# Ice Crystal Formation

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Freezing is a common form of preservation that offers considerable advantages for some foods compared to thermal processing that uses heat for canning products.

Most fruits and vegetables retain much of their fresh flavour and texture when properly frozen soon after they are harvested or picked. The real trick in freezing any food product is understanding the actual freezing process, and then taking every possible precaution to make sure that it is done right.

As an important first step, you must begin with high quality produce. There's no sense spending a lot of time and effort to freeze something which is sub-standard right at the start. Many fruits and vegetables require pre-treatments beyond just the usual washing and cutting. Be sure overlook or ignore any of these steps.

Previously, we have looked at blanching as a way of de-activating naturally occurring enzymes that can degrade quality during frozen storage. Peaches and other fruits that are susceptible to browning may require dipping in a Vitamin C solution so that they retain their colour and flavour. Lemon juice or commercially available products can be used for this purpose.

Now, let's take a look at what happens as our food goes through the actual freezing process. The best way to do this is to consider a container of pure water placed in your freezer. We can then follow its temperature through the time it takes to completely solidify. In the accompanying diagram, the water starts out at room temperature and begins to cool as soon as it is placed in the freezer.

The temperature drops over the first hour or so until it reaches its freezing point (i.e., zero degrees Celsius). At this temperature, we begin to have a change in state of the water from a free-flowing liquid to a rigid solid. A lot is going on at the molecular level and is not visible to us. While it was in its liquid state, the water molecules had no real organization relative to each other. However, in their solid state as ice, the water molecules become arranged in a much more structured fashion which we refer to as ice crystals.

In order to create the proper alignment, heat must be removed from the water to overcome the transitional barriers between the liquid and solid state. Even though heat is being removed, the temperature of the water and ice does not change until all the liquid water is converted to ice. Since the effects of the heat removal are hidden from us and there is no apparent change in temperature, we call this heat removal, the latent heat of fusion.

Ice formation begins with a few molecules of water being converted to ice and coming together in a process known as nucleation. All through the liquid, tiny ice crystals begin to grow. As long as there are water molecules present as liquid, we will have ice crystal growth. Once the last water molecules become properly oriented into the ice crystals, the temperature of the ice will begin to drop until it reaches the temperature of the freezer in which it is being held.

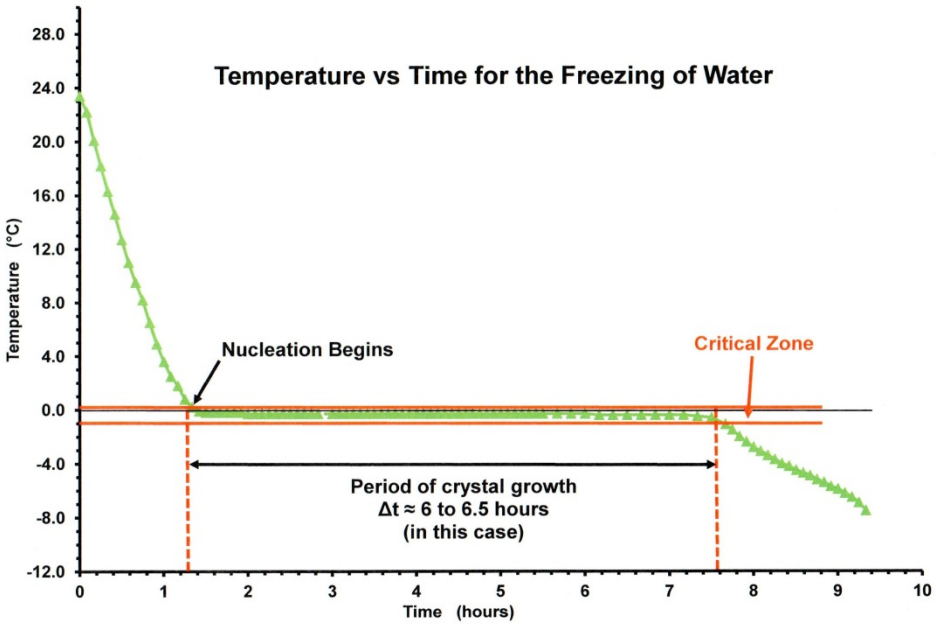
Sometimes, the temperature of the water may fall three or four degrees below the freezing point and yet the water is still liquid. This happens when there are no nucleation sites to promote ice crystal formation and we get what is called “super-cooling”. Eventually, nucleation will start and the temperature of the super-cooled water will actually rise up to its freezing point while the freezing process proceeds from there.

The important thing to note in the diagram is the length of time between the start of the nucleation and the complete freezing of the water. This “Critical Zone” is the time period for ice crystal growth. Rather than forming many tiny ice crystals, larger ice crystals are growing from the nucleation sites.

Unfortunately, large ice crystals can ruin product quality by drawing moisture out of the plant tissue, causing plump tissue cells to shrink or collapse. In order to ensure the best possible quality, we must get our fruits or vegetables frozen quickly so that they spend as little time as possible in the critical zone where ice crystal growth causes severe damage.

The most efficient and practical way to speed freezing is to spread the material evenly on a tray or cookie sheet with spaces between the individual pieces. This works extremely well for strawberries since it allows heat to be removed from each individual berry more quickly than would be the case if you had a solid mass of berries in a sealed plastic bag. Once the individual berries are frozen on the tray, they can be transferred to a freezer bag which should then be sealed, and labelled with the date included.

The bottom line here is that you need to get all the water inside the fruit or vegetables into the form of ice as quickly as possible and avoid the unwelcomed growth of large ice crystals.


Temperature vs Time for the Freezing of Water
Temperature (°C)
28.0
24.0
20.0
16.0
12.0
8.0
4.0
0.0
-4.0
-8.0
-12.0
Nucleation Begins
Critical Zone
Period of crystal growth
Δt ≈ 6 to 6.5 hours
(in this case)
0
1
2
3
4
5
6
7
8
9
10
Time (hours)