Cooling Technology: Why and How utilized in Food Processing and allied Industries

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Module No 11

Lecture 54
Freezers

Good afternoon. Now, we are in the last phase of freezing. As you know earlier also, I had shown you and told you that, the freezing curve, ok, we have said, but the water, which gets frozen is asymptotic in nature, right. So, this is what we will come to know and afterwards we will do the different freezers, right, different freezers in detail we will talk about. So, what we see that, this one, this one. I had perhaps, told you earlier also that, if you plot time versus percent water frozen, then, you will get, I mean rather, temperature versus percent water frozen. Now, which one will be, you are plotting temperature and percent water frozen.

So, which one will be in the x, that is, x direction, and which one will be in the y direction, that is, which one will be independent variable, and which one will be dependent variable, right. So, if you could find out, very nice, otherwise, you see what we call independent, which is, on which some other is depending, right. So, which one is depending here, percent water frozen is depending on the temperature, right. So, temperature is in the x axis, and percent water frozen is in the y axis, right, and if you have a plot, right, you will see, you will get a temperature curve, like this, or a temperature curve depending on how you are plotting, what are the temperatures, what are the percent water frozen.

So, these are called, both these and that are called asymptotic, A S Y M P T O T I C. So, this is called asymptotic in nature, right. That means, just in the previous class, we said that the water, which is freezable, right, which indicates that there is some bound water, that means, that cannot be frozen so easily. This is called bound water right. So, this curve or this plot or this Table tells us that thing, that there are some water, like here, 90 percent, you could have frozen at minus 30 ^{o}C, but if to make it 91 or 92, you may have to go to minus 45 ^{o}C, or things like that. So, that is not easily freezable, right, there is nothing in the world, which cannot be frozen, you can freeze the entire thing, but you have to pay for that, right.

In normal freezing, you cannot freeze more than around 90%, or depending on the material, 90, 95, 92, 89, 85%, depending on the material, some water is freezable, some water is unfreezable, which is not freezable, that is called bound water, right. So, we

come to storage life of frozen foods, and that is normally at or below minus 18 degree centigrade. So, products with storage lives between 3 to 6 months and there are some mammalian meats, poultry, etc. Products with storage lives of 3 months or less, again that is mammalian meats, bakery products, etc. Products with lives of 6 to 12 months at or below minus 18 degree centigrade, say fish, mammalian meat, poultry, bakery products, etc. and products with storage lives of not 3, more than, greater than or equal to 12 months, or more, like fruits, they are sugared food, fruits, vegetables, mammalian meats, fish, egg, bakery products etc. at minus 18 ^{o}C, or below temperature, this is the normal life span for the frozen material, right.

Then, there are freezers, then we come to freezers, ok. Now, the moment we come to freezers, we tell that, we had given you a story of, we had given you a story of drip loss, of our prime minister, and US president, right. And that have paid, because the choice of freezer was not appropriate. By definition, we have 3 types of freezers, that is by definition, 3 types of freezers are there, one is called primary freezer, right. So, what we use in primary freezers, that is products are in direct contact with the refrigerant, in the form of a cryogenic gas or cryogenic liquid, or maybe solid.

Now, cryogenic liquid, solid, we know liquid nitrogen is a cryogenic liquid. Liquid oxygen is also a cryogenic liquid, but normally liquid oxygen is not used because, liquid oxygen is used mostly, in maybe, steel plant, or more in medical hospitals. But, yes, liquid ammonia, even is cryogenic liquid, solid carbon dioxide is a cryogenic solid, right. Solid carbon dioxide, I hope you know, what it is called, it is called dry ice, right. Dry ice is solid carbon dioxide, whose melting point is minus 78 degree centigrade, right, whose melting point is minus 78 degree centigrade, that is called solid carbon dioxide, or dry ice right.

Now, all these cryogens, unlike we have read the vapor compression refrigeration system, unlike with that, there are different cycles, by which air is liquefied, and then this liquefied air is distilled and obviously, the boiling point of oxygen is less than that of nitrogen. So, first oxygen comes out, and the nitrogen proportion goes up. In many developed countries, this is used as a byproduct, that nitrogen is used as a byproduct, and liquid oxygen is used as a main product, because that is more useful in hospitals, and also many other places like steel factories, and many others. So, oxygen is produced from the air, and liquid nitrogen, in those countries, is obtained as byproduct. The advantage of getting it as byproduct is that the price of this is much much less compared to that of the oxygen, main product, right.

So, in their countries, in developed countries, this primary freezers are many in use. Unfortunately, in our country, it is not there as of now, right. I know one case, that

British oxygen or BOC, they had given one such freezer to some company, and asked them with all facility, including liquid nitrogen supply, without taking any price, perhaps, I am not sure about that, asked some company to run it for 2 years, and give the report. I came to know, it was said that no it is good, but is not fit to our systems, or etc. Yes, I agree to one part, that this liquid nitrogen, typically is not available everywhere. In eastern India it is available in Kolkata in Jamshedpur.

So, what about in between places? In IIT Kharagpur, we have our own machine. So, there, we are producing, and we use, but, what about in between places? So, if I have one unit at Jhargram, or say Kharagpur, then where from the nitrogen will come? So, availability of this is one great disadvantage in developing countries, but in developed countries, they get it as byproduct, so, the price is also low. However, those, which come directly in contact with the material, like, if it is a say, fish, or say a meat, or whatever fish, and if it comes in direct contact with liquid nitrogen, or maybe some other liquefied gases, then there, you know, liquid nitrogen has a boiling point of minus 195.6 degree centigrade. So, such a huge delta T, right, this temperature is plus 30 ^{o}C, say and minus 195 ^{o}C. So, 220 to 230 degree centigrade is there as delta T, right, and overall heat transfer coefficient, is also high. So, almost instantaneously, the freezing is done, almost instantaneously, right. In our country, either moderate freezing rate, that kind of freezers, where it takes several hours, whereas, here, it is taking, maybe few seconds to couple of minutes, because of the temperature difference, and high heat transfer coefficient, overall heat transfer coefficient, right. So, those, which come in contact with the refrigerant directly, those freezers are called primary freezers, right. Obviously, the merits are very very high, like with that high temperature difference and high overall heat transfer coefficients, the size of the ice crystals, which are formed, are very very small.

So, number of ice crystals forms are very very high, whereas, size of the ice crystals formed are very very less, right. So, we can get frozen material, which has very small ice crystals, more in number, and when, it is thawed back, the drip loss is also as minimum, as possible, maybe, negligible, right. So, that is one of the biggest advantage of this, that the quality of the product is very very high, and we have said earlier also that, one of the prime reason of quality assessment, is one of the prime factor is that, finding out what is the size of the crystal, and how many numbers in crystals are there. So we get very suitable for small and thin product, very small ice crystals, insignificant dehydration, colour, flavour, structural changes are minimum, and drip loss in thawing is also negligible or as minimum as possible. It being such a beautiful freezing device, why then it is not used in developing countries?

One of the reason, which I just said that, the availability, is not available everywhere uniformly, and also the price, one of the prime factor, because, the moment the primary

refrigerant is coming in contact with the material to be frozen, that primary refrigerant is getting vaporized, and this vapour is not reusable, unlike vapour compression refrigeration systems, where, the liquid vapor refrigerant, when it is vaporized, in the evaporator, it can be recycled through compressor, but this type of refrigerant are called total loss refrigerant, right, total loss refrigerant, and because of this, total loss, that means, you are not able to put it back, price is also high right. Unfortunately, this is also negotiable, because if your consumption is very high, then you will get at a very considerable rate. When, I was in Quality Frozen Foods, Mumbai, I used to get from BOC at a rate of 5 rupees per cubic metre. It was very very cheap. However, this is one demerit, that is, not available everywhere uniformly, and the price. Another technical defect is that, the price, but because of the delta T, high, this is the food product, because the delta T is very high, is around, less than 200 degree, right.

The surface gets frozen very quickly compared to the interior. So there is a delta T difference, from inside to outside, and this may cause a thermal crack. This may cause a thermal crack. Obviously, it is also taken care of, but, if you can take care of it, that the refrigerant will not come directly in contact with that, then you can avoid it, right, because, here you are getting both latent heat as well as sensible heat, both you are getting, because, you are getting 200 degree minus say, may not be 200 say, minus 190 degree centigrade, you are getting vapour. So, that vapour also, you can utilize, right. So, if you correctly choose it, then you may apply, you may get benefit out of that, there is no ambiguity about the quality of the frozen material, but this is one technical difficulty, that the thermal crack may be there, for which, you have to take care of the freezing system, right ok.

So, the large frozen product may display severe cracking, due to extremely uneven cooling at the surface and interior, as I explained just now, right. So, there is then the another type that is called secondary one, secondary freezers, right. So, secondary freezers, by its name, we can understand that, if this is the primary, then it is giving it to some other one, which in turn is giving to the material to be frozen. So, that is why, it is secondary, right. Two steps, that refrigerant is cooling the, sorry, the refrigerant is cooling the freezer, cooling the freezer plates, generally, it is plate freezers, by and large. So, you have the cooling coil down below, and these are adjustable.

So, you can, you can do this way, and that way this can be adjustable, and the food material is kept in contact with this, and that, right. So, this is called plate freezers, and plate freezers are very widely used in developing countries, unlike developed countries, right, where these plate freezers are not normally, nowadays, used because of, as we have shown, the drip loss is very very high, right. Another thing, which is that, this plate freezer, it has coil in both the plates and you have kept your material, you see, it being

plate, two plates. So, either the material has to be rectangular shaped, or cubed or similar kind of things. So. it is shape dependent, you cannot take any irregular shape, which is not there in the primary, because primary, whatever be the shape, the entire material is coming in contract with the primary refrigerant.

So, shape is not affecting, size, may be size, everywhere in heat transfer, size is one of the factor, right, but shape, in this case is the one, primary one, unless it has a definite shape, it will not be, it will not be possible to do that, right. But, it has a great advantage, what is that advantage? Because, it is vapour compression refrigeration system, because the plates are cooled by the coil, refrigerant coils, right, and the refrigerant is passing through this and then ultimately going to the back to compressor. This being evaporator, going back to the compressor and again through condenser then expansion device then coming back to the evaporator back to compressor. So, this is in a in a cycle. So, that is reducing the running cost very sharply, right, running cost is very low, that is why, in developing countries, where you get the support of buying one time, that support, you get, but, running it, you do not get any financial support. So, it is very very difficult for those which are having high running cost, then the installation cost right.

If installation cost is high, they do not mind, because some financial organization will help, but running cost high is not tolerated in the developing countries, right. So, the demerits, which we can say. are that, irregular shaped product, very difficult to freeze, time of freezing is very high, and larger ice crystals are formed. So, quality is also questionable one, right. Then the third one is called tertiary type, right, from that word tertiary, means, primary is giving to secondary, secondary is giving to tertiary, which in turn is giving to the food product, that is three steps. So, primary refrigerant, that is not the primary refrigerant, which we were referring to earlier.

It is the refrigerant, whatever you are using, whether vapour compression or any other, that refrigerant is cooling some device, normally called air handling unit, AHU, and that air handling unit, which is a, which is a heat exchanger, is cooling in turn air and this cold air is then blasted over the material, and the material gets frozen. So, tertiary means, that primary one is giving to a secondary one that is the air handling unit, and that air handling unit is a heat exchanger, is giving to the food material, air, sorry, giving it to or lowering it that, lowering the temperature of air, and this air is then blasting over the material, and the material is getting frozen. It has advantage in one way, that, it can also, like the primary freezer, it can also handle any shape, or size. So, like primary one, individual quick freezing, IQF, is possible with this type of freezer also, but one of the defect, as I said earlier also, is that freezer burn may be possible and somewhat drip loss, may not be, to the tune of secondary freezer, but somewhat drip loss is a concern. Then, lastly let me show you this is one primary refrigerant, that is liquid nitrogen freezer, right,

this is how the single units are getting frozen, there will be three zones, one is freezing zone, one is pre cooling zone, and other is the equilibration zone, right.

And this is another one plate freezers, I did not show, I normally, it is very easy to visualize that, these are the two plates, and their coils are there, ok. This is a tertiary freezer, or air, frozen air, rather, cold air is blasted, right, and this is very very in compact, and may be used by, say, single person, and this is a spiral freezer, right. So, with this our time is up, we have concluded the freezing ok. Thank you very much.