Dairy Proteins

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Introduction

The two main protein fractions found in cow's milk are casein and whey protein. Casein is a micelle that makes up about 80% of total protein, and is found in the colloidal phase. Casein is made up of alpha-s1, alpha-s2, beta, and k caseins. Whey is about 20% of total protein, found in the aqueous phase, and consists of beta-lactoglobulin, alpha-lactalbumin, lactoferrin, and other proteins.

The primary sugar in milk is a disaccharide called lactose, which is a glucose bonded to a galactose molecule. Lactose is primarily associated with whey, in the aqueous phase of milk.

The fats and proteins in milk are able to form emulsions and foams which are important in the formation of ice cream. The proteins like casein and whey help form emulsions by adsorbing to the surface of fat droplets. After homogenization, fat droplets are coated with a layer of casein that prevents the fat from forming a layer. This creates more surface area for the proteins to adhere to at the oil-water interface. Proteins in milk also help aerate ice cream by unfolding and holding air bubbles, stabilizing them. The proteins increase viscosity by being able to hold more water as well as forming networks when heated or undergoing a pH change, leading to more coagulation and interactions. Adding additional emulsifiers to the mixture during the aging stage of making ice cream results in the destabilization of the fat globule structure, allowing the fat to partially coalesce. Whipping the ice cream with a scraper also destabilizes the fat globules, and stabilizes the air bubbles in the mixture. The fat in milk also creates a coating mouth feel, which is also desirable in ice cream.

Milk has a variety of proteins that can be altered and precipitated under different conditions to form different cheeses. The proteins in milk add flavor, color, texture, viscosity, and can help form emulsions in cheeses. To make cheese from milk, a curd needs to be formed from casein, and whey needs to be removed. Because the proteins in milk, like casein, have a minimum solubility at a pH equal to the pI, and precipitate at a pH of 4.6, changing the isoelectric charge can precipitate those proteins and cause them to aggregate to form curd. Enzymes with chymosin, like rennet, can also be used in enzymatic coagulation, aggregating and precipitating casein micelles. Globular proteins like whey are water soluble and can be easily denatured by heat and removed when making cheese. Slowly heating curd also causes it to coagulate tighter, and whey can then drain out.

Ice cream is a partially frozen foam and an oil-in-water emulsion. It's made up of at least 10% milk fat and 20% milk solids. The proteins in milk have three main roles that create ice cream. The casein and whey in milk adsorb to the surface of the small fat droplets and have properties that allow it to emulsify. After homogenization, the fat droplets in milk are coated with the protein casein, which prevents the fat from forming a separate layer. Casein is a micelle made up of four main types of proteins; alpha-s1, alpha-s2, beta and k caseins. Overall, caseins are hydrophobic, however, k casein, a protein only found on the surface of the micelle, has a hydrophilic C-terminus that helps it stay in the aqueous layer of milk. This helps keep the fat in solution in ice cream, and allow it to emulsify, becoming an oil-in-water emulsion. The emulsification qualities of ice cream give it a consistent texture, and a creamy, full mouth feel.

The proteins in milk also serve as aerator stabilizers in ice cream. The proteins interact with any added emulsifiers and partially coalesce fat that stabilizes the air bubbles, stopping them from collapsing. Whipping ice cream also destabilizes fat globules and stabilizes air

bubbles, by reducing their size and distributing them. This aretation, also called the overrun of the ice cream, gives ice cream its cohesive, fluffy texture. Proteins also affect the solution behavior of ice cream by changing the water-holding capacity, leading to increased viscosity. The proteins in ice cream form a network with each other that traps air, so not all the water in ice cream freezes into ice crystals. The water that doesn't freeze contains a concentrated solution of sugar. The sugar solution affects the freezing and melting point of the ice cream, and the viscosity. The viscosity of ice cream gives ice cream a certain thickness and chewiness. The addition of nonfat milk solids also helps to add additional proteins to the ice cream, preventing ice crystal formation by binding to water, and trapping air to increase overrun.

Another factor that affects ice cream quality is the amount of fat. Fat adds a creamy, coating mouthfeel to ice cream, and without it makes it icy and melt too quickly.

The two main ways to trigger coagulation of casein micelles in cheese making is enzymatically or through lowering the pH. Using an enzyme with chymosin, like rennet, cleaves the 105 Phe-106 Met bond in casein, and releases the soluble C-terminal part of the k casein, which leads to the casein micelles aggregating and precipitating out of the colloidal phase. The casein aggregating together is what forms the curd needed to make cheese. Lowering the pH of a milk causes the casein micelle to precipitate out because its minimum solubility is at a pH equal to its isoelectric point. At a lower pH, casein carries a net positive charge due to increased protonation, which reduces the electrostatic repulsion between micelles and their water solubility, allowing them to aggregate and precipitate out of solution.

Dairy should be included as part of a healthy diet for most people. Dairy products contain many important vitamins and minerals, such as vitamin D, calcium, vitamin B12 and vitamin A. Vitamin D and calcium are both very important for bone health and should be

consumed together in order to get optimal absorption. Vitamin D should also be consumed with fat, given it is a fat soluble vitamin. Dairy provides both these nutrients, as well as fats to help absorption. Dairy also serves as a good quality protein source, containing all the essential amino acids in adequate amounts. Getting enough quality protein is important for muscle tissue, skin health, and insulin sensitivity. Adding on, the primary disaccharide in dairy, lactose, takes longer to break down and digest, lowering glycemic index, and making dairy products a healthier option for glucose levels. Dairy products can also be fermented, adding probiotics to encourage a healthy gut flora, and having anti inflammatory properties. Someone might want to reduce their dairy intake if they are lactose intolerant. Lactose intolerance can lead to increased GI discomfort if not aided with lactase, the enzyme needed to break down lactose in the small intestine. Without lactase, lactose will pass undigested to the large intestine, and be fermented by bacteria, releasing gas that contributes to GI discomfort.

The purpose of this experiment is to investigate the effects of milk fat, milk solids, a stabilizer, and overrun in the formation of ice cream, and its body, texture, perceived coldness and weight. Another purpose of this experiment is to evaluate the different methods of casein coagulation in cheese making, and how that affects flavor, texture, firmness, and pH.

I hypothesized that the ice cream with more fat would be generally more creamy, have a better mouthfeel, and low perceived coldness. I hypothesized the ice cream with stabilizers would have a chewier, fluffier texture and a lower perceived coldness. I also hypothesized that the ice cream with milk solids would have a creamier texture and more full mouthfeel with less ice crystals and lower perceived coldness, and that overrun would significantly improve the softness of the ice cream and reduce ice crystal formation.

For the different cheeses, I hypothesized that the Chipotle-lime Oaxaca would be very firm due to the amount of heating and folding, have a creamy, elastic texture, a sour flavor, and a low pH from the lime juice and natural acidity of dairy. I hypothesized that the Curried paneer cheese would have moderate firmness due to liquid still being in the cheese after pressing, have a light, soft texture, a spicy tangy flavor, and also a low pH from the lime juice and acidity of dairy. I lastly hypothesized that the Squeaky cheese would have strong firmness, a resistant, bouncy texture, a salty fermented flavor from the spices and ale, and a moderately low pH as well.

Methods:

Ice Cream

In order to prepare the ice cream, sugar, non-fat milk solids, and stabilizer for several variations of ice cream were added to their own bowl. Every variation had 50g of sugar. The 4% milk fat variation had no non-fat milk solids and no stabilizer added. The 4% milk fat and milk solids variation had 20g of non-fat milk solids added and no stabilizer. The 12% milk fat and milk solids variation had 30g of non-fat milk solids and no stabilizer added. The 12% milk fat with milk solid and stabilizer had 30g of non-fat milk solids with 2.5 g of stabilizer added. The 15% milk fat variation had no non-fat milk solids or stabilizer added. Lastly, the 15% milk fat and no overrun variation had neither non-fat milk solids or stabilizer added.

Next, milk and cream was warmed to about 100 degrees fahrenheit, while adding the dry ingredients gradually, making sure everything dissolved. The first variation, 4% milk fat, had 377g of milk and 57g of cream, and the second variation had 357g of milk and 37g of cream. The next two variations both had 233g of milk and 171g of cream, and the last two with 220g of milk and 214g of cream.

Once the mixture reached 100 degrees fahrenheit, 5g of vanilla and 10g of corn syrup was added. Then, the ice cream mixture was put in an ice bath and cooled to 35-42 degrees fahrenheit while stirring. To determine percent of overrun, a 250ml beaker was filled to 200ml with the mixture before and after overrun, and weighed for each variation.

The no overrun variation was then poured into a freezer bowl and frozen for 30-45 minutes, until completely frozen. All other variations were poured into an ice cream maker and stirred for 25 minutes at about 18 degrees celsius. Once done, the variations were removed from the ice cream maker and placed in the freezer.

All 6 variations were put in a beaker and weighed, then evaluated for body, texture, and perceived coldness.

Cheese

Chipotle-Lime Oaxaca

To create the Chipotle-Lime Oaxaca cheese, 1 teaspoon of rennet was mixed with ¼ cup of bottled water. Separately, 1 and ½ teaspoons of citric acid was mixed with ½ cup of bottled water. Then, 1 gallon of low-fat milk was mixed with the citric acid and slowly heated. Next, the rennet was added and stirred with a slotted spoon, using a back and forth motion. The milk was heated to 43 degrees celsius, watching for curd formation. Then. 20g of curd was removed and put into a beaker, with 50mL of deionized water added, and stirred until homogeneous. The pH was measured. The rest of the curd was lowered to 41 degrees celsius while slowly stirring with a slotted spoon. Once it was similar in texture to scrambled eggs, the curd was scooped into a medium glass bowl using the slotted spoon. It was then microwaved on high for 30 seconds, and folded over on itself 5 times. Then, it was microwaved again for 15 seconds and the whey

drained. After adding ¼ teaspoon of salt and 1 teaspoon of lemon pepper on the cheese, it was folded over 10 times to incorporate. It was then microwaved on high for 15 seconds and kneaded until stretchy. Next, 2 teaspoons of chipotle chili powder, 1 tablespoon lime juice and ½ teaspoon of salt was mixed, and folded. The final cheese was evaluated for sensory qualities.

Curried Paneer

To make the curried paneer cheese, 1 gallon of whole milk was mixed with 2 tablespoons curry powder, and heated on medium heat to 93 degrees celsius. The milk container was saved. Then, ½ cup of lime juice was added, adding 1 more tablespoon if needed until coagulation occurred. Once curd was formed, 20g was removed and put into a beaker, with 50 mL of deionized water mixed in until homogenous. The pH was then measured. The rest of the curd was put on low heat and stirred for 2 minutes. After, the mixture was poured into a glass bowl through a cheesecloth lined colander. It drained for 5 minutes. Then, 1 teaspoon of salt was added. The cheese was bundled in the cheesecloth and put on a plate, being covered with a second plate. The milk container was filled with water and set on top of the plate, being pressed for 15-20 minutes. The final cheese was then evaluated for sensory qualities.

Ale-Washed Squeaky Cheese

To make ale-washed squeaky cheese, 1 gallon of low fat milk was put in a pot with 3 tablespoons of lemon juice stirred in. It was then heated on medium heat to 35 degrees celsius. Next, 1 teaspoon of rennet and ½ cup of bottled water was mixed and added to the milk. The milk was then heated to 43 degrees celsius and watched for curd formation. Once a clean break was achieved, the curd was cut into 1-inch cubes. In a beaker, 20g was removed and

homogenized with 50mL of deionized water. The pH was then measured. The rest of the curd was heated to 46 degrees celsius, being stirred gently with a slotted spoon, until a scrambled egg texture was reached. Curds were then spooned into a cheesecloth lined colander over a glass bowl. The curds were pressed into a slab, then broken into 1-inch pieces. The whey was heated to 74 degrees celsius, with the curds being added, as well as 2 teaspoons of salt. The mixture was cooked for 10 minutes. Next, 1 scoop of ice and 12 ounces of cold ale beer was added to a bowl. The curds were spooned into the ice/ale bath using the slotted spoon, stirring until the curds became cool and had a springy texture. They were then spooned onto a paper towel and dried. Lastly, 1 teaspoon of mustard and ½ teaspoon of white pepper was coated onto the cheese, and the result evaluated for sensory qualities.

Statistical Analysis

The percent overrun for each ice cream variation was calculated using the formula below:

$$\%\ overrun = \frac{mass_{mixture} - mass_{ice\ cream}}{mass_{ice\ cream}} \times 100\%$$

Using the 12% milk fat and milk solids ice cream as an example calculation, %overrun was calculated by plugging in the weight in grams before and after the mixture was aerated.

-3.73% overrun=((193.02-200.5)/200.5)*100%

The total solids, total solids non fat, and caloric value was also calculated for each ice cream variation using the formulas:

Total Solids=[(W(solids-non-fat dry milk solids)+W(skimmed milk solids)+W(solids in cream)+W(solids in sugar))/W(sum)]*100

Example Calculation with 12% milk fat and milk solid variation-

[(((0.367+0.555)*30g)+((0.032+0.048)*233g)+((0.021+0.032+0.35)*171g)+(0.82*10g)+(1*50g))/499g]*100=34.75g

Total Milk Solids Nonfat=[(W(solids in nonfat dry milk solids)+W(solids in skimmed milk)+W(solids in cream))/W(sum)]*100

Example Calculation with 12% milk fat and milk solid variation-

[(((0.367+0.555)*30g)+((0.032+0.048)*233g)+((0.021+0.032)*171g))/499g]*100=27.57g

Total Calories=[((Cal protein+Cal carbs+Cal fat))/W(sum)]*100

Example Calculation with 12% milk fat and milk solid variation-

((0.367*30g)+(0.032*233g)+(0.021+171g))*4.27=94.18 calories from protein

((0.555*20g)+(0.048*233g)+(0.032*171g)+(0.82*10g)+(1.00*50g))*3.87=354.13 calories from carbohydrates

(0.35*171g)*8.79=526.08 calories from fat

[((94.18 calories from protein)+(354.13 calories from carbs)+(526.13 calories from fat))/499]*100=195.27 total calories

Results

Table 1. The % overrun, total solids, total solids non fat, and caloric value for six variations of ice cream is shown.

Variations	4% Milk Fat	12% Milk Fat + Milk Solids +Stabilizer	4% Milk Fat + Milk Solids	12% Milk Fat + Milk Solids	15% Milk Fat	15% Milk Fat + No Overrun
% Overrun	59.22	49.22	69.20	-3.73	28.78	66.57
Total Solids (g/100g)	22.31	34.58	28.40	34.75	32.47	32.47
Milk Solids Not Fat (g/100g)	16.67	15.49	14.29	15.57	15.82	15.82
Caloric Value (cal/100g)	107.08	194.30	159.42	195.27	200.45	200.45

The percent overrun was highest in the no overrun variation, and with stabilizer. A higher weight of total solids was seen in ice cream variations with higher milk fat percentages and when non fat milk solids were added to the mixture, seen in Table 1. The higher caloric contents were seen in variations with high fat percentage milk used.

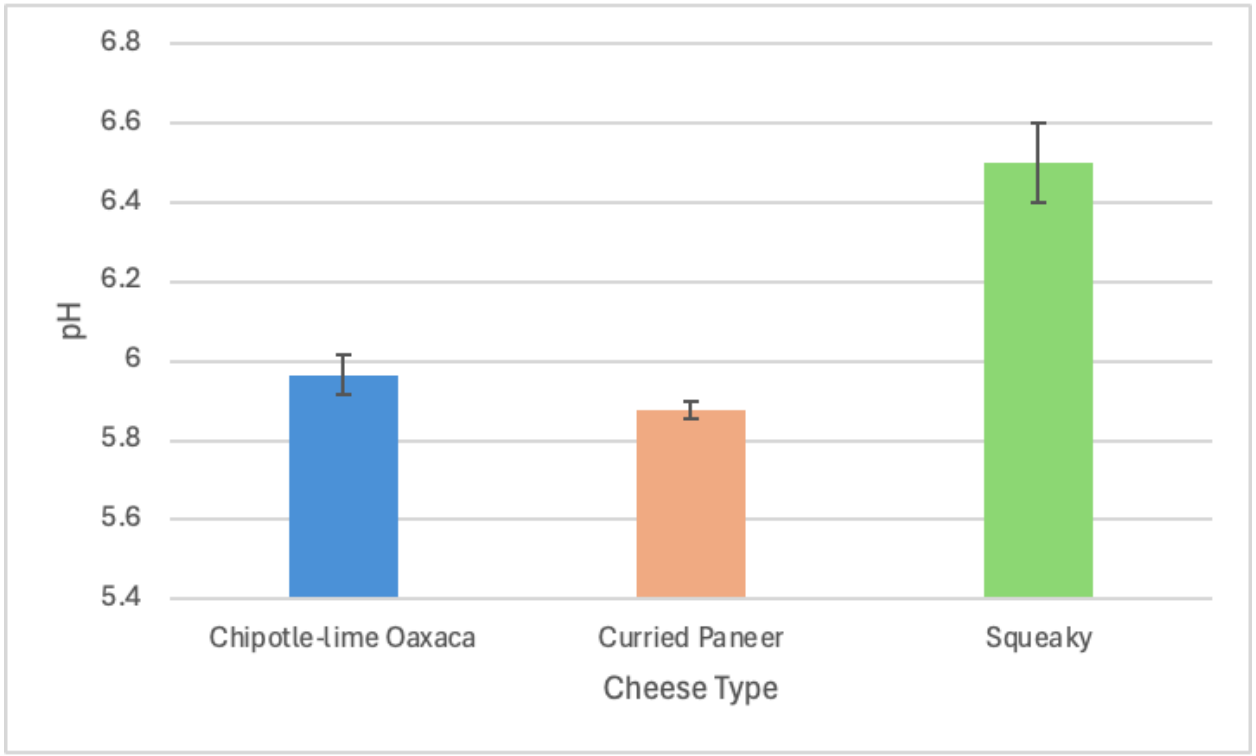

Figure 1. The pH of Chipotle lime Oaxaca (blue), Curried Paneer (orange), and Squeaky (green) cheese is shown. The standard deviation of each cheese type is expressed through the error bar on each bar.

The squeaky cheese had a significantly higher pH than the other two cheeses, with no overlapping of error bars seen in Figure 1. The Chipotle lime Oaxaca cheese and Curried Paneer also have significantly different pHs because they have no overlapping of error bars, with Curried Paneer having a lower pH.

Ice Cream Sensory Evaluation

The 4% milk fat ice cream had a soft, slushy texture, tasted very cold, and had a weak, crumbly body. It melted quickly, and had minimal mouth coating.

The 4% milk fat with milk solids ice cream had a slushy texture, tasted very cold, and also had a weak body. It had a sightly creamier texture than without milk solids.

The 12% milk fat and milk solids ice cream had a very liquidy texture, was not cold, and had a crumbly body.

The 12% milk fat, milk solids, and stabilizer ice cream had a creamy, thick body, melted quickly, and was cool in perceived temperature. It coated the mouth and had a nice balance of sweet and vanilla flavor.

The 15% milk fat ice cream had a grainy texture and was mildly cold. It had ice crystals throughout it and a weak body. It had a very slight buttery, fatty taste.

The 15% milk fat and no overrun ice cream had many ice crystals in it giving it a very coarse texture. It tasted grainy and had a very weak body. It was also very cold.

Cheese Sensory Evaluation

One of the chipotle lime Oaxaca cheese variations was a pale white color, and had a rubbery, tough texture to it. It was very firm, and pulled apart similar to string cheese. It had a spicy flavor. The other variation was less spicy and was not firm at all. It had a crumbly and dry texture.

The curried paneer cheese variations were both very yellow and had a tofu-like texture. They were firm but not tough and easy to chew. They had little flavor overall. One variation had less elasticity to it, and was softer.

The Squeaky cheese variations were white in color and had a cottage cheese appearance. They had a rubbery, firm texture and had a squeaky, sticky feeling when chewed. One variation had a strong fermented flavor and was slightly soggy. The other variation had little flavor.

Discussion

Milk fat in ice cream gives it a creamy, full mouthfeel. A higher milk fat percentage has a creamier, thicker texture and somewhat reduces the perceived coldness of the ice cream. Milk solids in ice cream help to trap air bubbles created through aeration and absorb some amount of water, preventing ice crystal formation (1), and thus creates a creamier, fluffier texture and decreases the coldness. The CMC/stabilizer in ice cream gives it a consistently thick and creamy texture, and helps keep a cool perceived coldness, while not melting too quickly. The stabilizer increases the viscosity of the ice cream through binding with water, thickening the product. It also stops large ice crystals from forming by binding with water, leading to its smoothing effect on ice cream. The overrun in the ice cream helps aerate the liquid mixture, creating a fluffy and soft texture. Overrun destabilizes fat globules in the mixture creating a smoother texture, and stabilizes air bubbles adding to the softness of it. It also reduces melting temperature because of the incorporation of air acting as an insulator. Overrun helps reduce large ice crystals from forming and reduces the perceived coldness. The ice cream variation with no overrun has a very icy, coarse texture and grainy feel. It is also very cold tasting compared to the other variations. The ice cream variation with 12% milk fat, milk solids, stabilizer, and overrun has the best texture and coolness overall because it has a higher fat content to add a creamy, full mouthfeel, milk solids to reduce large crystal formation and help trap air, stabilizer to help increase viscosity of the mixture to add stability and thickness, and overrun to increase small air bubble

incorporation to create the most stable and fluffy texture. This variation is the preferred variation by myself and many other students due to its qualities.

The caloric content of the ice cream variations generally increases with higher milk fat content, as seen in Table 1. Milk solids add some caloric content as well. Fat has a higher caloric content per gram than protein and carbohydrates, which is why a higher calorie content is seen in the higher fat variations.

The ale-washed squeaky cheese and chipotle-lime oaxaca use enzymatic coagulation through the addition of rennet, while the curried paneer uses acidic coagulation through the addition of lime juice. The squeaky cheese and chipotle-lime oaxaca uses rennet as an enzymatic coagulator, adding it after gently heating the milk. The curried paneer cheese uses a significant amount of acid in the form of lime juice, after the milk is heated much higher than the other two cheeses. My determination of acidic and enzymatic coagulation of cheeses makes sense given the obtained pH values in Figure 1. The curried paneer cheese has the lowest pH, as seen in Figure 1, at roughly 5.8. It is significantly more acidic than the other two cheeses, indicated by the lack of overlapping of error bars. The curried paneer relies on acidic coagulation, and thus requires a much lower pH than the other cheeses. The casein in milk has a very low solubility at pH 4.6. When the pH is lowered in the mixture to roughly 5.8, some of the micelles begin to coagulate and form curd. Rennet contains chymosin which cleaves the 105 Phe-106 Met bond of the k casein protein on the surface of the micelle, releasing the C-terminal, coagulating and precipitating the micelles, but not affecting the pH, which are both around 6-6.5. The chipotle-lime oaxaca cheese may have a slightly lower pH than the squeaky cheese because it has lime juice added in addition to rennet to add flavor and aid in some coagulation. This also

explains the rubbery, firmness of the oaxaca cheese, compared to the soft tofu-like paneer cheese and the crumbly, squishy texture of the squeaky cheese.

The oaxaca cheese is microwaved multiple times and folded onto itself. Microwaving and folding the cheese creates a much firmer texture, removing moisture and developing the proteins more. It also is warmed to a lower temperature, coagulating the proteins over a longer period of time. One variation of the oaxaca cheese was very crumbly and looked similar to canned tuna. This defect may be due to heating the milk too quickly, causing the proteins in the mixture to coagulate quickly and lose the fat globules around them, creating a small amount of curd with no cohesiveness and no emulsification properties. The paneer cheese was warmed to a much higher temperature and only pressed in a cheese cloth after curd formation. The paneer cheese has a much softer and moist texture from less protein coagulation and from retained moisture. The squeaky cheese also has a lower temperature heating process and is pressed in a cheese cloth. However, it also is placed in an ice bath. The ice reduction in temperature may have stopped coagulation prematurely, which is why we see a slightly less firm cheese than the oaxaca, and a more rubbery, squeaky cheese.

Plant-based alternative ice cream and cheese likely have different sensory qualities. Without the same proteins found in milk, like casein, and fats that give ice cream and cheese its ability to either form viscous, fluffy textures or coagulate, the textures of these alternatives are different. Ice cream without the same proteins to help emulsify the fat in the mixture leaves a less creamy, cohesive ice cream. Without the stabilization of air bubbles by milk proteins, the product is more icy and liquid, and less fluffy and creamy. The solution behavior is also changed because the proteins in milk interact with water in a way that promotes increased viscosity, and reduced large ice crystals. Without those properties, a non dairy ice cream has more ice flakes and a more

wet mouthfeel, melting quickly. Non dairy cheeses aren't able to coagulate the same way as a normal cheese because the proteins used won't contain the casein micelles that are altered in order to get curd formation. A non-dairy cheese would not have the same melting temperature or firmness as a regular cheese. Without the fatty acids in cheese that give it a distinct aroma, the nondairy cheese would also likely smell different, or not smell at all. Additionally, a non dairy cheese altered enough to gain some similarities of dairy cheese would likely lack much nutritional value compared to regular. The differences in a nondairy ice cream and cheese would not make them a favorable substitute. The difference in melting temperatures, texture, mouthfeel, and aroma would make them overall less desirable, excluding lack of nutritional value.

The consumption of dairy in the diet is overall beneficial for the average, healthy person. Dairy provides many important nutrients such as calcium, vitamin D, and is a good quality source of protein, containing all nine essential amino acids. A cup of milk has about 8.14g of high quality protein. Dairy is especially important for growing children and adolescents. Calcium is especially important for children and adolescents because a significant amount of their bone mass is accumulated during growth and development, and inadequate intake of both nutrients can lead to rickets and brittle bones. One study found that without making major dietary pattern changes or the inclusion of multiple calcium fortified foods, the recommended daily allowance of calcium and other nutrients could not be met without dairy products (2).

Dairy products can be a healthy addition for someone with diseases like diabetes as well due to the lower glycemic index of lactose, the primary sugar in milk. When lactose is metabolized, galactose is first converted in the liver to glucose. This longer way of metabolism reduces glucose spikes, which can make managing diabetes easier. Dairy product consumption

also provides branched chain fatty acids that have been shown to be beneficial in reduction of proinflammatory markers by expressing less TLR-4 and reducing IL-8 proteins. (3).

Instances where someone may want to avoid dairy include allergies and intolerances. In the case of interlances, individuals can consume dairy with the additional consumption of lactase, the enzyme responsible for lactose breakdown. Without the help of lactase, a person may experience gastrointestinal discomfort, which may affect their daily life. Milk allergies, although rare, can cause symptoms like eczema, respiratory issues, and GI symptoms. If a person does not grow out of this allergy, they should not continue to consume dairy.

Conclusion

Dairy is a complex food group that provides favorable culinary attributes as well as important nutritional value. The proteins casein and whey and fat in dairy interact to form complex networks to aid in texture, taste, and body of foods like ice cream and cheese. Dairy as a food group helps people consume vital nutrients, serving as a desirable and complex vesicle that has potential to also provide anti inflammatory effects.

Works CIted

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