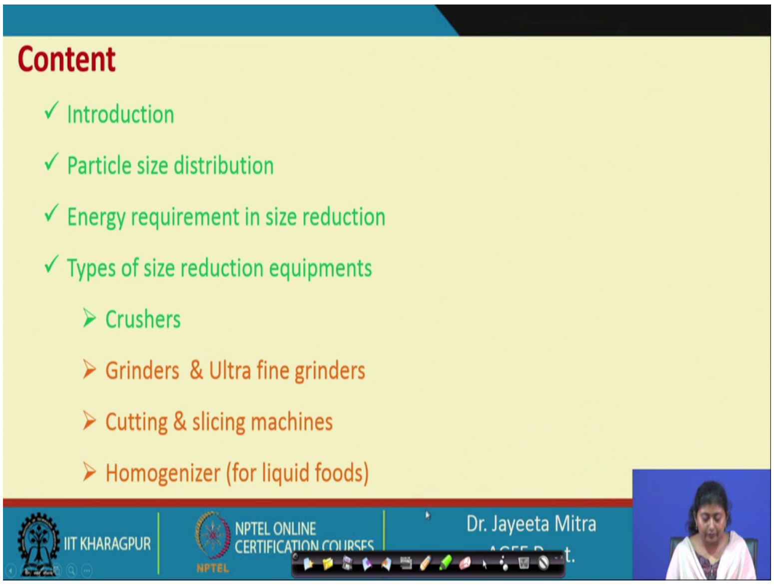
Fundamentals of Food Process Engineering

Prof. Jayeeta Mitra
Department of Agricultural and Food Engineering
Indian Institute of Technology, Kharagpur

Lecture - 40
Size Reduction (Contd.)

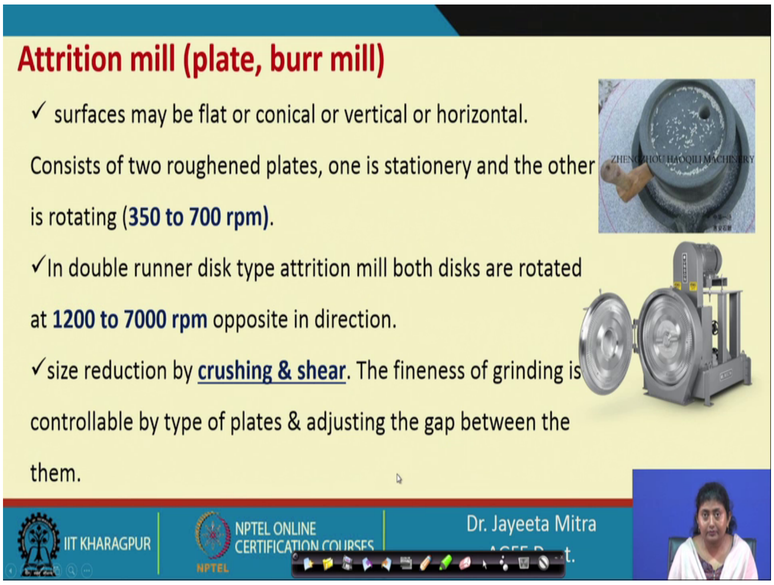
Hello, everyone; welcome to the NPTEL online certification course on Fundamentals of Food Process Engineering. We will continue today with size reduction and we are at the last stage of this particular chapter.

(Refer Slide Time: 00:38)



We have started discussing on different equipment which are being used for size reduction operation in industry and also in the you know small scale or large scale work. So, in that we have discussed the crushers, grinders and ultrafine grinders and cutting and slicing machines, all these will discuss today also, we will discuss the homogenizers, which is used for the liquid foods, size reduction of the liquid foods.

(Refer Slide Time: 01:08)



So, first is, in the last class we have discussed up to the ball mill and today we will discuss the attrition mill or that is also called the plate mill or burr mill.

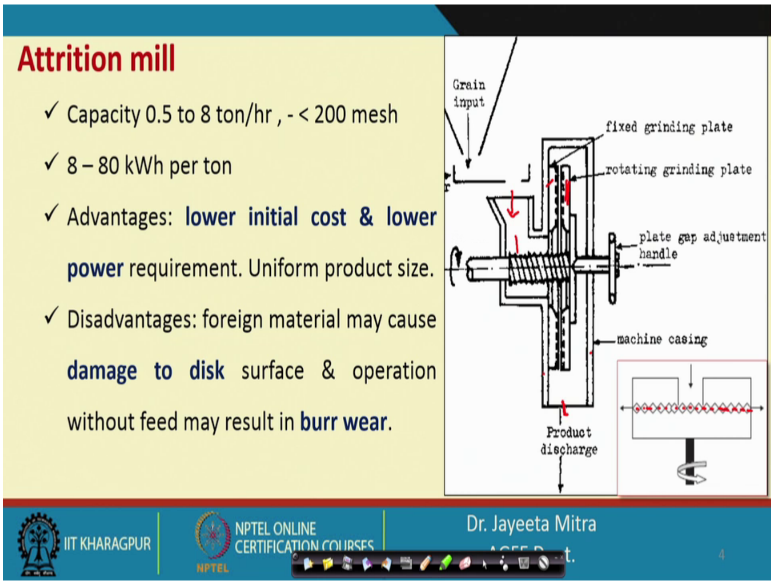
So, this looks like this the, the figures are like this. It may be horizontal, maybe vertical, surfaces is maybe flat or conical or vertical and horizontal, that consists of two roughened plates, one is stationary and the other is rotating with a speed of 350 to 700 rpm. So, in this particular case for example, if you look into this vertical attrition mill. So, the inner one is rotating and the outer one is fix, but they have a corrugated services throughout for better effect on the size deduction.

So, in double runner, this type attrition mill both disk are rotated. So, the second option is also available; that means, initially we have mentioned that they maybe one is stationary and one is rotating that the picture she has depicts that one, but there are double runner disk also, where both the disk are rotated at 1200 to 7000 rpm in opposite direction.

Size deduction by crushing and shear and the fineness of grinding is controlled by type and plates and also the adjusting gap between these two plates.

So, what happen that when, when we give the feed between these two based on the type and pattern or size of the fee size of the feed material. We can adjust the gap between these two plate. And also we can control the type of the plate for controlling the fineness of the grinding.

(Refer Slide Time: 03:21).



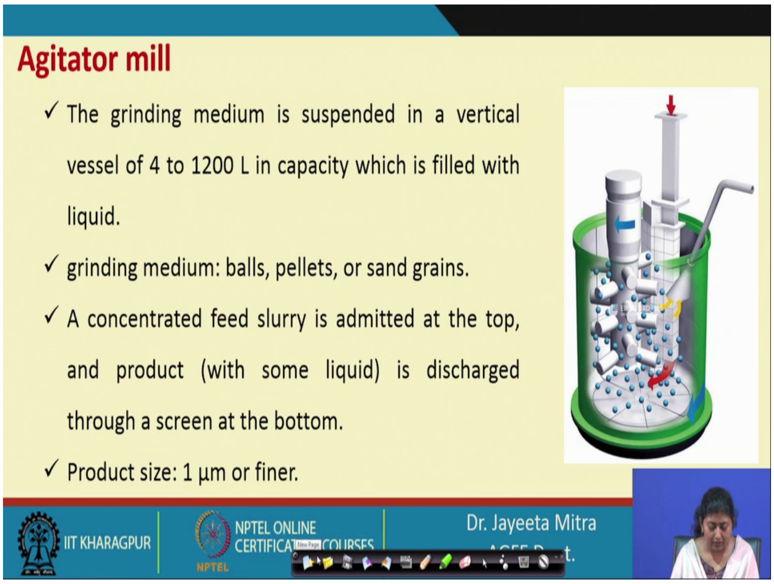
So, the capacity of these attrition mill generally varies from 0.5 to 8 ton per hour. So, we can see very small to very large scale; that means, home scale to large industrial skill production can be done, you think attrition mills. And the particle that we produced that generally have less than 200 mesh size. And the power requirement is 8 to 80 kilowatt hour per ton.

So, here we can see that every, every arrangement is a different kind of in this particular that has been given here the fix grinding plate is this one. And the rotating grinding is this one which is attached to a shaft, ok. The gap of this too can be adjusted and there is a machine casing.

So, product will be discharged from the bottom section and the feed is coming from the top. So, feed is coming from here then from, it is going through this top section. And then there is a screw, thread screw are there which is taking forward the feed to the gap between these two plates, ok. So, this is howif you see the, the product is in between these spaces, there is a corrugated plates in between these the product is there and because of the rotation rotational motion, the attrition mill works.

Now, the advantages that, this is lower in initial cost. If you want to set up a attrition mill, we can do it with very low cost and power requirement is also less, we are getting the uniform product size, so, that is an advantage. However, there are certain limitation as well that the foreign material. If they may come with the product, they can damage the disk surface and operation without the feet result in the bar wear because of this issues. So, we need to be careful that the only the pure product or, or the grain that we want to handle should come in between the two plates.

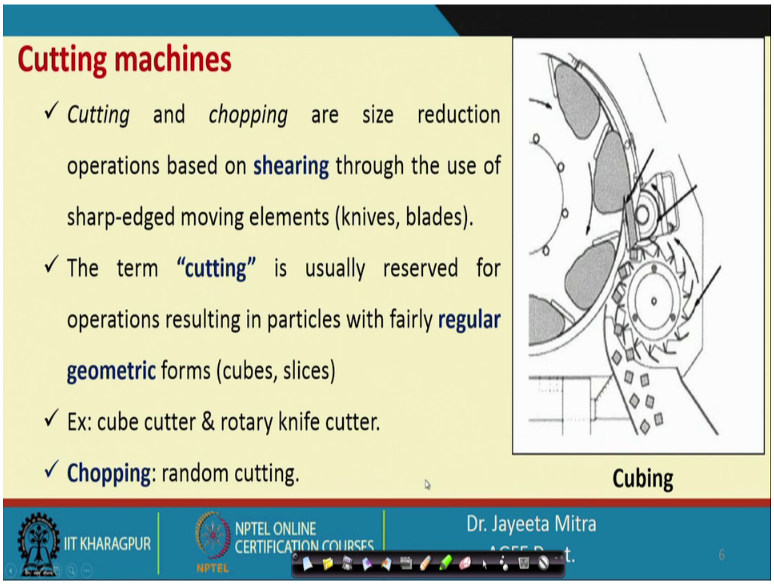
(Refer Slide Time: 05:43)



Now agitator mill, so, agitator mill, the grinding medium is suspended in a vertical vessel of 4 to 1200 litter in capacity which is filled with liquid.

Grinding medium is here, balls pellets or sand grains. And a concentrated feed slurry is admitted from the top and the product with some liquid is discharged through the screen at the bottom. Product size varies from 1 micrometre or finer.

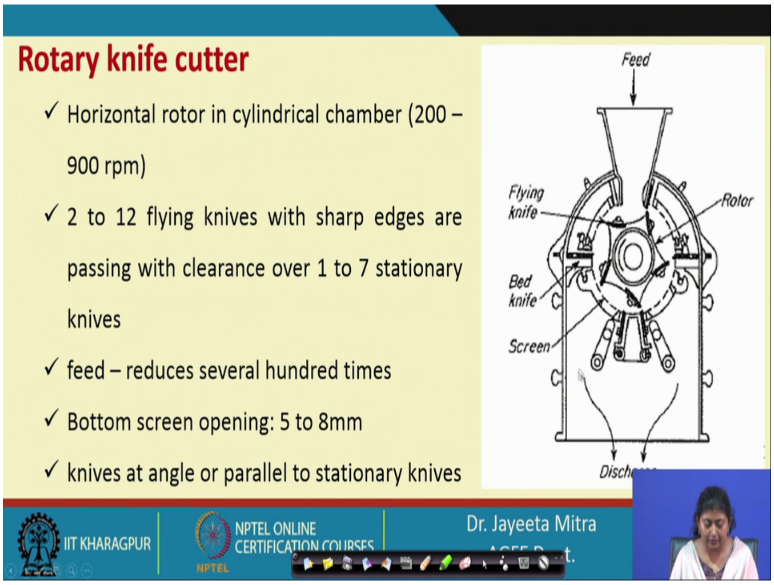
(Refer Slide Time: 06:16).



Cutting machine so, cutting and shopping are again size reduction operation based on shearing through the use of sharp edges moving elements like knives or blades. The term cutting is usually reserved for operation resulting in particle with fairly regular geometry forms like cubes and slices. So, rotary knife cutter is an example which we use for cutting the vegetables and all.

And chopping, it is a random cutting, so, sizing will not be uniform in that case. So, he is a, here is a cube cutter which have a specific serrated, geometry for the cutting blade. So, it will cut at a particular shape of, of a cubic shape of all the products and that is we, we can see here. And the in case of chopping we just put the abrupt force on the materials so, that the irregular shape particle may come out.

(Refer Slide Time: 07:23).



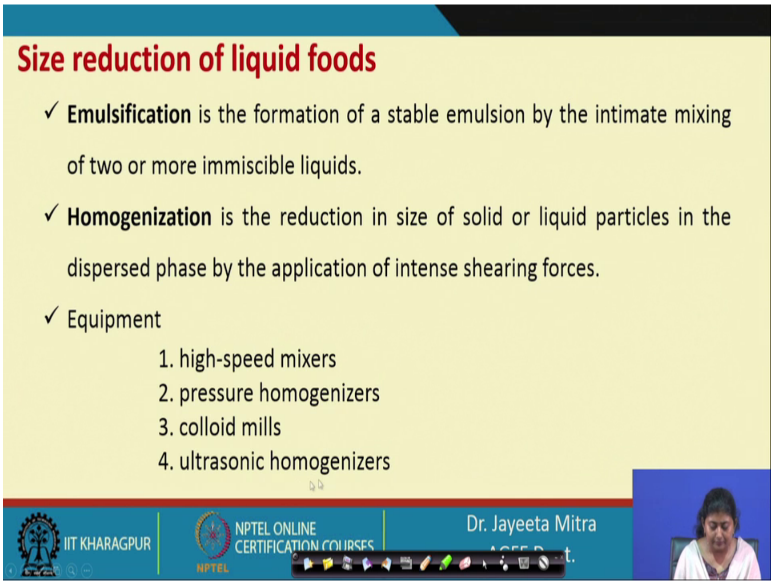
Rotary knife cutter, there is a rotary knife cutter which is the knives are attach with all the 5 different cones of the rotor, ok. And so this so, this knives are fixed with arranging, fixed with the screw, fix with the arrangement. And there is a screen also so, when the particle, when the particle will be reduced in the size because of action of this, these blades they will come down and discharge from the bottom. So, how they work? There is a horizontal rotor in cylindrical chamber and which rotates 200 to 900 rpm speed. 2 to 12 flying knife with sharp edge are passing with a the clearance over 1 to 7 stationary knives. So, here the stationary knives are there.

So, stationary knives and when the flying knives are coming in between these two contact point. So, then the sharing happens and the particle will break.

So, feed reduces several 100 times because of this arrangement. Bottom skin opening is 5 to 8 mm, so, when the particle size comes lower than that, it will come down from that sieve. Knives at an angle or parallel to the stationary sieve, so, this knives which are coming down every time. So, there is a two stationary knives hear and all the flying knives are attach with the rotor. So, these are you know coming with an angle or with just parallel to the stationary knives.

So, that the, the clearance between these two should be very less, the stationary knives and the flying knives, so, that the cutting action will be done.

(Refer Slide Time: 09:18)

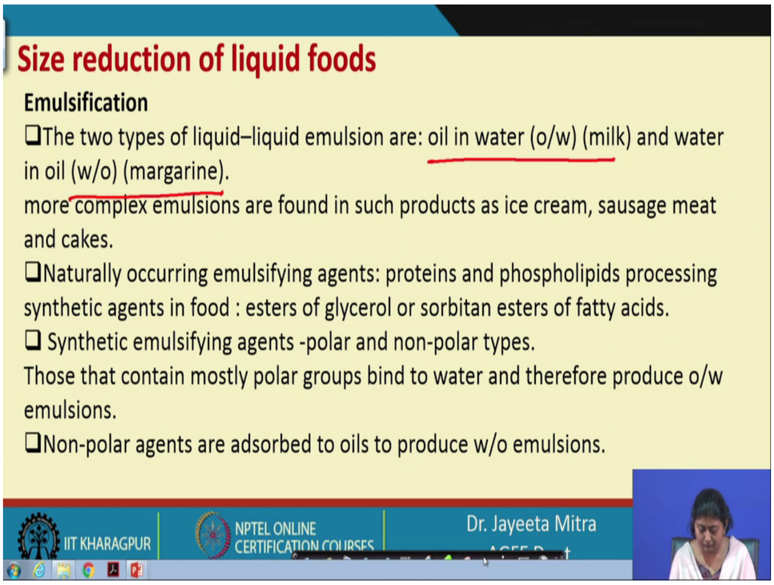


Now, coming to the size reduction of liquid foods. So, as we have seen that for the, for the solid material there are very different applications, very different kind of equipments are available which work on the compression, shear, impact, cutting force etcetera. Now, if we look into the liquid product so, there also in some application, we need to make the smaller particle. For example, the, the most common is the milk when we want to homogenise the milk, the distribution of fat in the milk we want to make you uniform. So, we try to reduce the fat particles, fat globule into the small, small size and distribution will be uniform because of that. So, those kind of operation we will see now.

In that generally we do Emulsification and Homogenisation. So, Emulsification is the formation of a stable emulsion by the intimate mixing of two or more immiscible liquid, ok. So, emulsion, we call it because there is a continues phase and there is a disperse phase, so, it founds an intimate mixer of two immiscible, two or more immiscible liquid, then we call it emulsion.

And what is homogenisation? Homogenisation is the reduction in size of solid or liquid particle in the dispersed phase by the application of intense sharing force. So, the equipment we used for this application is high speed mixers, pressure humanizer and colloid mill, ultrasonic homogeniser. So, we will see that one by one, how they perform and also we will see a few detail of the emulsification and homogenisation process.

(Refer Slide Time: 11:28)

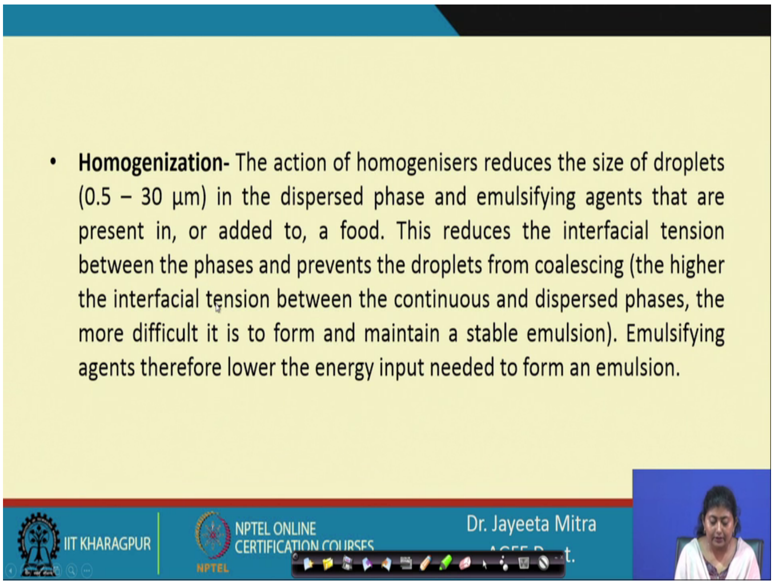


So, size reduction of liquid food. In that emulsification, when we want to perform we can, we can we can prepare two kind of emulsion liquid liquid- liquid emulsion, one is oil in water ok, one is oil in water emulsion that is milk and water in oil emulsion that is margarine,. So, more complex emulsions are found in such products such as ice cream, sausage meat and cakes because oil in water emulsion in milk or water in oil emulsion in margarine, these are most common.

And when we go for the ice cream preparation or cake preparation or sausage meat preparation, that time the formation of emulsion the formation of a liquid- liquid emulsion structure will be more complicated. Now, there can be naturally occurring or synthetic emulsifying agents that we commonly use.

So, naturally occurring emulsifying agents that are protein and phospholipids that we use in the processing. In the synthetic agents and the food are ester of glycerol or sorbitan esters of fatty acid, ok. So, synthetic emulsifying agents maybe polar and nonpolar type. Those that contain mostly polar group bind to water and therefore produces oil in water emulsion. And nonpolar emulsifying agents, these are absorbed to the oil to produce the water in oil emulsion. So, we have seen that where the importance of polar and nonpolar emulsifiers occurs.

(Refer Slide Time: 13:54)



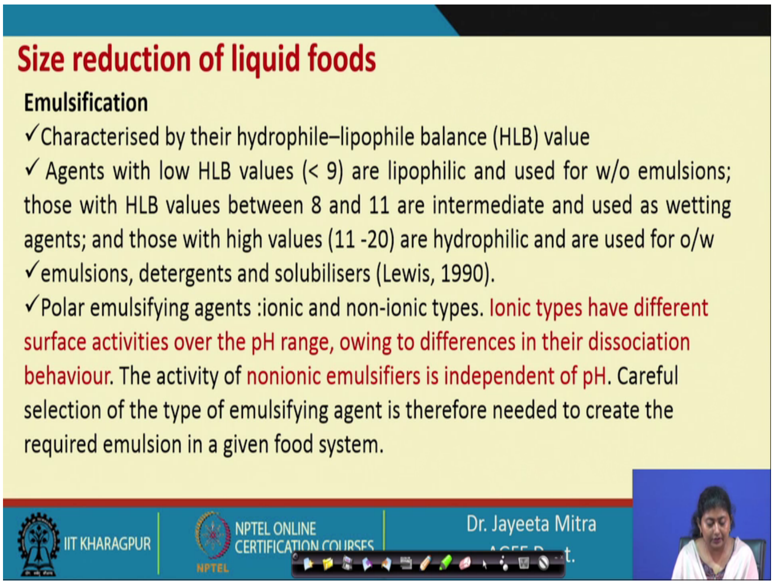
Now, if we look into Homogenisation, the action of homogenisation reduces the size of the droplets from 0.5 to 30 micrometer in the dispersed phase and emulsifying agent that are present in, ok. So, they, they degrade the size of both of them or it has been artificially added also to the food, the emulsifying agent. So, this reduces the interfacial tension because size has been reduced from very low, very low size from the initial size fraction.

So, because of this lot many energy is required and this reduces the interfacial tension between the phases, and prevent the drop prevent the droplets from coalescing. So, phases because the, the phase difference between the you know, the, the bubbles, the bubbles and the continuous face, continuous liquid will be there.

So, interfacial tension between these bubbles and the liquid phase will be lowered and that will that prevent the drops to coalesce once again and form the higher particles. The interfacial tension between the continuous and dispersed phases, the more difficult it is to form and maintain the stable emulsion. So, somehow, we need to lower the interfacial tension. Emulsifying agents therefore, lower the energy input needed to form an emulsion.

So, this emulsion and dispersion, you might have done some experiment in the lab where you have seen that to make an emulsion we need to give very high, very intensive energy input. So, that we can create the, we can, we can reduce the interfacial tension between the, the droplets and continuous medium.

(Refer Slide Time: 16:07)



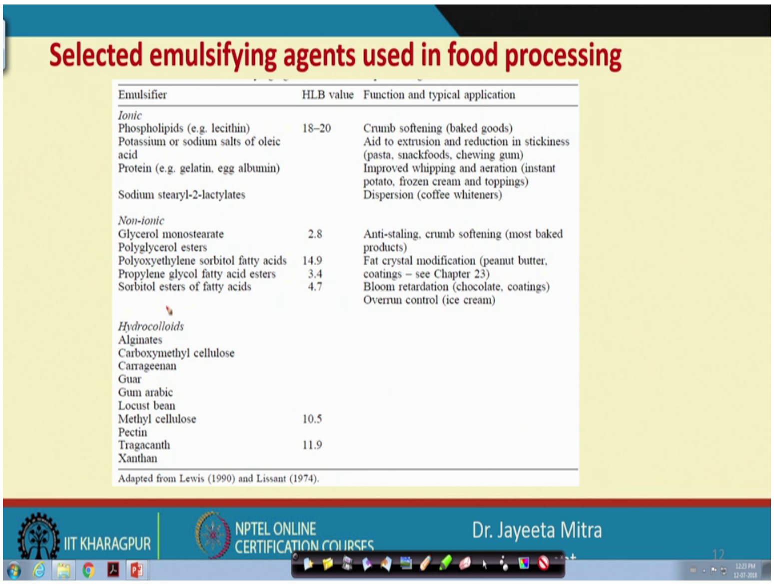
Now, emulsions, these are characterized by their hydrophilic, hydrophile and lipophile balance, that is called the HLB value. Hydrophile and lipophile balance by which they can added to the, added to the water or the lipids or the polar and nonpolar material. So, this agents that the emulsifying agents that we use they may have low HLB value or high HLB value.

So, this agents with the low hydrophile and lipophile balance value when it is less then 9 are lipophilic and used for water in oil emulsion, ok. Water in oil emulsion just for example, butter or margarine and those with the HLB values between 8 and 11 are intermediate intermediate cathartics and used as waiting agents.

And those with the hard value that is 11 to 20; these are hydrophile and used for the oil and water emulsion. So, we have three distinct cases when HLB is very low, lower than 9, then this is emulsifying agents will use for making the water in oil emulsion. When this HLB ranges from 8 to 11 then intermediate; that means, these emulsifying agents are use for increasing the vitavelity. And when this is increasing 11 to 20, this HLB value then the hydrophilic nature is increasing and oil in water emulsion will be there.

Now, polar emulsifying agents may be also ionic and non ionic types. Ionic types have different surface activities over the different pH range owing to the difference in their dissociation behaviour. However, the activity of non ionic emulsifier is independent of the rang of pH. We need to carefully select this emulsifying agent and is therefore, needed to create the required emulsion in a given food system. So, choice of emulsion is based on the types of the product and that is very important.

(Refer Slide Time: 18:44)



Emulsifier	HLB value	Function and typical application
Ionic		
Phospholipids (e.g. lecithin)	18–20	Crumb softening (baked goods)
Potassium or sodium salts of oleic acid		Aid to extrusion and reduction in stickiness (pasta, snackfoods, chewing gum)
Protein (e.g. gelatin, egg albumin)		Improved whipping and aeration (instant potato, frozen cream and toppings)
Sodium stearyl-2-lactylates		Dispersion (coffee whiteners)
Non-ionic		
Glycerol monostearate	2.8	Anti-staling, crumb softening (most baked products)
Polyglycerol esters		
Polyoxyethylene sorbitol fatty acids	14.9	Fat crystal modification (peanut butter, coatings – see Chapter 23)
Propylene glycol fatty acid esters	3.4	
Sorbitol esters of fatty acids	4.7	Bloom retardation (chocolate, coatings)
		Overrun control (ice cream)
Hydrocolloids		
Alginates		
Carboxymethyl cellulose		
Carrageenan		
Guar		
Gum arabic		
Locust bean		
Methyl cellulose	10.5	
Pectin		
Tragacanth	11.9	
Xanthan		

Adapted from Lewis (1990) and Lissant (1974).

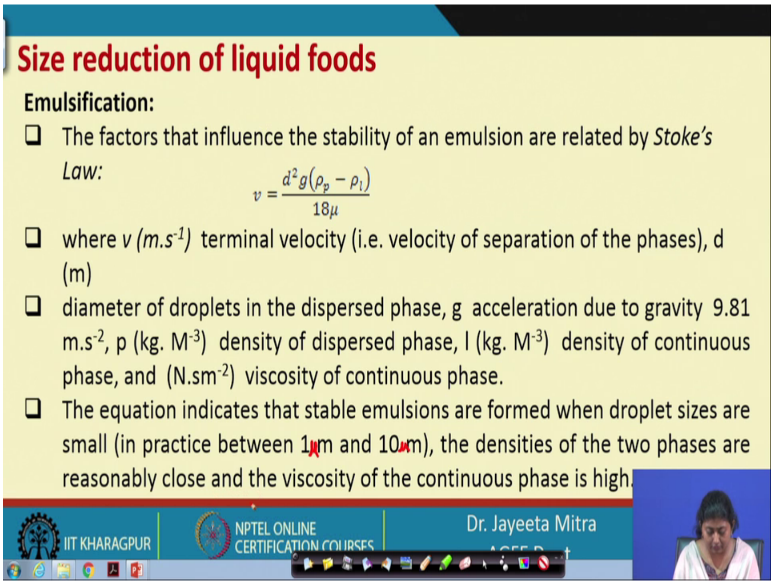
Now, selected emulsifying agents use in the food processing has given in this diagram even in this table. So, in the left side emulsifier list has been given, HLB value is given at the middle and the functions and typical applications are given at the right.

So, one or two we can see for example, in the ionic emulsifier phospholipds is there as for example, lecithin and this is use for crumb softening of the baked products. and that is also potassium or sodium salt of oleic acid, these are use to aid to extrusion and reduction in the stickiness of fast, fast snack food, chewing gum, etcetera.

Similarly, if we look in to the non ionic emulsifier, so, there are also glycerol monostearate that we are using, that we are using and this is using for anti sterling effect crumb softening for the backed product. So, we can see that both ionic and non ionic emulsifiers are exist for this baked product softening. And there are hydrocolloids also like alginate, carboxymethyl cellulose, carrageenan, etcetera.

So, based on what is our application, we can select different kind of this material. For example, bloom retardection, in the chocolate we have seen the fat bloom that is the fat crystallisation may happen on the surface of the chocolate sometime. So, that can be you know control by propylene glycol fatty acids ester, ok. Sorbitol easter of fatty acid, so, using this we can reuse the fat bloom on the chocolate surface.

(Refer Slide Time: 20:50).

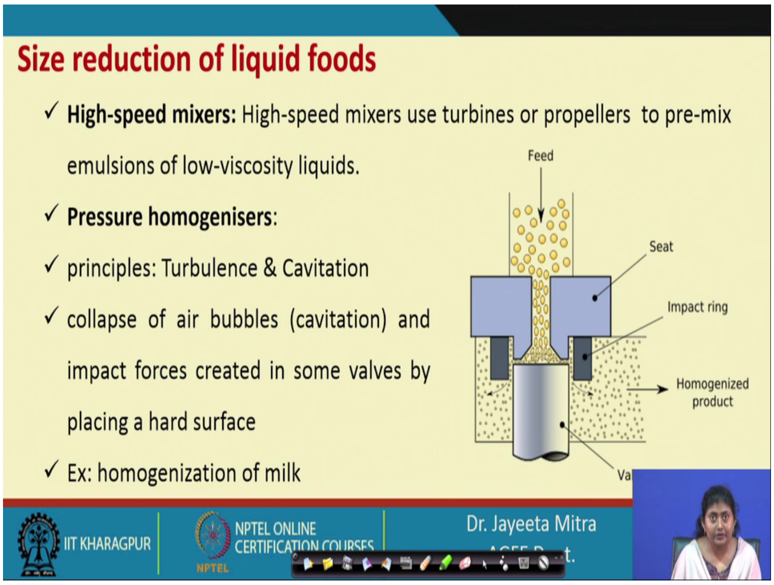


Now, size reduction when we, when we want to see the liquids using emulsification and homoginization behaviour, the factor that influence the stability of the emulsion, that is very important and that can be you know related using Stokes law. It says that the terminal velocity v will be d square into g into rho p minus rho l by 18 mu this is nothing, but the expression of terminal velocity.

Here the velocity is the separation velocity of the separation of the phases, ok, d is the diameter of the droplet in the dispersed phase, g is the acceleration due to gravity value is 9.81 meter per second square, rho is the density kg per meter cube of the dispersed phase and if, if he rho p and rho l is the density of the continuous phase of the liquid. So, here ideally, we should we should write rho l and rho p and mu is the viscosity, mu is the viscosity of the continuous phase.

Now the equation indicates the stable emulsion are formed when the droplet size are small, in practice between 1 to 10 micrometre. So, this will be 1 micrometre to 10 micro metre and the density of the two phases are reasonably close and the viscosity of the continuous phase should be high.

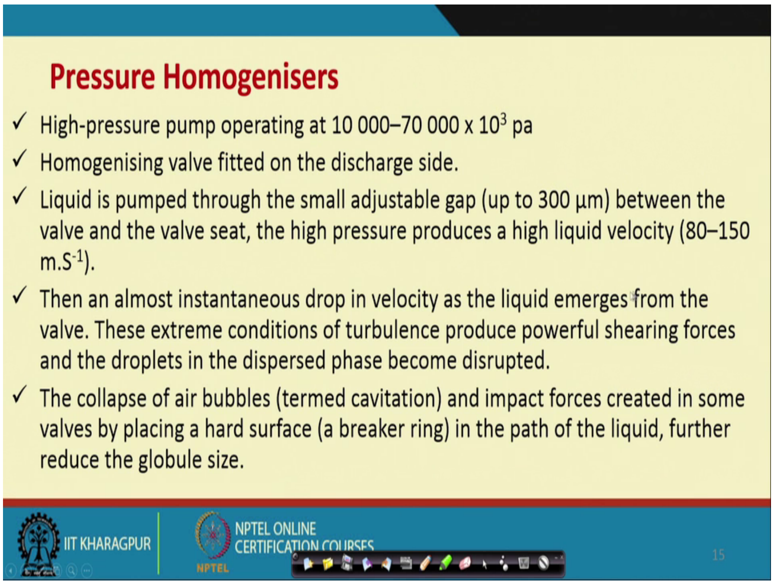
(Refer Slide Time: 22:49)



Now, there are different kind of equipment used for liquid homogenization and liquid droplet size reduction emulsification. So, one is high speed mixer, high speed mixtures used turbines or popular to premix the emulsion of low viscous liquids. And pressure homogenizer, pressure homogenizer actually works on the principle of turbulence and cavitation this is how the pressure homogenizer look like. The feed is coming from one side and there is a wall and as a wall and homogenizer product which is coming from this inner gap between these two, these two called the impact ring and there is a wall sheet also.

So, continuously this valve is facing on the wall sheet and the fat globules are in a (Refer Time: 23:44) and small particles will form and that will eventually mix with the continuous phase. So, was happen, what happen exactly, that will see. The collapse of this year bubbles which is called the cavitations and impact forces created in some wall by placing a hard surface, hard surface is a valve sheet here.

(Refer Slide Time: 24:09)



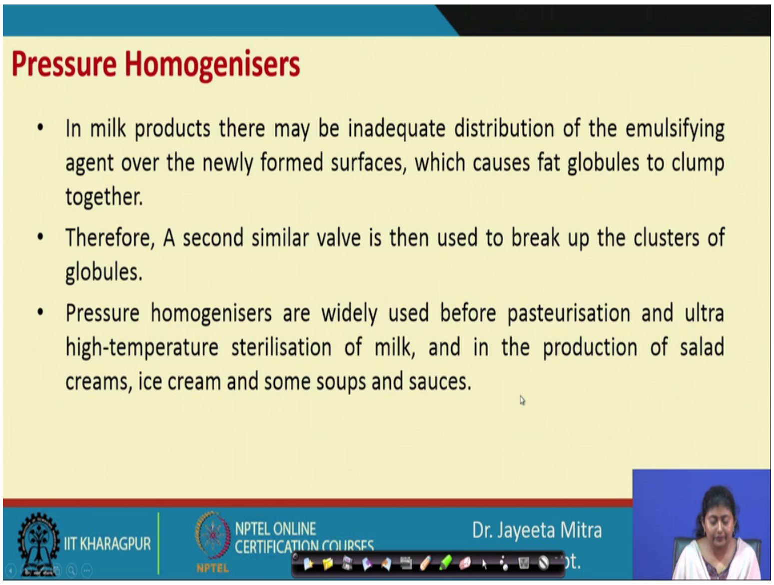
So, this process is being done in homogenization of the milk. So, high pressure pump that we use here has the pressure of 10000 to 70000 into 10 to the power 3 pascal. Homogenising valve which is fitted on the discharge side, so, we have just now seen that this is the discharge side from which the, from where the, the product is you know (Refer Time: 24:35) particles smaller particle is coming, coming out. So, in the discharge in the valve is there.

Liquid is pumped through the small adjustable gap that is up to 300 micrometre between the valve and the valve sheet. And the high pressure produces a high liquid velocity that is 80 to 150 meter per second. Then and almost instantaneous drop will be there, instantaneous the liquid velocity is very high because of the pressure. Now, instantaneously those velocity is released because the, the velocity is dropped as the liquid emerges from the valve and mix with the in the continuous section.

So, this extreme condition of turbulence produces powerful shearing forces and the droplets in the dispersed phase become disrupted. So, the collapse of the air bubble which is called the cavitation and impact forces created in same wall by placing a hard surface or a breaker ring sometime in the path of the liquid, we can for the reduce the size of the globule.

So, this is how because of the turbulence and cavitation, the size of the globule is reduced because of the pressure of homogeniser action.

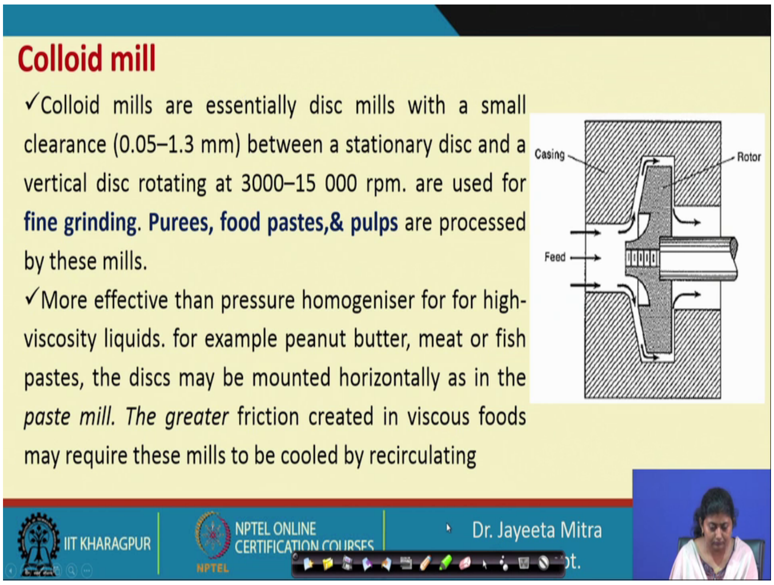
(Refer Slide Time: 26:00)



In milk products, there may be an may be inadequate distribution of emulsifying agent, ok. Over the newly formed surfaces which causes the flat fat globule to clump together. So, therefore, a second similar valve is used to break up those cluster of the globules, ok. So, pressure homogeniser are widely used before pasteurization and ultra high temperature sterilization of milk and in the production of the salad cream, ice cream and some soup and sauces.

So, because of the efficiency of pressure homogeniser to handle the, handle the, viscous or semi viscous liquid and to make the emulsification better, the ice cream production and also the salad cream production soup and sausage production, use this special homogeniser technology.

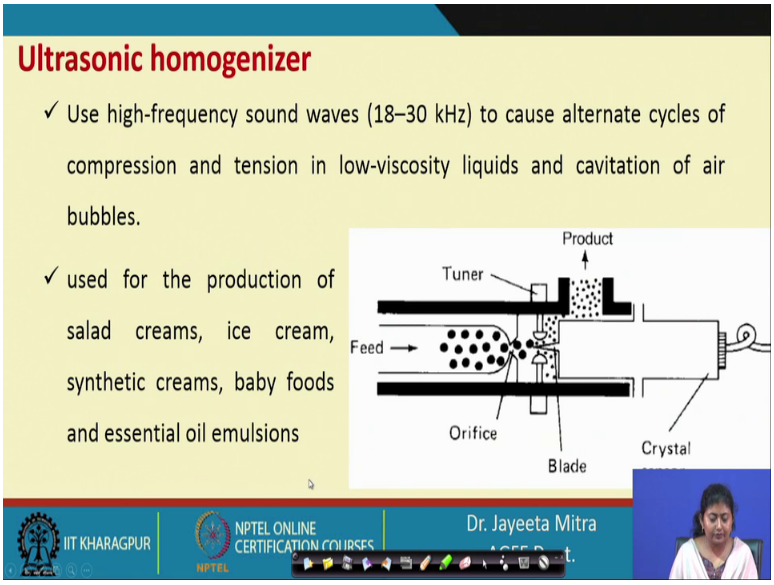
(Refer Slide Time: 27:06)



Now, the next is colloid mill, colloid mills are essentially disc mill with a small clearance 0.05 to 1.3 mm between a stationary disc and a vertical disc rotating at 300 to 15000 rpm. And these are used for fine grinding, puree, food paste and pulp and are process by this colloid mill more effective than the pressure homogenizer for the high viscous, high viscous liquid. However, for the low viscous this colloid mill is not suitable this is form the clump or aggregation.

For example, if for the high viscous product like peanut butter, meat or fish paste this colloid mill is used. So, disc may be mounted horizontally as in the paste mill. The greater friction created in viscous food may require this mill to be cooled by recirculating. So, recirculation we can we can have by chilled water, ok, so, to cool the to cool the system. So, here the feed is entering from one section and this is the disc which is rotating and here from the very fine gap it is coming out the other side. This one is a rotor and this is called the casing.

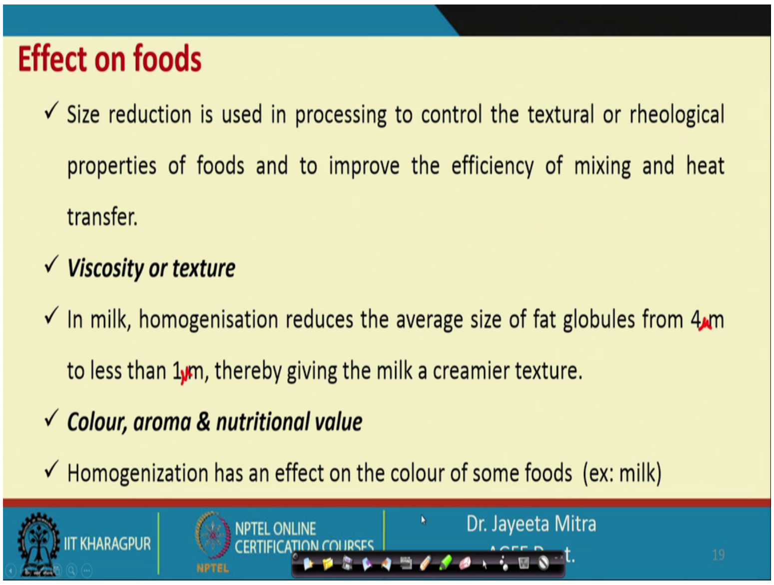
(Refer Slide Time: 28:49)



Next, we have ultrasonic homogenizer, ultrasonic homogenizer use high frequency sound wave, ranging from 18 to 30 kilohertz to cause alternate cycles of compression and tension in low viscous liquid and cavitation of air bubble occurs, ok. So, this is how it looks like. The feed is entering from one side there is an orifice which release very fine amount of, of, of the particle through this and there is a blade which is giving a cutting action to this; there is a crystal sensor and the product outlet.

So, sound waves are created which cause the alternate cycles of the compression and tension in low viscous liquids and cavitations also occur. This is used for production of salad cream, ice cream, synthetic cream, baby food and essential oil emulsions.

(Refer Slide Time: 29:51).

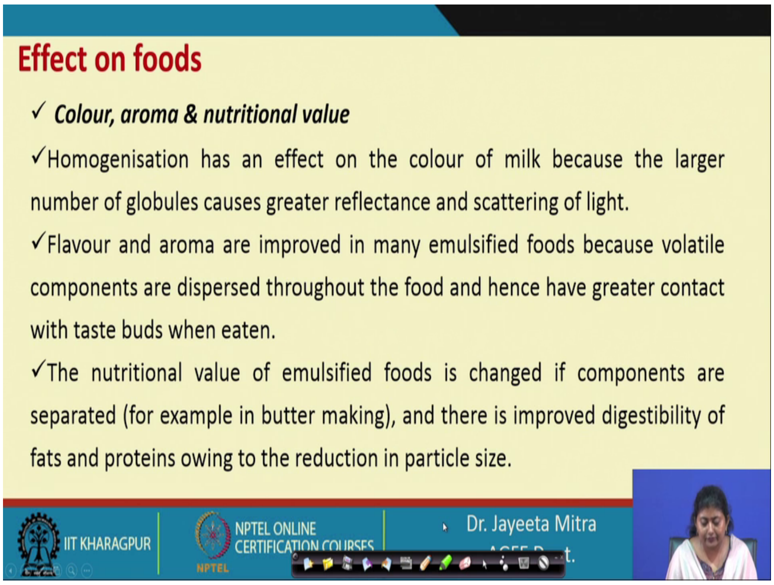


Now, all this emulsion and you know the homogenization that we do, they have certain effect on the quality of the food that we produce, ok. So, size reduction is used in processing and control the textural or rheological properties of the food to improve the efficiency of mixing and heat transfer. So, that is because, if this is true for solid particle size reduction and also for the size reduction of the liquid material.

So, when we increase the surface area so; obviously, the transfer process this can occur across the surface area will enhance that, that is one thing. Also, the similar type of particle, similar size and similar shape of the particle, similar characteristics of the particle will have better flow behavior both for the dry flour material and for the wet material.

So, if you look into the effect of this size reduction on the viscosity or texture especially, if we consider a particular food where we practice homogenization such as milk. So, homogenization reduces the average size of the fat, fat globules from 4 micrometer to less than 1 micrometer and thereby giving the milk a creamier texture.

(Refer Slide Time: 31:46)

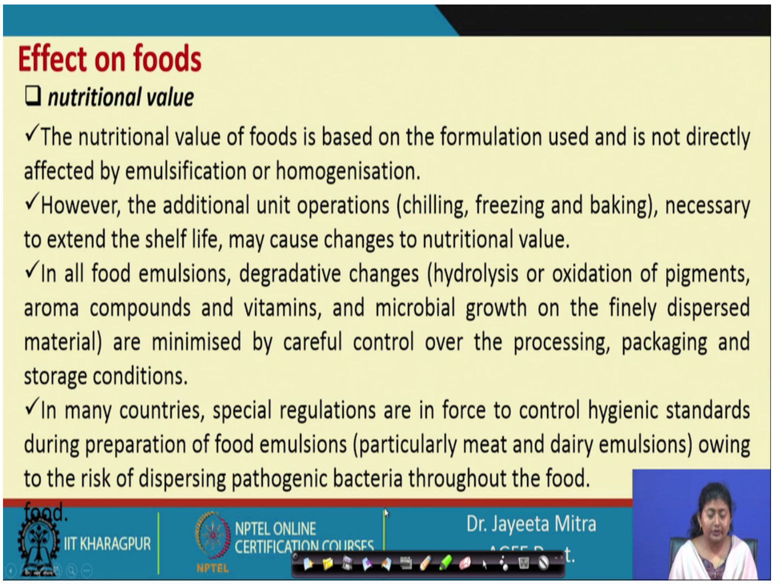


And colour aroma and nutrition value, if you see homogenization have an effect on the colour of some foods. For example milk, if you see how it is affecting. homogenization has an effect on the colour of the milk because larger number of the fat globules cause greater amount of reflectence and scattering of the light. So, this scattering of the light from all the fat globules uniformly change the colour of the milk.

Now, flavour and aroma are improved in many emulsified food, because volatile components are dispersed and throughout and the food hence, has greater contact with taste buds when they are eaten. So, flavours are improved in certain cases.

The nutritional value of emulsified food is changed if components are separated for example, butter making, if we separate the components the lighter and heavier components when we separate than the nutritional value will be definitely going to be affected. And there is improved digestibility of fats and proteins owing to the reduction in particle size. So, when particle size reduce, the digestibility of the fat and protein will also improve.

(Refer Slide Time: 32:58).



Now, also on the nutritional value, we can see that the food is based on different formulation, ok. So, the composition is, is an important thing. And based on the formulation used, it is not directly affected by the emulsification or homogenization; it is affected as the composition changes.

However, the additional unit operation what we perform some time after this size reduction thing for example chilling freezing, chilling of the milk or freezing phenomena, baking of the flour, etcetera. So, they are necessary to extend the shelf life and may cause changes to the nutritional value. And all food emulsion degradedive changes; that means, the hydrolytic rancidity or oxidation of the pigments, aroma compounds and vitamins microbial growth on the finely dispersed material these are minimized by careful control over the processing packaging and storage condition.

Because all of this cases, chances of this reaction the (Refer Time: 34:10) reaction will be high, if we do not maintain the proper storage or proper environment condition or do not follow the proper processing.

In many countries special regulations are there to control the hygenic standard during the preparation of food emulsion. Particularly in meat and dairy emulsion into the risk of dispersing pathogenic bacteria throughout the food because when we perform this kind of operation, if any contamination was there from you know prior of collecting the sample, then it will have a tendency to spread out, so that is why we need to be very careful. So, here we will stop, the size reduction chapter is over by now. So, we will move on to next topic in the next class.

Thank you.