Texturizing Dairy Products: Traditional vs. Plant-Based

Hydrocolloids address texture challenges associated with lower fat and protein in plant-based dairy alternatives.

by Nesha Zalesny and Dennis Seisun

Although plant-based products have been around for decades, they have recently become mainstream in a new way, reaching record sales levels and international interest. As devastating as the COVID-19 pandemic has been, it has been a boon to the food processing industry in many ways. Consumers are now more concerned than ever about health and wellness. Foodservice closures have meant that cooking from home is more of a necessity than a hobby. Financial considerations have further driven the eat-at-home trend, reflected by increased purchases of prepared items at the grocery store such as dressings, dairy products, or beverages.

In all of this, plant-based items have benefited more than other grocery categories. The numbers indicate more consumers are buying plant-based dairy products, whether to allay environmental issues, support health and wellness goals or simply due to availability. New consumers bring high expectations for mouthfeel and taste, which must match traditional dairy products.

This article will examine the texture of traditional dairy products, contrast them with their plant-based counterparts, and look at the hydrocolloids used to achieve those textures.

Fluid Milks & Creamers

Typically, 30% of all fluid milk is sold directly to the foodservice market. Due to restaurant closures during the pandemic, it is no surprise that traditional dairy consumption in the foodservice arena has dropped. However, the loss of only 1.4% of sales accounts for increased home consumption during the pandemic.

Traditional fluid milk has no stabilizers. It is homogenized, making fat (if present) and protein micelle particle size in the 1 (μm) micron range. The laws of physics indicate the protein won’t stay suspended in fluid forever, but with small particle sizes, they will remain suspended for at least the shelf life of the milk.

Chocolate milk is different. Insoluble cocoa particles average 10-30 microns (μm) will settle out rapidly unless the milk's viscosity is changed. The viscosity can’t be so high that the beverage ceases to be refreshing. This is a delicate balancing act. At high enough concentrations, hydrocolloids such as locust bean gum (i.e., carob bean gum), xanthan gum, or guar gum, will suspend the cocoa particles. However, the viscosity of the resulting beverage will be much too thick for most consumers: imagine taking a drink of chocolate milk only to have the texture of a salad dressing in the mouth.

Carrageenan & High Acyl Gellan Gum

The hydrocolloid system chosen for chocolate milk needs to have a high yield stress; in essence, the stabilizer should be gelled while the beverage is sitting still, but fluid when the beverage is in motion. Very few hydrocolloids fit this bill. However, carrageenan and high acyl gellan gum are two of the most useful here.

Carrageenan forms a stable complex with protein found in milk (κ casein), forming a network that suspends the cocoa particle and slows the settling of the cocoa particles. The protein reactivity allows for very low use levels due to the synergism between carrageenan and the protein. For non-dairy creamers that contain sodium caseinate, carrageenan can also be the hydrocolloid of choice to suspend protein, support the emulsification of fat, and help with feathering of the creamer when it is blended with coffee.

The other solution, high acyl gellan gum, is not protein reactive, so the suspension mechanism is different than that of carrageenan. Independent of protein content, gellan forms a fluid-gel network that also slows the settling of cocoa particles. It is important to note that the high acyl gellan gum used in ultra-high-temperature processing (UHT) processed dairy applications has been modified to avoid the development of off-flavors caused by the formation of para-cresol. The same applies to non-dairy creamers with caseinates.

The lack of milk protein reactivity makes high acyl gellan gum shine in plant-based milks and creamers. Historically, carrageenan was used in plant-based milks such as soy or almond milk, but gellan gum has all but replaced it in current products, especially in the United States.

Manufacturers have found that high acyl gellan gum is easy to work with, and it has a clean mouthfeel that suspends plant proteins easily. Its only drawback is that the mouthfeel is so clean that an additional hydrocolloid is usually added to provide some mouthfeel. Toward this end, locust bean gum (LBG), tara gum, or guar gum are excellent choices. These galactomannans provide a slight creaminess when used in conjunction with gellan gum.

Hydrocolloids to Emulsify

If fats are added to the plant-based milk, an emulsifying hydrocolloid is often a good thing to add to the blend. Gum Arabic (gum acacia), Senegal type, or a citrus fiber can help keep the fat from creaming and floating to the surface. There are several oat milks currently commercially available, and enzymatically modified or physically modified oat fiber can potentially suspend solids without the use of other hydrocolloids for a particularly clean label product.

The following chart summarizes hydrocolloids and usage levels for neutral fluid dairy and plant-based beverages and creamers.

Milk or Creamer	**Plant-Based**	**Dairy***
Carrageenan	0.03–0.05%	0.015–0.025%
High acyl gellan gum	0.028–0.035%	0.028–0.035%
Locust bean gum	0.05–0.085%	0.05–0.085%

Tara gum	0.05–0.085%	0.05–0.085%
Guar	0.05–0.085%	0.05–0.085%
Citrus fiber	0.1–0.5%	0.1–0.5%
Oat fiber	0.15–0.2%	0.15–0.2%

*Flavored/chocolate milk only and lactose-free (sodium caseinate) based creamer.

Source: IMR Estimates

As noted in the use levels, carrageenan exhibits strong synergy with milk proteins and has a very low use level. The lack of milk protein in plant-based formulations means that a higher use level (nearly double) of carrageenan is necessary to achieve the desired texture. LBG, tara, or guar gum are not added for suspension, rather for viscosity, so use levels are similar between dairy and non-dairy products.

Yogurt

Traditional dairy yogurt has seen a slight decline in sales in recent years, whereas plant-based yogurt sales have grown by at least 30% in the past year. Dairy yogurt comes in several varieties: custard, traditional, and Greek style. They can vary in protein content from 4 grams to 14 grams of protein per serving. In many European countries, stabilization of the white mass is not allowed; rather, the hydrocolloid is introduced to the white mass via the fruit prep in the finished product.

Where allowed, hydrocolloids are added to yogurt to help control syneresis or whey-off and also to provide additional mouthfeel, especially in custard-style and fat-free yogurts. Hydrocolloids such as gelatin, pectin, or starch are frequently used to modify the mouthfeel of the protein coagulum formed by bacterial fermentation. The quality of the coagulum is influenced by many factors, including protein quality. The addition of hydrocolloids gives manufacturers some process tolerance and quality control for a consistent product that meets consumer expectations.

Dairy Yogurt

For dairy yogurt, gelatin is often the stabilizer of choice. It is protein-based, and when incorporated into yogurt, the gelatin assists in the formation of a very fine coagulum. Gelatin holds 5-10 times its weight in water, and is also ideal because it has no viscosity during the homogenization and pasteurization process typically encountered in yogurt production. Gelatin does not set at temperatures typical of culturing either, so it does not interfere with the lactic acid formers, and also forms a reversible gel.

This means if the yogurt sent to school in a lunch box comes back uneaten after school, it can be tossed back in the fridge and served another time without the loss of texture.

LM & LMA Pectin

Pectin is another top choice, especially in organic yogurts. It is also used in flavored Greek-style yogurts. Yogurts typically have lower solids and a pH of 4.2–4.5. This dictates the use of low methoxyl (LM) or amidated low methoxyl (LMA) pectin, which are more calcium reactive and less dependent on solids to form a gel. A blend of LMA pectin and agar gives a silky smooth finished yogurt similar to gelatin. LMA pectin forms a reversible gel as well, but not to the same extent as gelatin. Pectin is also ideal because it does not interfere with the manufacturing processes typical for yogurt, similar to gelatin. Either gelatin or pectin can be combined with starch to create a pudding-like texture. Traditionally, modified cornstarch is used. Unmodified or native starch can fall apart during a typical yogurt process. Newer, physically modified starch, with similar functionality of chemically modified starch, is also an option.

Working with Less Protein

Gelatin is not an option for plant-based yogurts. Most plant-based yogurts contain significantly less protein than the dairy-based traditional product. Plant protein concentrates can be difficult to work with because they have starches and fibers that provide a viscosity that dairy protein does not have. Whereas dairy-based products contain 4–14 grams of protein per serving, plant-based products contain 1–6 grams of protein. In many cases, this means these products rely on the stabilizer rather than the protein coagulum for much of their texture. With a few notable exceptions, pectin combined with locust bean gum, agar or guar, are the systems of choice for most commercial products.

The most notable exception to pectin blends in plant-based yogurt is a major almond milk-based yogurt producer making good use of the synergism between xanthan and locust bean gum and locust bean gum and agar. When blended together and heated, xanthan and locust bean gum form a rubbery cohesive gel at higher concentrations. At lower concentrations, and blended with agar, the blend provides a spoonable texture similar to yogurt. Note that the xanthan gum blend should not be used in acidified dairy products. Xanthan gum is slightly charged and agglomerates with milk protein once the isoelectric point for the protein is reached. The table below showcases the hydrocolloid, its function in yogurt, and the use level range.

Hydrocolloid	Function	Type	Use Level
Gelatin	Forms gel, rehealing	150–220 bloom	0.2–0.4%
Pectin	Forms gel, rehealing	LM/LMA	0.12–0.6%

Locust bean gum	Mouthfeel, creaminess, syneresis control		0.05–0.2%
Starch	Texture	Corn (modified), Tapioca	1–4%
Agar	Texture, sheen, binding	Gracilaria	0.05–0.1%
Xanthan	Viscosity, mouthfeel	In combination with LBG (non-dairy ONLY)	0.1–0.5%
Guar	Mouthfeel, creaminess, syneresis control		0.1–0.2%

Source: IMR estimates

With the exception of xanthan gum, use levels for milk based yogurts will be on the lower end, and plant based will be in the higher range. The functional range for each hydrocolloid will depend largely on protein content and source and the desired texture. Tapioca starch has found a niche within the plant based yogurt market. If it is added to the white mass it will run in the 1-2%. If it is incorporated into the fruit prep it will run in the 3-4% range. Pectin can be, and often is also incorporated into the yogurt via the fruit prep. This is especially the case in countries where stabilization of the white mass is not allowed. Use level will be 0.12-0.16% in the white mass; 0.5-0.6% in the fruit prep.

Ice Cream

Ice cream is a complex system, composed of air bubbles, fat, ice crystals, and unfrozen water. It is subject to freezer temperatures that cycle to keep the freezer from frosting. Maintaining the quality of the ice cream from the time of purchase until the entire container is consumed can be tricky business. It is complicated by the necessary process tolerance that needs to be formulated to ensure the ice cream is the same from the start of production to the end. The mix viscosity needs to be thick enough to capture and stabilize air for the perfect overrun, but not so thick that air incorporation is hampered. Formulators have to keep all these factors in mind and even try to control the ice cream's melting characteristics. The choice of hydrocolloid influences all these factors.

Traditional dairy ice cream generally has a system consisting of carrageenan, locust bean gum, and guar. The carrageenan is largely for process tolerance. It helps keep the mix stable while aging prior to freezing. The locust bean gum and guar are added to control ice crystal formation and slow the melt. They also add a bit of mouth coating and creaminess to the finished product. At first glance, it may be surprising how many plant-based ice creams utilize the exact same system as dairy-based ice creams. However, plant-based ice cream is relatively new and still gaining a foothold among consumers. Manufacturers of these ice creams also make traditional dairy ice cream; SKU reduction by using the same stabilizing blend is likely the reasoning behind this.

There are some alternative hydrocolloids that are showing promise in plant-based ice cream. Tamarind seed gum, citrus fiber, and oat fiber are ingredients to consider for this system. Tamarind seed gum can emulsify added plant-based fats and help control ice crystal size. Citrus fiber can hold 7-10 times its weight in water, which also helps control the icing of the finished product. Citrus fiber can also help with emulsification of the vegetable fat added to plant-based ice creams, possibly reducing the need to add emulsifiers such as lecithin to keep the fat emulsified. Oat fiber is also helpful as a fat mimetic and enhances the mouthfeel of ice cream.

The hydrocolloid and use levels for both dairy and plant-based ice cream.

Hydrocolloid	**Function**	**Use Level**
Carrageenan	Mix stability, prevention of whey-off	0.025–0.04%
Locust bean gum	Mouthfeel, creaminess, control of melt	0.05–0.2%
Xanthan	Viscosity, mouthfeel	0.05–0.1%
Guar	Mouthfeel, creaminess	0.1–0.2%
Tamarind seed gum	Emulsification, mouthfeel	0.15–0.2%
Citrus Fiber	Emulsifier, ice crystal formation,	0.25–1%
Oat Fiber	Fat mimetic, mouthfeel	0.25–0.5%

Source: IMR Estimates

Cheese

There is an entire world of cheeses based on cow, sheep, goat, or even camel milk, among many others. These are generally unstabilized, not accounting for soft, unripened, fresh cheese such as cream cheese. The majority of texture and flavor comes from the protein coagulate formed from fermentation and enzymatic processing techniques, rather than from a stabilizer.

Plant-based cheeses are fairly new to the market, but have come a long way from the bland and rubbery offerings of a few years ago. Plant-based milks lack the fats and proteins that convert easily to the buttery butyrates and textures that make a great cheese. The holy grail for most plant-based cheese manufacturers is achieving similar melting profiles as dairy products. Picture a grilled cheese sandwich or a piece of pizza without the string of melted cheese dripping from the slice. Melt is affected by the choice of fat as well as the hydrocolloid system. Both choices should mirror the milk-fat profile.

Milk fat melts at 30–32°C (90–95°F). Some of the common fats used in plant-based cheese, like coconut oil, have a melt temperature of 26°C (78°F), while palm oil has a very similar melt temperature to milk fat. Melt temperatures of hydrocolloid systems are affected by other ingredients. For sandwich slice plant-based cheese, a popular system is a blend of potato starch, konjac, and xanthan gum. Similar to locust bean gum, konjac is very synergistic with xanthan gum, and the blend produces a meltable, very elastic gel at low concentrations. Shredded cheeses tend to utilize potato or tapioca starch, carrageenan, and xanthan gum. Depending on the type of carrageenan and added ions, it will melt anywhere between 46–65°C (113–165°F), ideal for pizza. The starches provide opacity and body to the cheese.

The plant-based dairy market is growing quickly and represents an opportunity to highlight the many properties and great versatility of hydrocolloids. Consumer education about how these ingredients affect products is essential. Hopefully, increased awareness of these ingredients and processes will engender an appreciation for the food scientists and formulators that meet consumer expectations for texture and balance processing and stability concerns.

Nesha Zalesny and Dennis Seisun are the authors of *The Quarterly Review of Food Hydrocolloids,* an in-depth analysis on hydrocolloids, produced by IMR International since 1991.