensions of velocity.

Knowing that length has dimensions [L] and time has dimensions [t] we have the dimensional equation:

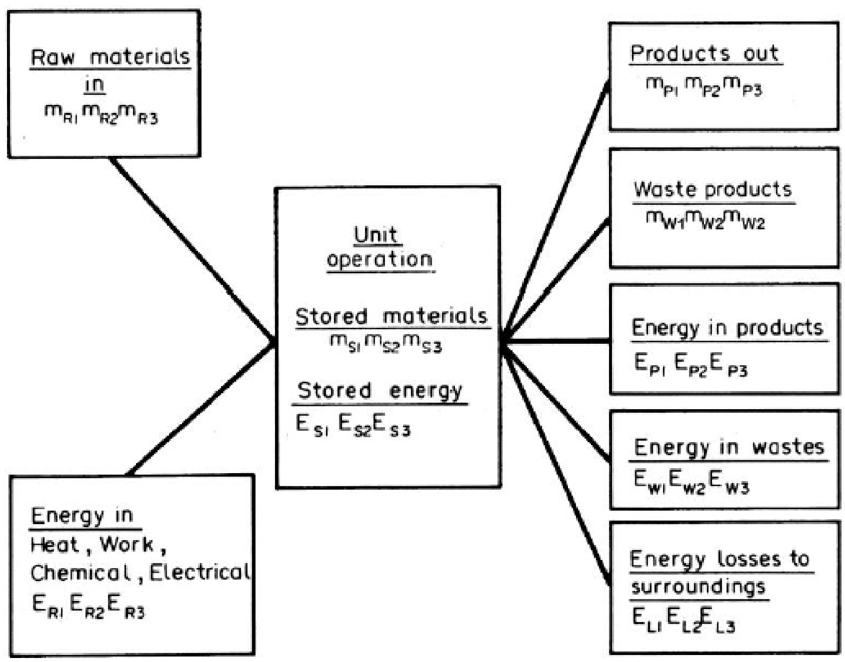
[v] = [L]/[t]

the dimensions of velocity must be $[L][t]^{-1}$

The test of dimensional homogeneity is sometimes useful as an aid to memory. If an equation is written down and on checking is not dimensionally homogeneous, then something has been forgotten.

Q.4 Explain mass and energy balance of unit operation with diagrammatically as a box. (4)

If the unit operation, whatever its nature is seen as a whole it may be represented diagrammatically as a box



The law of conservation of mass leads to what is called a mass or a material balance.

Mass In = Mass Out + Mass Stored

Raw Materials = Products + Wastes + Stored Materials.

$$\Sigma m_R = \Sigma m_P + \Sigma m_W + \Sigma m_S$$

(where Σ (sigma) denotes the sum of all terms).

Σm_R	=	$m_{R1} + m_{R2} + m_{R3}$	=	Total Raw Materials.
Σm_P	=	$m_{P1} + m_{P2} + m_{P3}$	=	Total Products.
Σm_w	=	$m_{W1} + m_{W2} + m_{W3}$	=	Total Waste Products.
Σm_s	=	$m_{S1} + m_{S2} + m_{S3}$	=	Total Stored Products.

If there are no chemical changes occurring in the plant, the law of conservation of mass will apply also to each component, so that for component A:

m_A in entering materials = m_A in the exit materials + m_A stored in plant.

For example, in a plant that is producing sugar, if the total quantity of sugar going into the plant is not equalled by the total of the purified sugar and the sugar in the waste liquors, then there is something wrong. Sugar is either being burned (chemically changed) or accumulating in the plant or else it is going unnoticed down the drain somewhere. In this case:

$$(m_{AR}) = (m_{AP} + m_{AW} + m_{AS} + m_{AU})$$

where m_{AU} is the unknown loss and needs to be identified. So the material balance is now:

Raw Materials = Products + Waste Products + Stored Products + Losses

where Losses are the unidentified materials.

Just as mass is conserved, so is energy conserved in food-processing operations. The energy coming into a unit operation can be balanced with the energy coming out and the energy stored.

Energy In = Energy Out + Energy Stored

$$\Sigma E_R = \Sigma E_P + \Sigma E_W + \Sigma E_L + \Sigma E_S$$

where:

ΣE_R	=	$E_{R1} + E_{R2} + E_{R3} + \ldots\ldots$	=	Total Energy Entering
ΣE_P	=	$E_{P1} + E_{P2} + E_{P3} + \ldots\ldots$	=	Total Energy Leaving with Products
ΣE_W	=	$E_{W1} + E_{W2} + E_{W3} + \ldots\ldots$	=	Total Energy Leaving with Waste Materials
ΣE_L	=	$E_{L1} + E_{L2} + E_{L3} + \ldots\ldots$	=	Total Energy Lost to Surroundings
ΣE_S	=	$E_{S1} + E_{S2} + E_{S3} + \ldots\ldots$	=	Total Energy Stored

Energy balances are often complicated because forms of energy can be interconverted, for example mechanical energy to heat energy, but overall the quantities must balance.

Q.5 Skim milk is prepared by the removal of some of the fat from whole milk. This skim milk is found to contain 90.5% water, 3.5% protein, 5.1% carbohydrate, 0.1% fat and 0.8% ash. If the original milk contained 4.5% fat, calculate its composition, assuming that fat only was removed to make the skim milk and that there are no losses in processing. (4)

Basis: 100 kg of skim milk. This contains, therefore, 0.1 kg of fat. Let the fat which was removed from it to make skim milk be x kg.

Total original fat $= (x + 0.1)$ kg
Total original mass $= (100 + x)$ kg

and as it is known that the original fat content was 4.5% so

$$\frac{x + 0.1}{100 + x} = 0.045$$

whence

$$x + 0.1 = 0.045(100 + x)$$
$$x = 4.6 \text{ kg}$$

So the composition of the whole milk is then:

fat = 4.5% , water $\frac{90.5}{104.6}$ = 86.5 %, protein = $\frac{3.5}{104.6}$ = 3.3 %, carbohydrate = $\frac{5.1}{104.6}$ = 4.9%

and ash = 0.8%

Total composition: water 86.5%, carbohydrate 4.9%, fat 4.5%, protein 3.3%, ash 0.8%