WATER CONTROL

Keeping Ice Crystals at Bay in Frozen Foods

Numerous hydrocolloids can help mitigate the damage to product quality once in the consumer's hands.

by Nesha Zalesny

Few things can cause more damage than out of control water. Because water's volume increases around 9% as it freezes, the combination of ice and water can find weak points in even the hardest stones and crack them apart. This is how glacial waters formed continents and mountain ranges.

So if water can form landmasses and crack boulders, imagine what uncontrolled water can do to more delicate materials such as fruit or vegetable tissue or a foam.

Controlling the flow of water in food systems is paramount to the quality of the finished product. Fortunately, food formulators have a few tools to accomplish this—many of which are hydrocolloids.

Hydrocolloids are long-chain polysaccharides that are evenly dispersed throughout water. They can help maintain frozen foods' quality by modifying the flow of water.

Deeper Dive into Water

Is there anything worse than scooping out your favorite ice cream and taking that first bite, only to find it sandy? This all-too-common occurrence is the result of heat shock. Perhaps the ice cream was left in a warm car a little too long on the way home from the grocery store, or your partner or child served themselves and left the carton on the counter for a while before remembering to put it back in the freezer.

This extra time in warm temperatures enabled the small ice crystals that are formed during production to partially melt. Similar to glacial forces, once the ice cream is re-frozen, that melted water freezes into large ice crystals, which disrupts the foam and creates an unpleasant sandy texture.

Unfortunately, all frozen food is subject to the same ice-to-water-back-to-ice migration problem. The results are not only sandy ice cream, but spinach artichoke dip with pools of water surrounding the vegetable inclusions, or meatloaf with gravy that has a dehydrated skin on it and watery run-off around the meat. Multi-component foods like pizza or pasta can have components with vastly different water content, such as crust, sauce, and cheese topping.

Osmotic moisture migration between the components is inevitable, which can lead to a soggy crust or watery cheese. All of these reduce the quality of the eating experience for the consumer and are examples of defects that happen when water is not controlled.

Anticipating Behavior

One of the most difficult aspects of formulating frozen foods is anticipating what may go wrong when that product leaves the manufacturer. Whether that is heat shock, over or under cooking, or any myriad of things that the consumer may do to the finished product, formulators must predict different scenarios and formulate, process, and package accordingly.

As much as a formulator would like to remove all water and package products in a vacuum, this is not usually practical nor palatable. Food manufacturers have access to equipment that will freeze foods nearly instantly. In the case of ice cream, the finished product is frozen while it is being churned, which helps form tiny ice crystals. Food that looks great coming off the production line will look and taste quite differently after being heat-shocked.

Freezing Speed

A key method to creating high-quality frozen food is to control the speed at which the food is frozen. Slower freezing rates create foods with fewer but larger ice crystals. Rapid freezing creates smaller crystals, but these smaller crystals are more susceptible to temperature fluctuations.

Prepared foods are usually processed and packaged, then run through blast chillers. These chillers freeze foods nearly instantly at around -60°C. The water is frozen instantly and contained within the plant or meat matrix. Because the water is crystalized so quickly, small ice crystals form, which do not disturb the vegetable or meat structure.

Unfortunately, because they are small, they quickly melt into free water if the storage temperature increases only slightly. This water then freezes into larger ice crys-

› *Viscosifiers, such as xanthan, guar, tara gum and konjac gum, can slow moisture migration between individual components such as the sauce and crust of frozen pizza.*

tals once frozen again. This kind of temperature cycling can easily occur in most anti-frosting home freezers.

Technically, unless the food drops below the eutectic point for each component, the product is never completely frozen. Rather, it is an amalgamation of crystalline and free water, along with all the other ingredients in the product. Even blast chillers do not generally reach low enough to completely freeze the water in the system. Certainly, once the product has left the manufacturer, storage temperatures will fluctuate and create free water.

Sweet Functionality

Another method formulators use to maintain the quality of frozen foods is to control the sugar dissolved in the water of the formulation (otherwise known as soluble solids).

Sucrose is one type of soluble solid. It is a disaccharide comprised of fructose and glucose. Other soluble solid types include maltodextrins and corn syrup solids, which have different functionalities.

Maltodextrins are longer in length than sucrose; they are usually measured in terms of dextrose equivalents (DE). A maltodextrin is technically anything between 3 and 20 DE, whereas corn syrup solids will be around 24 DE.

Most ice cream manufacturers use sucrose and corn syrup solids. Simple sugars are sweet, and they lower the freezing point of water. Consequently, they will soften frozen products.

Higher DE products like corn syrup solids are not as sweet as sucrose; they add solids but do not lower the freezing point of the finished product. Corn syrup solids will add bite and harden the product and raise the freezing point slightly. Ice cream manufacturers call this a "warm bite."

Manufacturers blend sucrose and corn syrup solids to create the best texture with just the right amount of sweetness.

Controlling Water in Savory Applications

The addition of sucrose or slightly sweet corn syrup solids may not be an option for all foods. For savory applications, maltodextrins or starches are a better choice as they tend to be bland or flavorless. While maltodextrins have a DE of 3–20, starches are very long chains of glucose.

They can hold upwards of 20 times their weight in water and are a very cost-effective ingredient for controlling water.

There are many grades of these ingredients as they can be sourced from several raw materials such as corn, rice, potato, or tapioca. Each of these has a different functionality because they have different ratios of amylose, which is linear in nature, to amylopectin, which is highly branched.

High amylose starch retrogrades more easily than highly branched starch. The branches of the high amylopectin starches physically keep the chains separated and the water contained within the starch granules.

Contained water is less likely to freeze into large ice crystals, which helps maintain quality in frozen applications. Starches from corn, tapioca, or potato are higher in amylose and are more linear; the waxy versions of these tend to have higher amylopectin content.

More effective yet are highly crosslinked or hydroxypropylated starches. These starches exhibit even better freeze-thaw stability as the crosslinking prevents the granule from collapsing. Maltodextrins that are more highly branched are also recommended for frozen applications.

Reduction Not Removal

Unfortunately, there are a lot of supply chain issues with maltodextrins and starches right now. They are so functional in frozen foods that formulators find them incredibly difficult to replace in most applications.

› *Heat shock and subsequent refreezing can give ice cream a sandy texture, resulting from the melting and merging of small ice crystals into bigger ones.*

In the past, these ingredients were the first thing most formulators reached for when creating a new product. Today, availability may be an issue.

Rather than replacing, one strategy may be to use synergistic hydrocolloids and reduce the total starch concentration—reduction rather than removal. To do this, formulators should consider the finished texture desired.

If viscosity is needed, xanthan, guar, locust/carob bean gum, tara gum, konjac gum, highly substituted CMC (cellulose gum), and microcrystalline cellulose (cellulose gel) are good options. These hydrocolloids have lots of branches off the backbone. Like highly branched amylopectin, the individual hydrocolloid particles are sterically hindered by those branches from associating with themselves. These hydrocolloids also add viscosity to any water that remains unfrozen. This can slow moisture migration between individual components such as the sauce and crust of pizza.

Soluble Fibers & Solids

Other options to consider are fibers, such as soluble corn fiber for added soluble solids or citrus fiber. Soluble corn fiber is especially helpful for adding solids without adding calories in reduced calorie or dietetic foods. Citrus fiber is especially useful at binding water. The structure of citrus fiber is analogous to a cotton ball. The cellulose and hemicellulose structure of the fiber has a lot of surface area to hold onto water. Keeping any free water bound within the cotton-ball structure prevents it from forming large ice crystals when the food freezes.

Gum acacia, which can be a soluble fiber source, is another option. The senegal type of gum acacia is an emulsifier. It can be added to emulsions such as a cream sauce to help stabilize the emulsion during freeze/thaw cycling. Fibers do not typically add a lot of viscosity, so using them in combination with viscosifiers, such as xanthan, guar, or CMC, helps make the most of these ingredients.

Gelling Agents

If a gelled texture is needed, there are some options available. Like viscosifying hydrocolloids, gelling hydrocolloids that are more highly branched will be sterically hindered from associating with themselves.

When gelling hydrocolloids associate with themselves, the structure will squeeze any free water out (syneresis). This water is then able to freeze in large ice crystals, which will disrupt the food matrix.

High acyl gellan gum, iota-like carrageenan, and gelatin are useful gelling agents in frozen applications. Combinations of xanthan + tara, xanthan + locust bean, or xanthan + konjac gum can also be highly effective at binding water and preventing large crystal formation from syneresis. These gelling agents are often combined with waxy starches to create frozen desserts that are consumed frozen.

Challenging Supply Times

Hydrocolloids are commonly used to prevent loss of quality due to temperatures the product may face once it leaves the production facility. Formulating hydrocolloid systems for frozen foods is tricky due to the complexity of freezing foods with different components and unique ingredients. This is even more difficult right now because many hydrocolloids are facing challenges in terms of availability. The reality is that formulators can only make educated guesses as to what will ultimately give the most stable finished product.

Standby ingredients such as starch and even xanthan gum can be hard to source. It's recommended to work closely with internal purchasing agents and external hydrocolloid suppliers alike to find the ingredients that are most available and develop a few systems that work. Having some flexibility in the formulation may help keep production going if an ingredient becomes unavailable. ▼

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› *With maltodextrins and starches in short supply, formulators may reduce their total starch concentration with the use of branched hydrocolloids and/or fibers.*