BS.c THESIS

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2024

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Food Engineering Bachelor's

The Use of Dairy-by Products in the Development of Ice-Cream

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Budapest

2024

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1. Introduction and Objectives

Ice cream, an immensely beloved frozen dessert, is a complicated development of dairy and non-dairy ingredients processed under systematic technological conditions to achieve its desired creamy and smooth texture. The food sector is highly prioritizing sustainability and growing diversity in product offerings, leading to the development of new ice cream brands using leftovers as eco-friendly substitutes (Oana-Viorela Nistor, 2020). Dairy by-products in ice cream are a sustainable and environmentally friendly method, scaling with a global focus on sustainable practices and the circular economy (Gupta & Sharma, 2022).

The use of dairy by-products, such as whey and buttermilk, in ice cream manufacturing puts in focus their benefits in terms of sustainability, cost effectiveness, and nutritional improvement. Examining the use of dairy by-products in ice cream formulation offers important observations for researchers and industry experts alike, as consumer demand for nutrient-dense and environmentally friendly food items continues to rise (Smith et al., 2020). Dairy by-product incorporation helps in reducing food waste, optimizing resource use, and promoting sustainability. . It enhances ice cream's texture, flavor, and nutritional profile, such as whey protein. According to research by Smith et al. (2020), sweet whey's emulsifying and water-binding qualities improve ice cream's texture and decrease its iciness. Buttermilk, a natural emulsifier, reduces artificial ingredients and improves nutritional profile, making it a desirable choice for health-conscious consumers looking for dairy-based protein and micronutrient benefits (Ahmed et al., 2021).

The study aims to thoroughly evaluate the use of dairy by-products, specifically sweet whey and buttermilk, in the development of ice cream. The two types of ice cream were made, one with sweet whey and the other with buttermilk, using milk, cream, sugar, dextrose, and locust beans. Our goal is to investiagte how different by-product substitution concentrations affect important quality measurements of ice creams such as color, dry matter content, overrun, pH, viscosity, and sensory qualities.

2. Literature Review

2.1 Ice Cream: Composition and Production Technology

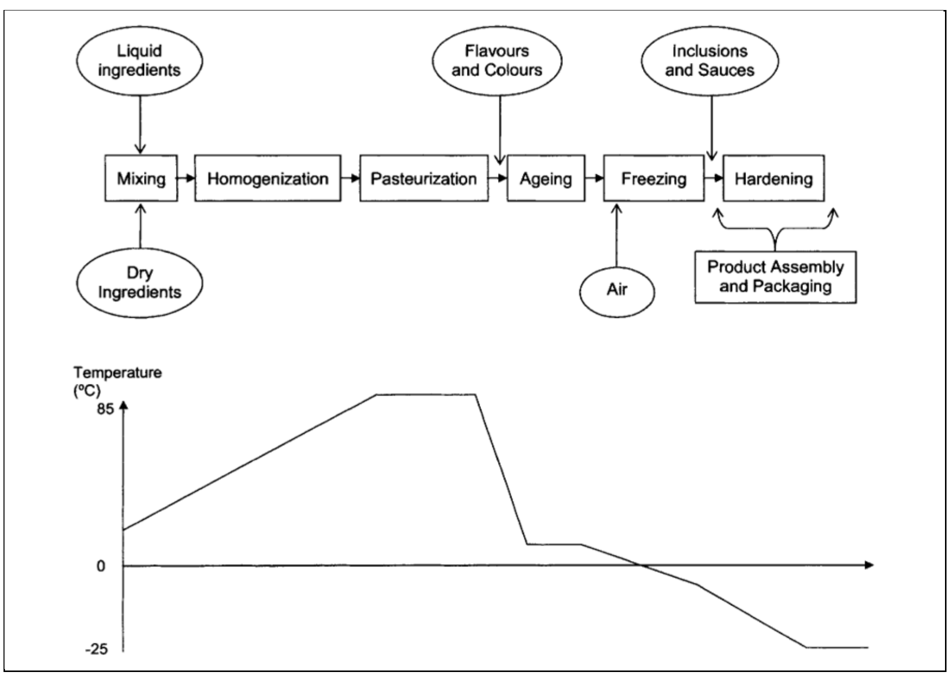
Ice cream, for instance, contains components of emulsions, foams, and frozen systems that make it one of the most intriguing scientific edible products (Goff and Hartel, 2013). The main raw materials of ice cream are milk, cream, sugars, stabilizers, emulsifiers, and air, which undergo various manufacturing processes such as homogenization, pasteurization, and controlled freezing to achieve the end product's total sensory and textile properties.

2.2 Production Process

Ice cream undergoes several stages of manufacturing, including mixing, pasteurization, homogenization, aging, freezing, and hardening (Figure 1), all of which contribute to achieving the desired structural characteristics of the final product.

Figure 1: The manufacturing Process of Ice-Cream

(Clarke, 2004)



2.2.1 Homogenization

The process of homogenizing the mix after pasteurization reduces the size of fat globules to a consistent size of 1-2 micrometers. This is crucial for emulsification, as it prevents the fat globules from coagulating and creating a greasy mouthfeel. Homogenization also enhances the capability of the mix to hold air, and this is critical for the right amount of overrun (Goff & Hartel, 2013).

2.2.2 Mixing and pasteurization

During production, the process involves mixing solid ingredients and liquid ingredients separately and heating them to approximately 68–85°C, a process known as pasteurization. This step destroys possible pathogens; this makes the product safe for use. Further, pasteurization aids in solubilizing sugars and hydrating proteins and stabilizers, making the texture and viscosity of the mix better (Tharp & Young, 2012). The heat process also aids in the formation of additional flavor qualities through Maillard reactions, resulting in the creation of a rich, creamy, and enjoyable quality that is typically present in any milk product (Marshall et al., 2018).

2.2.3 Aging

After homogenization, we let the mix ferment at low temperatures, preferably 4 °C, for a few hours. As the formula ages, the fat in the product crystallizes and stabilizers become fully hydrated, leading to enhanced viscosity. This step plays a crucial role in ensuring the emulsion's stability and the final product's texture. It also enhances the whipping capability of the mix by achieving improved air entrainment during freezing (Smith et al., 2020).

2.2.4 Freezing and Aerating

Concentration is decisive in the creation of ice cream. We perform this step in a continuous freezer, rapidly bringing the mix's temperature down to sub-zero areas, which range from -5°C. Rapid freezing is necessary for the formation of the small ice crystals, which give the Ice-cream its smooth texture.As the mixture begins to incorporate, air gradually enters, achieving an overrun that leads to the formation of an ice cream structure (Marshall et al., 2018).

2.2.5 Hardening

The final step, known as the hardening stage, involves exposing the product to a temperature of approximately -25°C to complete the freezing process and fortify the structure of the frozen matter.

This step helps stabilize the air cells and solidify the ice crystals, resulting in a firm yet scoopable texture for the product. Correct hardening is required to keep the right structure and minimize shrinkage during storage (Goff & Hartel, 2013).

2.3 Main Components and Their Functions

That recipes are diverse is quite logical; therefore, the basic components inherent in ice cream are milk fat, non-fat milk solids, sweeteners, stabilizers, emulsifiers, and air. Every addition provides some characteristics, which in turn affect the taste, texture, shelf life, and quality of the final product protein (Goff, 2002).

2.3.1 Milk Fat

Ice cream formulation requires milk fat as one of the ice cream mix constituents and can range from 5 to 15 percent of the total formulation. It plays a major role as a texturizing stabilizer and flavor-enhancing composition, significantly influencing the texture of the ice cream, particularly the fat content, which in turn influences its mouthfeel (Marshall et al., 2018). The structure of milk fat also provides the ideal matrix to encapsulate the necessary air, resulting in the product's lightness and softness. Moreover, milk fat can crystallize under controlled freezing conditions, resulting in excellent ice cream and the melting properties that customers appreciate in superior-quality ice creams (Goff & Hartel, 2013).

2.3.2 Non-Fat Milk solids

Non-fat milk solids consist of proteins like casein and whey, with lactose accounting for 10–14% of the ice cream mix. These solids serve multiple purposes in the production of ice cream, serving as both a body and texture component, as well as providing nutritional value (Tharp & Young, 2012). Specifically, casein proteins play a crucial role in stabilizing fat particles in the emulsion, preventing coalescence, and promoting a smoother texture in the fat portion. While whey proteins serve as stabilizers, giving the ice cream its structure, they also function as a water binder, preventing ice crystals from rounding during storage and preventing the ice cream from becoming gritty (Smith et al., 2020). Lactose, as “milk sugar,” provides mild sweetening properties and adds bulk, changes the freezing point of the ice cream mix, and contributes to smoothness.

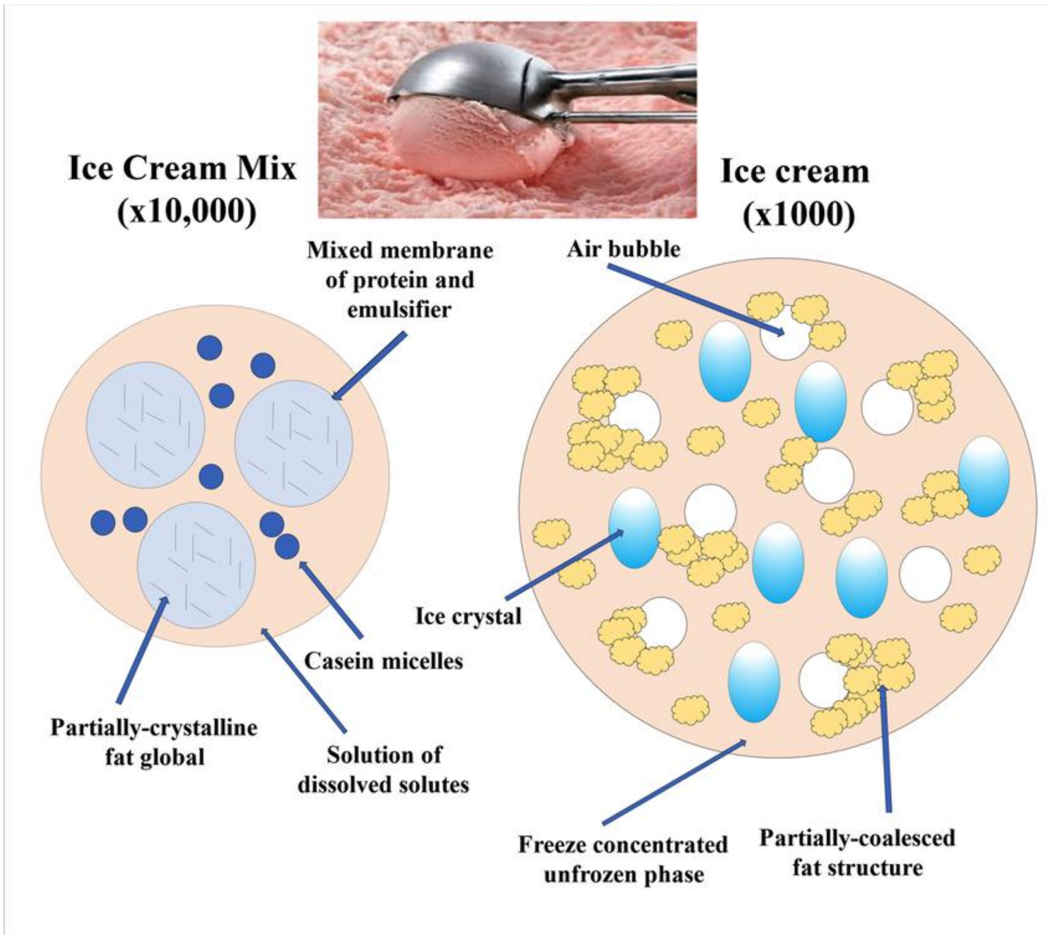
Table 1: Compositional ingredients of ice cream: Essential and Optional (Goff, 2016).

Essential ingredients		**Optional ingredients**	
Name	**Sources**	**Name**	**Sources**
Dairy Ingredients			
Milk Fat	Whole milk, butter, cream	Non-dairy fat substitutes	Vegetable fats
Milk Solid Non-Fat (MSNF)	Condensed milk, skim milk powder,	Additional dairy	Condensed milk, evaporated milk, milk powder
Cream	Whole milk	Flavor-infused dairy	Flavored milk or cream
Whole or low-fat milk	Whole or low-fat milk		
Sweetening Agents			
Sucrose	Table sugar	Natural Sweeteners	Honey, agave nectar, maple syrup
Glucose	Glucose or Corn syrup	Alternative sweeteners	Stevia, aspartame, erythritol
		Fruit sugars	Fruit purees or concentrates
Other Components			
Stabilizers	Guar gum, locust bean gum, carboxymethyl cellulose	Add-ins	Nuts, chocolate chips, cookie dough, fruit pieces

Emulsifiers	Egg yolks, mono and diglycerides	Flavorings	Natural or artificial flavors like chocolate, vanilla, etc.
		coloring	Natural or artificial colorants
		Acidifiers	Citric acid for fruit-flavored ice creams
		Air (overrun)	Incorporated during churning for volume and texture

The typical and variable range of ingredients that make up ice cream is as follows: 15% (13-20%) sugar, 12% (8-20%) fat, 11% (8-15%) milk solid nonfat, 0.3% (0-0.7%) emulsifiers and stabilizers, and 38.3% (36-43%) total solids. Carbohydrates, proteins, and lipids each contribute 5.65, 9.45, and 4.10 Cal/g on a calorimetric measuring basis. However, according to the body's absorbability, the contributions of fat, proteins, and carbs are, respectively, 9, 4, and 4 Cal/g (Arbuckle, 2013).

Figure 2: Illustration of the Structure of Ice Cream Mix
(Mohammed et al., 2022)



The microscopic structure of ice cream at two different stages, the ice cream mix and the frozen ice cream product can be seen in the Figure 2. The ice cream mix is shown at 10,000 times magnification on the left. The partially crystalline fat globules in this stage are enclosed in a protein-emulsifier mixed membrane. Before freezing, the casein micelles are spreaded throughout a solution of dissolved solutes to form a stable emulsion.

2.3.3 Sweeteners

Sugars play a special role in ice cream due to their unique taste and texture. Sweeteners also contribute to the texture of ice cream. The usual sweeteners in use today are sucrose and glucose syrups from corn. Sugars make up an average of 12 percent of the mix, and the key function of sweeteners is to impart the sweet taste of ice cream (Goff & Hartel, 2013). However, sweeteners also play a critical role in reducing the freezing point of the mix to generate the desired soft and scoopable texture at the freezer temperature (Marshall et al., 2018). The freezing point depression provides a means whereby ice cream can contain both frozen and melted water, which gives it a creamy texture~~.~~

2.3.4 Stabilizers

Stabilizers are added in limited quantities, probably about 0.2–0.5 percent of the total mix, despite their importance in determining the texture and firmness of the ice cream. Normal stabilizers include guar gum, locust bean gum, and carrageenan, which are excellent at holding water and stopping ice crystals and syneresis from forming during storage (Cruz et al., 2021). Stabilizers are typically beneficial to the ice cream mix in one way or another since they assist in maintaining a smooth and even texture of the ice cream at least after some freeze-thaw cycle. This position is especially crucial when making low-fat or non-dairy products, particularly those containing little milk fat, given that the fat aids in texture control (Smith et al., 2018).

2.3.5 Emulsifiers

These play a crucial role in forming stable fat-water emulsion bases, typically utilized in a weight range of 0.2 to 0.5%. The major emulsifiers include mono- and diglycerides, lecithin, and polysorbates (Goff and Hartel, 2013). Emulsifiers help lower the interfacial tension between fat (like input) and water. This makes it easier for fat globules to spread out evenly and speeds up the freezing process by letting more air in. Furthermore, emulsifiers contribute to the establishment of a stable fat network, which is crucial for the air incorporation step as well as for the texture and melting of ice cream (Tharp & Young, 2012). Without the use of emulsifiers, the ice cream may melt quickly and develop a coarse texture due to improper stabilization of the fat phase.

2.3.6 Air

People rarely consider gaseous substances, yet air plays a crucial role in shaping the texture of ice cream. Air, also known as overrun, can range from 30% in high-end ice cream to over 100% in substandard ice cream products (Marshall et al., 2018). Air makes the ice cream less dense than it would be if it were denser, making it easier to scoop. Deliberately adding air during the churning process is crucial for achieving a smooth and rich texture, as it prevents the formation of large ice crystals. Overrun is crucial to achieve the desired texture of the ice cream (Goff and Hartel, 2013).

2.4 Dairy By-Products

Dairy by-products are the remaining residual material obtained during milk processing from milk to its primary products such as butter, cheese, cream, or yogurt. Few decades ago, these by-products were considered as waste, but with advancements, dairy by-products are valued as high nutritional and functional contents with unique properties in animal feed, human food, cosmetic products, and nutraceuticals. These by-products have different nutritional compositions and are thus useful not only in the food industry but also in the agricultural, pharmaceutical, and cosmetic industries (Aime et al., 2001). An important role played by dairy by-products is in sustainability of current resources, aligning with circular economy and zero-waste models within the dairy sector (De Boer, 2014).

2.4.1 Types & Nutritional Value

The most frequently produced dairy by-products include buttermilk, whey, caseins, ghee and ghee residues, and lactose, all of which possess different nutritional profiles and functionality. Specifically, whey, the residue from curdling milk during cheese production, contains a high content of protein, lactose, vitamins, and minerals. Vital amino acids embedded in the protein complements make it a common ingredient in nutritional products, especially for athletes and health-conscious individuals (O'Mahony & Fox, 2014). It interacts with whey protein to quickly digest and aid in muscle repair. Due to their high protein content, people commonly use two types of whey: whey protein concentrate and whey protein isolate. These forms are also incorporated into numerous food systems to enhance such properties as texture, water retention, and shelf stability of food items such as baked goods, ice cream, and beverages (Aime et al., 2001)

2.4.2 Whey

Sweet whey is a by-product with high nutritive value, is gained during cheese manufacturing particularly from Swiss or cheddar cheese (hard cheese) when the coagulation of milk is performed via rennet (Macwan et al., 2016). It is used in preparing frozen desserts such as ice-cream, and also in sports drinks and brews; whey is also utilized in the synthesis of a special type of cheese called ricotta cheese. In sweet whey, the composition of whey protein is different as it contains fragment of casein molecule called glycomacropeptide, formed during rennet clotting (rennet-based whey) and it makes 20% of whey protein giving its sweet taste (Glass & Hedrick, 1977). Whey is high nutrition product and it is rich in whey proteins such as alpha-lactalbumin and beta-lactoglobulin, lactose sugar, and vitamins particularly B-complex (Macwan et al., 2016). Sweet whey also have bioactive peptides contributing to muscle repair and immune functioning.

Whey Protein Isolate and Whey Protein Concentrate are the two most widely accessible forms of whey protein. While whey protein isolate is a more refined form that contains 90% or more protein with less lactose and lipids, whey protein concentrate typically contains 70–80% protein along with lactose, fats, and minerals (Smith et al., 2020). Both provide distinct functional characteristics that influence the texture, stability, and nutritional makeup of the ice cream, offering producers flexible options to enhance product quality (Goff & Hartel, 2013). Whey proteins support the sensory qualities and structural integrity of ice cream. Whey protein improves emulsification, which helps to stabilize fat globules during synthesis (Marshall et al., 2012). Whey protein's capacity to create a gel network enhances ice cream's melt resistance, a feature that customers much appreciate (Muse & Hartel, 2004). Whey protein enhances ice cream's protein level and provides nutritional value by containing important amino acids and bioactive peptides that support the immune system and muscle recovery, among other health advantages. Since whey protein is regarded as a "complete protein," it is increasingly used in foods that are fortified with protein, such as ice cream (Ha & Zemel, 2003). Whey protein is used in functional food formulations targeted at health-conscious customers who look for products with extra health benefits, according to recent studies (Gupta & Sharma, 2022).Whey protein can impact an ice cream's flavor and texture, among other sensory qualities. According to research by Warren and Hartel (2018), whey protein mostly improves the creamy texture, which is crucial for customer acceptability, even though it can somewhat change the flavor profile. Research indicates that whey protein isolate and concentrate may interact with milk fat and other solids in ice cream to provide a creamier texture and richer mouthfeel (Clarke, 2015).

Since whey protein upcycles dairy by-products that would otherwise contribute to food waste, its usage in ice cream production promotes sustainability. By turning waste into useful ingredients, the use of whey protein supports the industry's circular economy objectives, as highlighted by Oana-Viorela Nistor (2020). The potential to satisfy environmentally concerned consumers and cheaper production costs as a result of less reliance on main dairy sources are the two economic advantages.

Buttermilk is an important liquid by-product of butter formed during butter production. During the process of churning, when milk fat is processed to separate fat granules in the liquid phase, buttermilk is achieved. Buttermilk is used in the manufacturing of ice-cream and other food products due to its richness in proteins, milk fat, and the milk fat globule membrane (MFGM). Buttermilk contains protein, particularly casein, which play a role in giving structure and creaminess to those products to which it is added. Moreover, buttermilk is characterized by a sour taste resulting from the presence of lactic acid, which gives food products a certain taste. The MFGM is rich in glycolipids and phospholipids, proposing emulsifying properties, and health benefits linked with immunity and cognitive function (Skryplonek et al., 2019).

2.4.3 Buttermilk

Another dairy product of significant food uses is buttermilk, which is a byproduct of the butter churning process. The former is formed once cream has been churned for butter formation, while the liquid part you are left with is what you call buttermilk. This byproduct has high phospholipid concentrations, which makes buttermilk a suitable ingredient for enhancing emulsification properties in dairy and bakery products and sauces. Buttermilk also contains protein, particularly casein, with a role in giving structure and creaminess to those products to which it is added. Moreover, buttermilk is characterized by a sour taste resulting from the presence of lactic acid, which gives food products a certain taste. For example, more ice crystals may form, giving the ice cream a rougher texture that lessens its creamy appeal (Arellano et al., 2012; Berger et al., 1972)
When cream is churned during the buttermaking process, a byproduct known as buttermilk is generated. It is the last liquid phase that contains cream's water and water-soluble ingredients. Buttermilk's general makeup is quite similar to that of skim milk; it includes lactose, proteins (casein and serum proteins), and minerals. Food technologists are particularly interested in buttermilk because of its high level of milk fat globule membrane elements. Buttermilk is a promising material to generate new food items with functional attributes because of its strong nutritional qualities, low acquisition costs, similarity to skim milk, good sensory features, emulsifying properties, and positive impact on human health. Buttermilk improves the whippability of mixtures, which could lead to more ice cream being produced than needed (Szkolnicka et al., 2020).

2.4.4 Milk permeate

Milk permeate, which comes as a byproduct of ultrafiltration, is another useful ingredient in the food industry. Milk permeate, which is rich in lactose and minerals, is used as an economical substitute to milk powder in applications such as bakery products, dairy drinks, and confectionery. In these applications, milk permeate is involved in the browning process, aiding in flavor development as well as texture in baking products. Milk permeate contains minerals such as calcium and potassium and can be incorporated into fortified products and nutritionally enhanced beverages to form valuable ingredients for consumers who are health conscious, especially in relation to bone health and electrolyte balance. Moreover, the functionality of milk permeates lower fat and cholesterol content, and it can be used to make low-calorie products and still contain the acceptable mouthfeel that consumers associate with dairy products. For this reason, milk permeate is often added in reduced sugar or reduced fat products where it gives body and taste without contributing to the calorie content (Anklam et al., 1997).

Used more or less in conjunction with whole milk powders for bakery as well as dairy products, it imparts flavor, browning, and texture to the products. Because of its high levels of minerals, especially calcium and potassium, milk permeate is richly suited for the enhancement of food products. (American Dairy Products Institute, 2024). Milk permeate also has functional properties because it has nutritional characteristics that are suitable for pets' diets when incorporated in the development of pet foods. It is also used for natural minerals for feed ADD health purposes in animals, especially in livestock and milk production in cows and others (Helen, 2019).

2.4.5 Skim milk powder

Skim milk powder, which is processed by dehydrating skimmed milk, is another flexible intermediate dairy product. Dairy based proteins are extensively used in the production of food and particularly in the food preparation as proteins and as baking aids, softeners, stabilizers, and emulsifiers in confectionery and meat products (American Dairy Products Institute, 2024). Due to the high levels of protein in skim milk powder, the product is also useful in protein-enhanced foods and nutrition supplements (Skim Milk Powder, n.d.). Skim milk powder is also used in food applications apart from pharmaceuticals and nutraceuticals, where it serves as a source of natural bioavailability calcium as well as proteins that are very vital to human beings. Another advantage is that skim milk powder can easily be reconstituted into liquid milk; its reconstitution possibility is a boon, especially when there are constraints with fresh milk supply (RECOMBINED MILK PRODUCTS, 2019).

2.5 Uses of dairy by-products in the Food Industry

Nutritionally, dairy by-products are very rich and diverse, providing a range of proteins, amino acids, vitamins, and important minerals. For example, whey protein is preferred due to its rich protein and branched-chain amino acids that play an important role in muscle synthesis and repair. (Auestad & Layman, 2021). Milk and products also contain minerals such as calcium, phosphorus, and potassium, which are required for bone formation, proper functioning of the nerves, and proper balances of salts in the body (Dairy Nutrition & Vitamins, n.d.). The vitamins found in the dairy by-products, such as B vitamins, and fat-soluble vitamins, such as A and D, make them have a lot of added nutritional value that can be very useful in fortifying foods and supplements. Other than the functional macropeptides, the bioactive compounds existing in the dairy products, including the lactoferrin and the immunoglobulins, and the growth factors also contribute to the health benefits, such as the immune booster and the antioxidants. (Newell, 2024).

It is worth admitting that more and more dairy by-products are used in the modern food industry because they improve product quality, offer essential functional and nutritional values, and allow for optimizing production processes as well as contributing to further sustainable food production. Among them, whey, buttermilk, skim milk, and milk permeate are some of the most versatile by-products widely incorporated in many food sub-sectors, as each has different functional attributes related to taste, texture profile, product stability, and nutrient content (RECOMBINED MILK PRODUCTS, 2019). Cheese production produces whey as a side product, which represents high added value as it contains quality protein for food products and has high digestibility for health-conscious products. Whey protein concentrate and whey protein isolate are being employed in beverages, sports supplements, and protein-enriched food products in which they act as a source of added protein, which gives the food and beverages a pleasant taste and texture. Their uses in bakery products also enhance dough flexibility, enhance browning, and increase shelf life, which are favorable characteristics in high-protein products (American Dairy Products Institute, 2024).

A more refined dairy by-product is buttermilk, which is also in high demand due to its amazing ability to act as an emulsifying agent in sauces, dressings, and ice cream, among others, and in baking. The drink has a high level of phospholipids, which enable forming stable emulsions, necessary for obtaining the ideal texture of dairy products. Consumers also appreciate the sour taste that characterizes buttermilk ("Comprehensive Reviews in Food Science and Food Safety," 2010). Buttermilk is useful because it not only adds taste to food like pancakes, biscuits, muffins, etc.; it also contributes to a soft texture. Further on, the protein in the form of casein in buttermilk helps in retention of water when baking, making goods moist and possessing good texture. The same applies to the production of the low-calorie or lesser-fat dairy products, where the buttermilk is used to create a smooth texture without the added fat. They have used it in the formulation of ice cream; it provides functional and sensory advantages because buttermilk provides a creamy texture and assists in holding the fat in ice cream from crystallizing during freezing. (Home | ThinkUSADairy by the U.S. Dairy Export Council, n.d.)

Dairy by-products also contribute to the nutritional content and texture of ice cream, in addition to their use in yogurts. For instance, whey proteins and buttermilk, as ingredients, play a crucial role in the production of low-fat and high-protein ice creams due to their ability to impart a creamy texture and prevent the formation of ice crystals. (Goff, 2015). Concentrated and isolated whey proteins enhance the viscosity and body of the mix, enabling the processing of ice cream mixes with a superior texture that closely resembles full-fat ice creams. Buttermilk, because of the presence of natural emulsifiers, helps in improving fat rheology and in effect maintaining fat stability to the splitting up, and this is very crucial as far as texture and mouthfeel or the creaminess of the ice cream is concerned. Moreover, ice cream mixes often incorporate casein to achieve the necessary structure and viscosity, ensuring the correct melt rate and texture after serving (Goff, 2015).

It serves as a natural additives in processed foods and also enhances their texture. For instance, companies add whey protein and casein to meat products to improve their water holding capacity, meat tenderness, and shelf life (Sánchez-Ortega et al., 2014).Whey proteins enhance the juiciness and shelf life of processed meats such as sausages by increasing their water holding capacity, thereby reducing cooking losses. Sodium caseinates are used as emulsifying and stabilizing agents in convenience foods and sauces for unctional improvement, better binding of the ingredients, and enhanced mouthfeel (Bende, 2023). The use of dairy by-products in processed foods enhances their enjoyment and aligns with the emerging industry trend of clean label formulations, which views dairy-based ingredients as more natural than synthetic stabilizers or emulsifiers (Berry, 2018).

In the production of beverages, a notable practice is the incorporation of dairy by-products to create nutrient-enriched beverages and shakes that are commonly consumed by fitness-minded individuals. (BSc, 2023). Sports drinks and protein shakes, as well as meal replacement products, incorporate whey protein as a supplement, providing individuals with complete protein and aiding in muscle tissue repair. (Berry, 2013). These dairy by-products also enhance the value of the fortified beverages, resulting in better sensory properties, such as a smoother texture and a better mouthfeel. Furthermore, these dairy by-products not only enhance the sweetness of milk products but also serve as a mild source of carbohydrate energy in fermented milk drinks. (Moss et al., 2023)

Over the past few years, by-products from the dairy industry have also attracted attention as functional ingredients when creating new products, including gluten-free and plant-based ones. For instance, gluten-free bakery applications utilize whey protein and casein to imbue final gluten-free breads and baked foods with the cohesiveness and elasticity of gluten, thereby facilitating the structural modifications required to produce superior breads, cakes, and pastries. Furthermore, the solubilizing properties of buttermilk can add structure and perception to products like non-dairy cheeses and creams. Additionally, this application broadens the consumer base for dairy by-products and aligns with the industry's development trend towards restricted diets and individualization (Deshwal et al., 2024).

In conclusion, the food processing industry recognizes the immense value of dairy by-products for their functions and usefulness in enhancing the flavor, texture, and longevity of the foods they utilize. These include high-protein supplements and low-fat dairy products, gluten-free bakery products, and meat substitutes, as demonstrated by their cross-cutting category outputs (Rațu et al., 2023). Study shows how it is possible to incorporate by-products of dairy in food formulations that contribute to better and more efficient utilization of resources, improve sustainability aspects, and at the same time supply the market with foods that will respond to the changing needs and expectations of consumers (Feil et al., 2020).

2.6 Applications of Dairy by-Products in other industries

Dairy by-Products are not only used in Food Industry but also products of dairy in feeding animals, which enable them to manage excess production, cut waste, and add value to the dairy chain. In addition, whey and other dairy by-products find their uses in biotechnological processes as a source of fermentation media to yield peptides, enzymes, and organic acids. These compounds are useful for many purposes, such as preparing antimicrobial agents, antioxidants, and fortificants for nutritionally enhanced food products (Yang et al., 2021).

Dairy by-products are used in non-food sectors in addition to the food-producing sector. For example: Whey proteins: Because they are biodegradable, they are used in packaging films. Nutritional Supplements: To meet the needs of a rising consumer base interested in nutrition and dietary supplements, dairy by-products are being used more and more in health and wellness goods (Seow, 2024).

In cosmetic industries, dairy products, especially buttermilk and casein, are used, attributed to the benefits they have on skin. Lactic acid in buttermilk acts as a natural scrub; hence, the skin will be smoother and better moisturized (Sanghvi, 2022). Casein, because of its ability to provide moisture and emollience properties, is used in the preparation of skin care formulations in which it acts as an effective by improving the skin's elasticity and its ability to retain moisture (Casein in Skincare, What Is? | Lesielle, n.d.) There is also usage of whey proteins in cosmetic products for hair as they enhance hair strands firmness and overall feel of hair. The components obtained by hydrolyzing dairy proteins are also incorporated in anti-aging products due to the perceived antioxidant and skin regeneration properties of the peptide fragments.

Overall, dairy by-products enthusiastically can be used in food production, medicine, agriculture, and cosmetics industries (Barbulova et al., 2015). Due to their nutritional richness and multifunctional characteristics, they can be considered valuable ingredients in the formulation of products, which, promoting the utilization of otherwise wasted dairy products, contribute to effective utilization of resources available to the industry (Sar et al., 2021). Industries need to fully exploit their potential for enhancement of these by-products to sustain innovation as well as to serve the ever-increasing consumer base for the need for nutritious and functional food ingredients in food production.

3. Material and Methods

Buttermilk and sweet whey have been used as the main dairy by-products in experiments aimed at creating ice cream. Buttermilk and sweet whey are significant ingredients in ice cream formulation, providing nutritional benefits and saving waste by recycling dairy by-products, according to our assessment of the product's major attribute.

3.1 Materials

The experiments were conducted at the Labortory in The Hungarian University of Agriculture and Life Sciences (MATE), Buda Campus, Hungary in the Department of Livestock Product and Food Preservation Technology. For the experiment we used the following:

- Buttermilk from Alföldi Tej Kft., Hungary.
- Sweet whey obtained from Alföldi Tej Kft. in Hungary.
- Cream sourced from Milli, Friesland Hungária Zrt., Budapest, Hungary.
- m-GEL Hungary Kft., Budapest, Hungary, supplies dextrose.
- Sugar was acquired from Magyar Cukor Manufaktúra Kft. in Kaposvár, Hungary.
- Locust bean gum is obtained from Danisco Ltd., which is represented by KUK Hungary Kft. in Győr, Hungary.
- Milk obtained from Spar, Budapest, Hungary.

Milk is utilized as the basis due to its nutritional attributes, which include a buttery texture and high-quality proteins. Sweet whey is employed to improve the nutritional value and flavor of products by increasing their protein content. The product's texture and viscosity are enhanced by the presence of cream, which imparts a richness. Its flavor profile, sweetness level, and prospective texture are influenced by the use of dextrose and sugar as sweeteners. Locust Bean Gum functions as a stabilizer and thickener, preventing separation and increasing viscosity in the formulation. BM represents buttermilk, SW represents Sweet whey.

Table 2: Recipe of Buttermilk (BM) Ice-Cream

Ingredients:	**0% BM (g)**	**20% BM (g)**	**40% BM (g)**	**60% BM (g)**	**80% BM (g)**	**100% BM (g)**
Buttermilk	0	55.7	111.4	167.1	222.8	278.5
Milk[a]	278.5	222.8	167.1	111.4	55.7	0
Cream[b]	125	125	125	125	125	125
Sugar	64	64	64	64	64	64
Dextrose	32	32	32	32	32	32
Locust Bean	0.5	0.5	0.5	0.5	0.5	0.5

[a] ***(3.5% Fat)***

[b] ***(30% Fat)***

Table 3: Recipe of Sweet Whey (SW) Ice-cream

Ingredients:	**0% BM (g)**	**20% BM (g)**	**40% BM (g)**	**60% BM (g)**	**80% BM (g)**	**100% BM (g)**
Sweet Whey	0	55.7	111.4	167.1	222.8	278.5
Milk[a]	278.5	222.8	167.1	111.4	55.7	0
Cream[b]	125	125	125	125	125	125
Sugar	64	64	64	64	64	64
Dextrose	32	32	32	32	32	32
Locust Bean	0.5	0.5	0.5	0.5	0.5	0.5

[a] ***(3.5% Fat)***

[b] ***(30% Fat)***

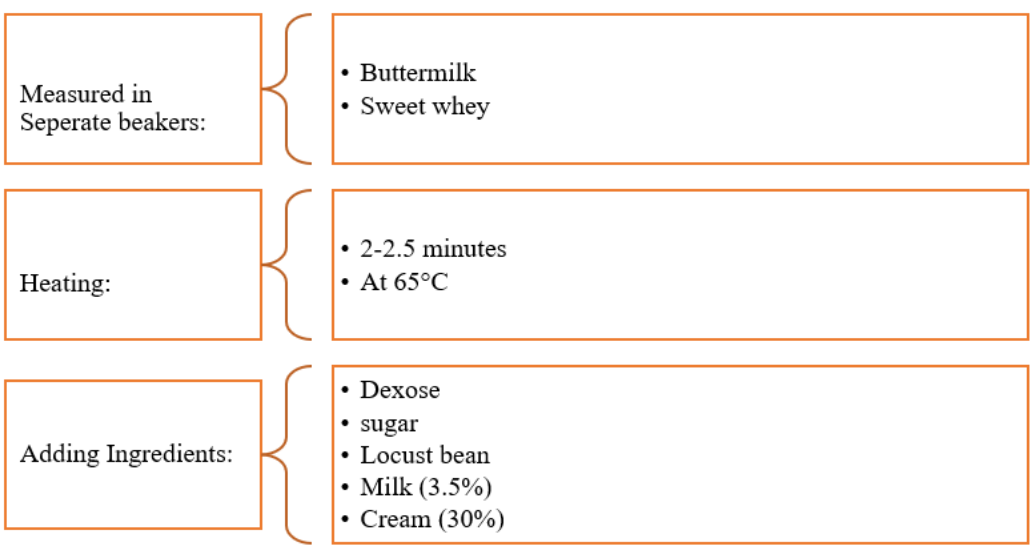
3.2 Ice-Cream Making Procedure

A laboratory balance was used to weigh each powdered ingredient separately in different beakers. Additionally, the sweet whey and buttermilk were measured in different beakers. After that, the buttermilk and sweet whey were heated to 65°C in the microwave for 2 to 2.5 minutes. After the drink was heated, the pre-weighed powdered ingredients were added, and a Robot Coupe Mini MP 160 V.V. mixer (Robot Coupe, Montceau-en-Bourgogne, France) was used to homogenize the mixture. To guarantee a consistent mix, the homogenization process was run for two to three minutes at speed 3 (with a speed range of 1 to 9, or 2000 to 12500 rpm).

The mixture was homogenized, then put into PA-PE (polyamide-polyethylene) bags and sealed using an impulse sealer. After that, the sealed bags were pasteurized for 30 minutes at 75°C in a water bath. To speed up the age process, the bags were submerged in cooled water at 4°C for 24 hours as soon as pasteurization was finished. A horizontal freezing machine (Telme CRM GEL 5; Telme, Codogno, Italy) was used to produce ice cream for 13 to 15 minutes after the age time. After that, the ice cream samples were placed in plastic containers and allowed to solidify for an hour at -30°C. To finish the freezing process, they were lastly kept at -24°C for a day or two.

Figure 3: Ice Cream making procedure

Own source based on (Clarke, 2004)



3.3 Methods

3.3.1 Color Measurement

We checked the surface color variation in CIELAB values immediately following the aging process using the Konica Minolta CHROMA METER CHR-400 tristimulus color measuring system (Konica Minolta Sensing Europe B.V., Nieuwegein, Holland) (L*: lightness range from 0 (black) to 100 (white), +a*: redness, -a*greenness, +b*: yellowness, -b*:blue). Triplets were used to measure the values of all blends. Each of the ice creams containing varying amounts of buttermilk and sweet whey was put in a clear bag and distributed evenly according to the measurement. Next, we used the following formula to obtain the color difference values after verifying the color measurements.

$$\Delta E^*{}_{ab} = \sqrt{\Delta L^{*2} + \Delta a^{*2} \Delta b^{*2}} \qquad (1)$$

Where:

ΔE*: color difference visible for human eyes

ΔL*: lightness difference

Δa*: redness color difference

Δb*: yellowness color difference

Table 4: Values for color difference visible for human eyes

Visibility range	Observation
0-0.5	not visible
0.5-1.5	only slightly recognizable
1.5-3.0	recognizable
3.0-6.0	well visible
6-12	great difference

3.3.2 Dry matter Content

Dry Matter Content is evaluated by weighing 1 to 2 grams from each sample in pre-weighted Petri plates using an analytical balance, per AOAC (1995). Three duplicates of each were made. They were then dried for 24 hours at 105°C in a drying oven. They were taken out and placed in a desiccator to cool. Additionally, an analytical balance was used to weigh the samples, and the following formula was used to determine the dry matter content.

$$DMC = \frac{Wd}{Wo} \times 100 \tag{2}$$

Where:

DM: dry matter content (%)

Wd: weight of dry sample(g)

Wo: Weight of initial sample(g)

3.3.3 pH measurement

A portable digital pH meter type (206-pH2, Testo SE & Co. KGaA, Titisee-Neustadt, Germany) was used to measure the pH of ice-cream mixes from each sample at room temperature, three replicates have been done.

3.3.4 Rheological measurement

We used an MCR 92 rheometer (Anton Paar, France) to assess the rheological properties of the samples in accordance with Hidas et al. (2021). The spinning cylinder and concentric cylinder configuration of this rheometer had the following measurements: the bob length was 40.003 mm, the bob diameter was 26.651 mm, the cup diameter was 28.920 mm, the positioning length was 72.5 mm, and the active length was 120.2 mm. The equipment was controlled using Anton Paar RheoCompass software, and all measurements were performed at a constant temperature of 20 °C. We adjusted the shear rate logarithmically from 10 to 1000 1/s over 31 measurement sites to measure the shear stress, collecting data every 3 seconds.

3.3.5 Overrun Measurements

Ice cream formulation and acceptability are dependent on foam creation and stabilization. For that, we measured the overrun to check the foaming capability of ice cream. For that we measured the weight of samples before and after freezing in small disposable cups. All weight differential measures were determined in percentages. All measurements were taken in three replicas by using the formula mentioned below.

$$OR = \frac{Wbf - Waf}{Wbf} \times 100 \tag{3}$$

Where:

OR: overrun (%)

W_{bf}: Weight of samples before freezing.

$W_{af:}$ Weight of samples after freezing.

3.3.6 Sensory Analysis

Nine panelists between the ages of 20 and 30 participated in the sensory analysis, providing ratings on a scale of 1 to 9 (1 being the least pleasant, and 9 being the best). We prepared the items for our panelists in fifteen minutes after taking them out of the freezer. To ensure that it wouldn't alter their taste after consuming more ice cream, they drank water while tasting it. The sensory areas being examined were taste, smell, color, texture, and overall acceptability. We assigned each ice cream a three-digit numbers

4. Results and Discussion

This discussion situates the influence of buttermilk and sweet whey on the physical and sensory properties of ice cream, in accordance with industry trends for environmentally sustainable, nutrient-rich dairy products. In the results SW represents Sweet Whey and BM represents buttermilk.

4.1 Results of color measurement

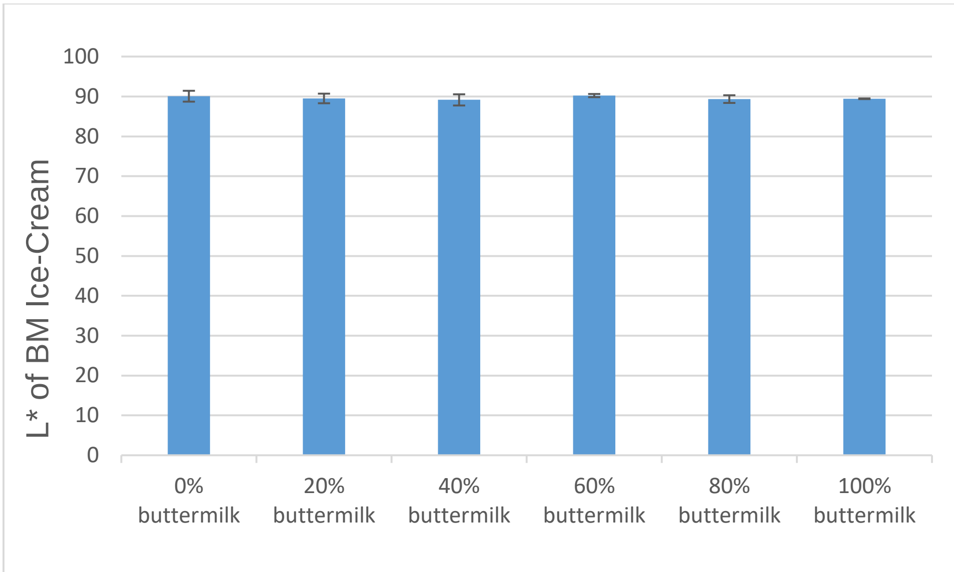
4.1.1 Color measurement in buttermilk ice-cream

a) L* value

According to the **figure 4**, trends in lightness and color, which are essential to the product's visual allure, are revealed by the L* values of ice cream samples with varying buttermilk concentrations. Beginning with 0% buttermilk, the lightness is high at 90.07. The addition of buttermilk progressively reduces the lightness, with 20% buttermilk resulting in a slight darkening effect. At 40%, the lightness is more variable, potentially as a result of changes in texture or opacity resulting from the increased dairy solids, which influence the consistency of the color.

The minor increase in lightness, which is indicative of a smoothing effect, may be helpful in enhancing visual uniformity as the concentration of buttermilk increases to 60%. Nevertheless, the pigment undergoes a slight deepening at 80% buttermilk, which may be attributed to the concentrated solids' impact on reflectivity. The luminosity stabilizes at 100% buttermilk, suggesting that no additional substantial color change occurs at this level.

Figure 4: Color Measurement in buttermilk Ice-Cream (L* value)

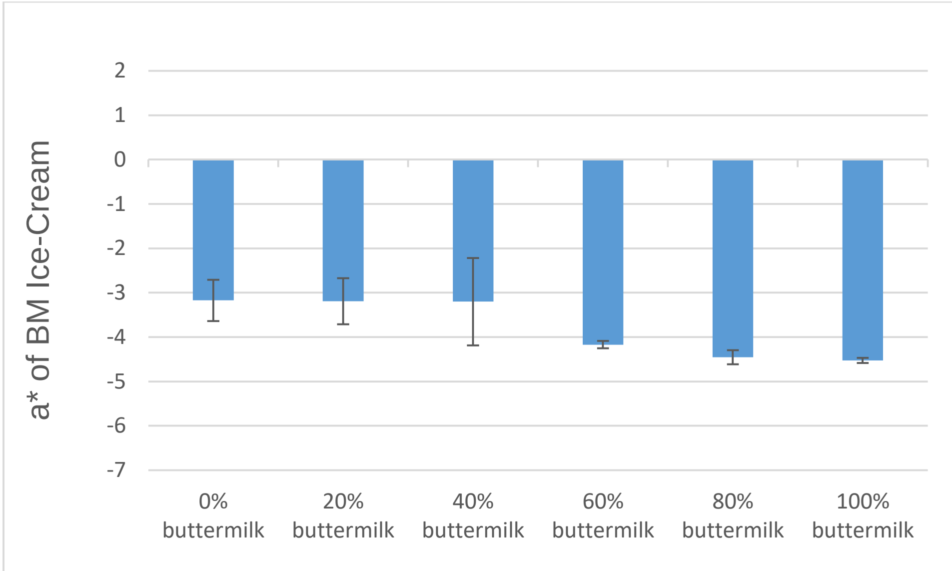


b) a* Value

In **Figure 5**, a subtle shift toward the green spectrum is observed in the a* values as the buttermilk concentration increases, indicating a subtle color change. However, the low variability of these a* values suggests that the reddish-green coloration is generally consistent across samples, with only minimal adjustments required as buttermilk levels fluctuate. It shows clear trend that if we add more buttermilk it shows a bigger negative a* values and eventually more greenish color. Despite the fact that the buttermilk addition affects other aspects, such as lightness, this stability in a* values implies that the red-green balance in the ice cream's color profile is not considerably impacted.

The research suggests that a consistent reddish-green coloration across samples is suggested by the fact that a* values (red-green spectrum) exhibit only minor variations. (Nyulas-Zeke et al., 2024)

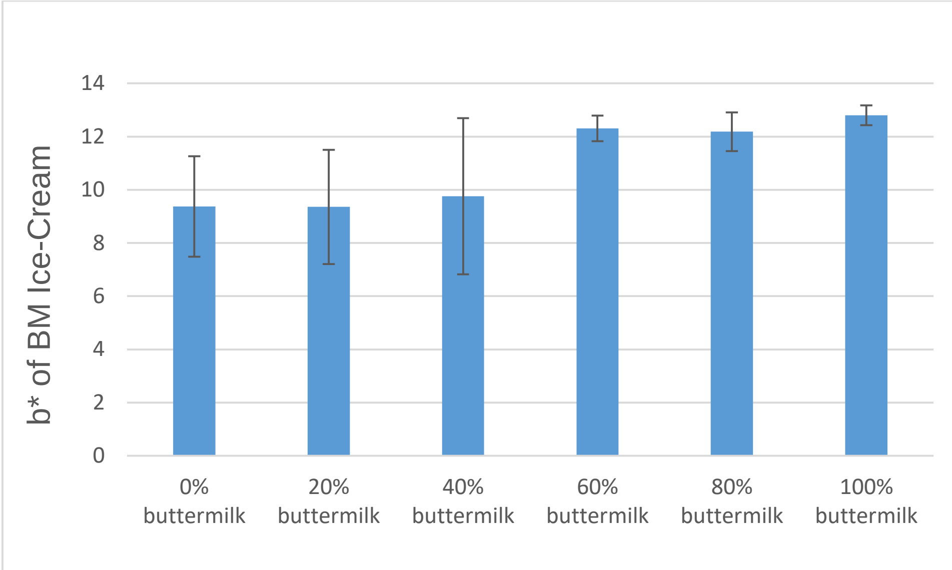
Figure 5: Color Measurement in buttermilk Ice-Cream (a* value)



c) b*Value

According to the **Figure 6** the b* (yellow-blue spectrum) values exhibit an obvious pattern as the buttermilk concentration in ice cream increases. The mean b* value is 9.372 at 0% buttermilk, indicating an inconsistent yellow coloration, with a high degree of variability. The mean b* values (9.356 and 9.762) exhibit significant variability with 20% and 40% buttermilk, indicating an unstable color distribution. The b* value increases to 12.31 at 60% buttermilk, indicating a more consistent yellow coloration, with minimal variability. This stability persists at 80% buttermilk, with a mean of 12.186 and moderate variability. Ultimately, the b* value reaches 12.8 with the least variability at 100% buttermilk, exhibiting a consistent and intense yellow coloration. This trend implies that a more stable, deeper yellow color in the ice cream is the result of higher buttermilk concentrations.

Figure 6: Color Measurement in buttermilk Ice-Cream (b* value)

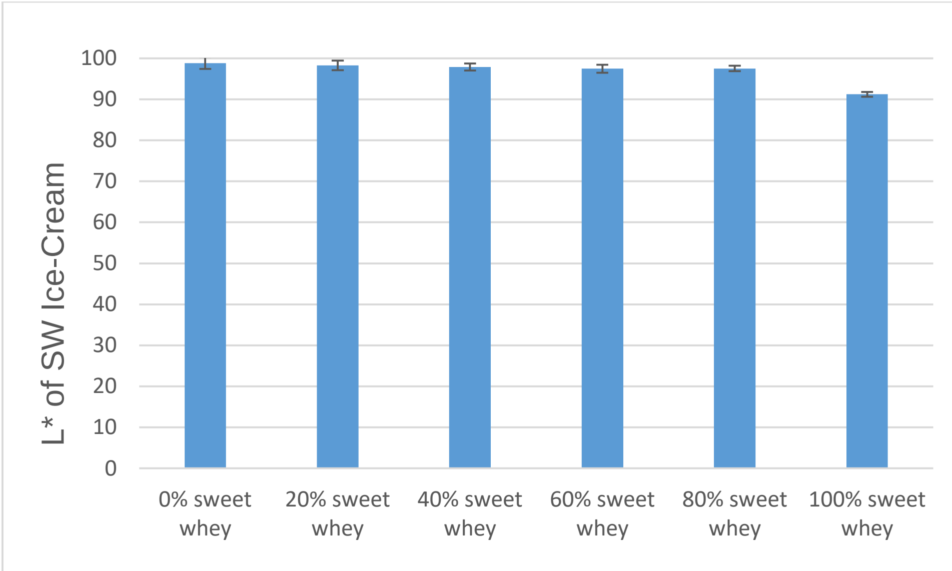


4.1.2 Color measurement in Sweet whey ice-cream

a) L* Value

In **Figure 7** the mean L* value of 0% Ice-cream indicates a lighter hue, with slight variations. The standard deviation is 1.43, indicating consistent lightness. The mean L* value drops to 98.27, with a slight decrease to 97.87 at 20% of whey Ice-Cream increases to 0.89, indicating variation between samples. The mean decreases to 97.47, indicating higher variation in brightness measurements and a small deepening of color. The standard deviation is 0.68, indicating reliable measurements with reduced fluctuation. The ice cream's color is gradually deepening, according to the L* readings; a deeper hue is produced by a higher whey content. This implies that adjusting the whey concentration won't drastically change the product's lightness The observed trend in L* values with differing whey concentrations indicates that whey has a minor impact on the overall lightness of the ice cream. The research suggests that a decrease in L* values, which signifies a reduction in lightness, is the result of an increase in whey protein content. (Mykhalevych et al., 2024)

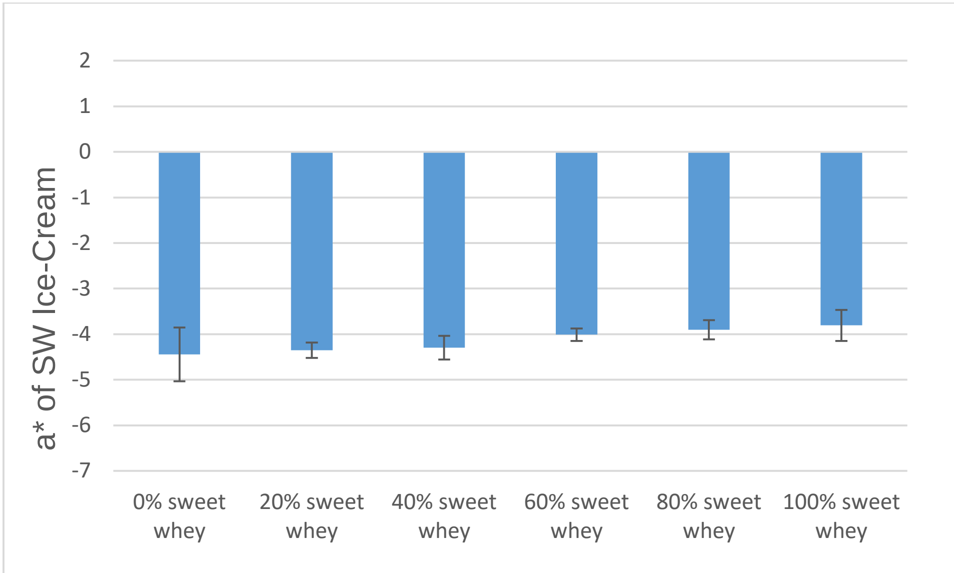
Figure 7: Color Measurement in Sweet whey Ice-Cream (L* value)



b) a* Value

Every sample has a little greenish hue, as shown by the negative a* values. All sweet whey ice cream concentrations have the same green color. The red-green color balance of the ice cream appears to be unaffected by the addition of sweet whey, as indicated by the a* values, which hold steady at varying quantities of sweet whey from 0%, to 100%). The data suggests that the concentrations of sweet whey ice cream does not significantly alter the greenish color. All sweet whey concentrations exhibit a consistent, somewhat green color, indicating that sweet whey has minimal effect on the ice cream's reddish-green color.

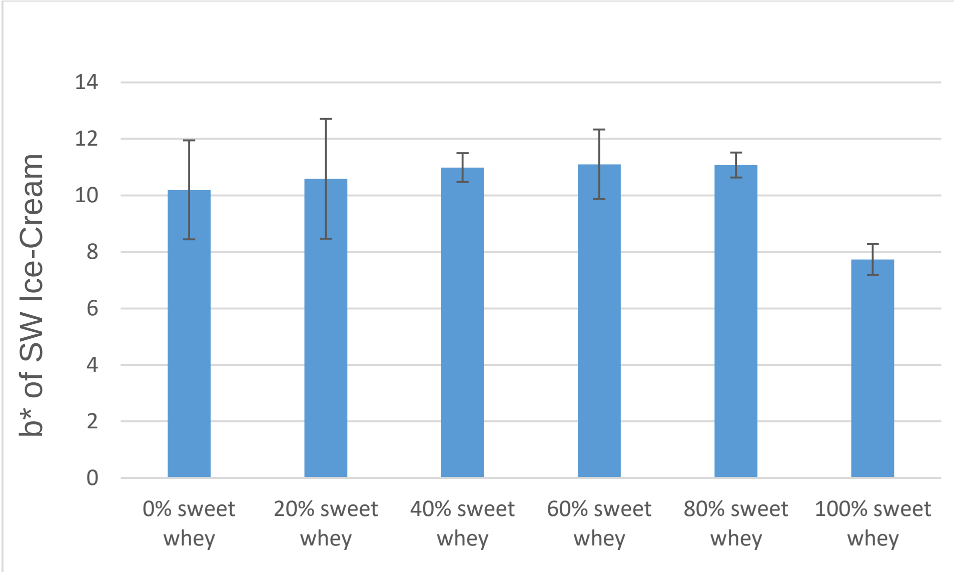
Figure 8: Color Measurement in Sweet Whey Ice-Cream (a* value)



c) b* Value

Figure 9 represents that with a 1.75 standard deviation, the mean b* value of 0% Sweet Whey shows a mild yellow tone. There is color variety when the mean b* value increases to 10.58. As the mean b* value increases to 10.98, more consistency is shown. There is moderate variability, as indicated by the mean b* value rising to 11.10. For 100% Sweet Whey, the mean b* value falls to 7.73, signifying a reduction in yellowness and steady quality. Up to 60–80% of the sweet whey concentration causes yellowness to increase; at 100%, it decreases. With little standard deviation across samples, high whey concentrations may lessen yellow tone.

Figure 9: Color Measurement in Sweet Whey Ice-Cream (b* value)



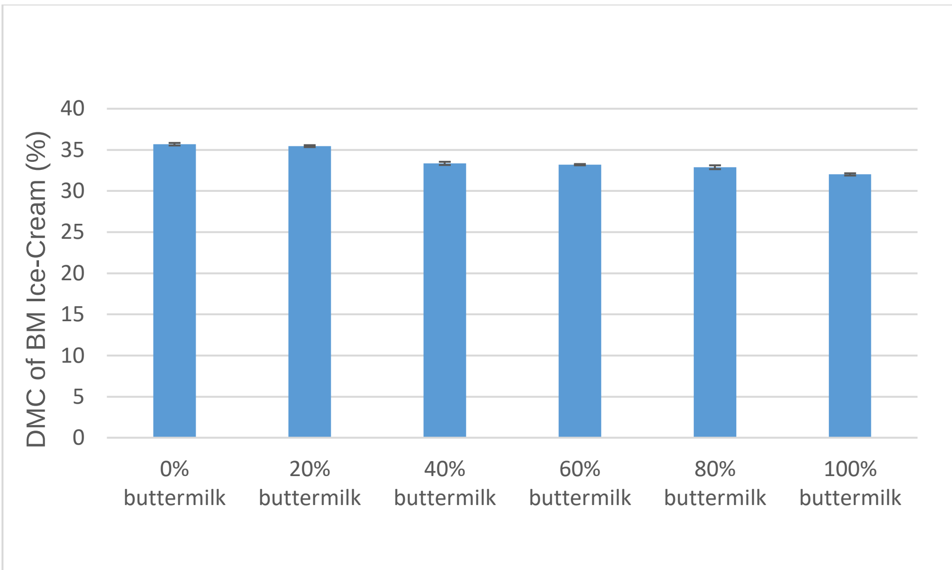
At larger quantities, sweet whey has a more pronounced effect on color variability, particularly in brightness and green and yellow tones. Buttermilk is a more consistent colorant in ice cream compositions because it produces a color profile that is largely stable with relatively minor variations. Buttermilk contributes to a more consistent color profile in dairy products. This is consistent with my observation that buttermilk is a more stable colorant in ice cream compositions, resulting in a color profile that is essentially stable with relatively minor variations (Jinjarak et al., 2006).

4.2. Results of dry matter content

4.2.1 Dry matter content in buttermilk ice-cream

As shown in the **Figure 10** Analysis is done on the average dry matter content (DMC) of various buttermilk samples. With a standard deviation of 0.14 and a high DMC of 35.69, 0% buttermilk stands out. The mean DMC shows a slight dip to 35.46 when 20% of buttermilk is added. Even more consistency is indicated by the even lower standard deviation. A small variation across samples is indicated by the mean DMC dropping to 33.36. Buttermilk has lower dry matter content than milk, so it is decreasing the dry matter content of the ice cream if added in higher percentage. The study reveals that as buttermilk concentration increases, the dry matter content (DMC) decreases, potentially impacting the texture and density of the finished product, with minimal variation observed across samples at every buttermilk level. The trend in DMC indicates that the product's mouthfeel and consistency may be improved by increasing the buttermilk content. Additionally, the minimal variation observed across samples suggests that the buttermilk addition contributes to a uniform distribution of dry matter, thereby ensuring the quality of the product. DMC decreased as the concentration of buttermilk increased, with a range of 34.4 g/100 g at 0% buttermilk to 31.9 g/100 g at 100% buttermilk, according to the research. (Nyulas-Zeke et al., 2024)

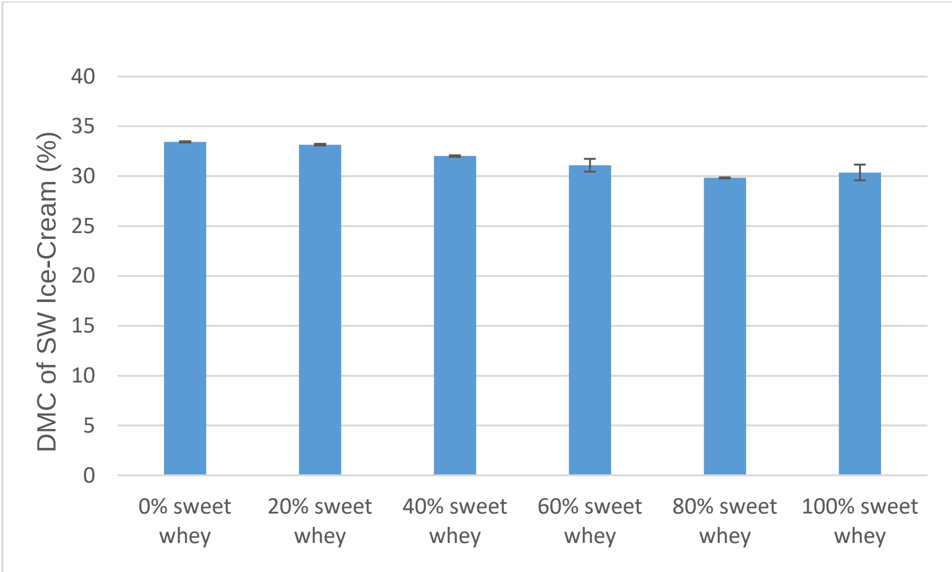
Figure 10: Dry Matter Content (%) in Buttermilk Ice-Cream



4.2.2 Dry matter content in Sweet Whey

As shown in **Figure 11** it is constant across samples, the Dry Matter Content (DMC) of 0% Sweet Whey ice-Cream is 33.44. The mean, DMC decreases to 33.16 at the addition of whey, indicating a little decline. At 40% Sweet Whey, reliability in dry matter content is shown, with a comparable standard deviation. 60% Sweet Whey has more sample variability and a more noticeable drop to 31.11. At 80% Sweet Whey, measurements are constant, but the mean DMC continues to decline to 29.84. 100% There is significant diversity among samples, as seen by Sweet Whey's little rise from 80%. As ice cream's sweet whey concentration rises, particularly to 80%, its DMC falls, which may have an impact on the texture and density of the product. Less consistency is indicated by higher concentrations, such as 60% and 100%, which exhibit more unpredictability than buttermilk. The research emphasizes that the concentration of whey in ice cream formulations tends to diminish dry matter content and influence texture. As whey levels increase, the distribution of dry matter across samples becomes more variable (Wang & Zhao, 2022)

Figure 11: Dry Matter Content (%) in Sweet Whey Ice-Cream



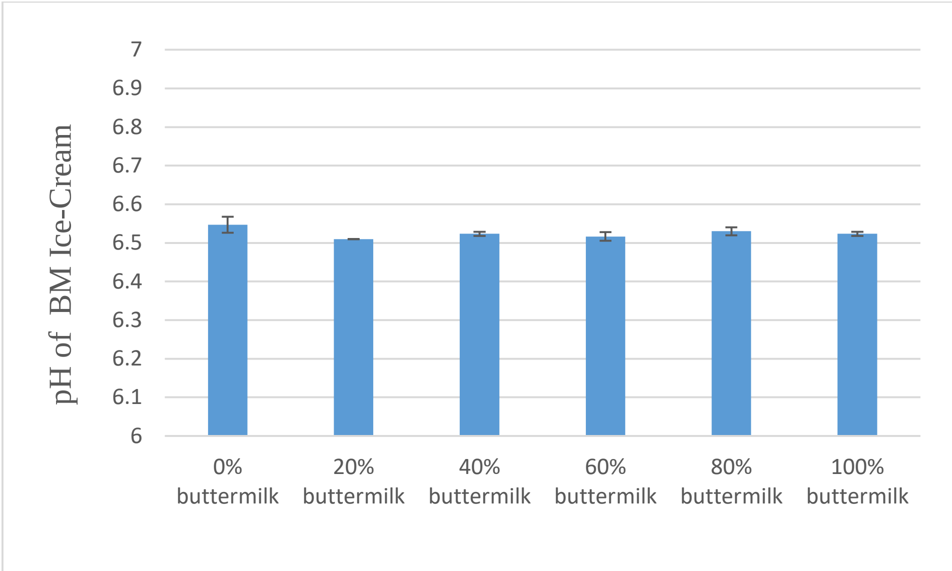
Buttermilk and sweet whey both decrease the DMC, impacting density and texture. Sweet whey has more variability, especially at higher concentrations, while buttermilk provides consistent results. Sweet whey may require additional control for homogeneity, while buttermilk offers a consistent texture.

4.3 Results of pH Measurement

4.3.1 pH measurement in buttermilk Ice-Cream

Figure 12 represents that with a mean pH of 6.55, 0% of buttermilk Ice Cream has a relatively neutral pH. The mean shows excellent pH consistency as it drops slightly to 6.51. With a standard deviation of 0.0058, the mean pH is around 6.52. With a standard deviation of 0.01, the mean pH increases somewhat to 6.53. pH values from 100% buttermilk are reliable and repeatable. As the quantity grows, the pH of buttermilk stays consistent, varying very slightly around the neutral 6.5 range, indicating a stable pH profile that could improve the flavor of ice cream.

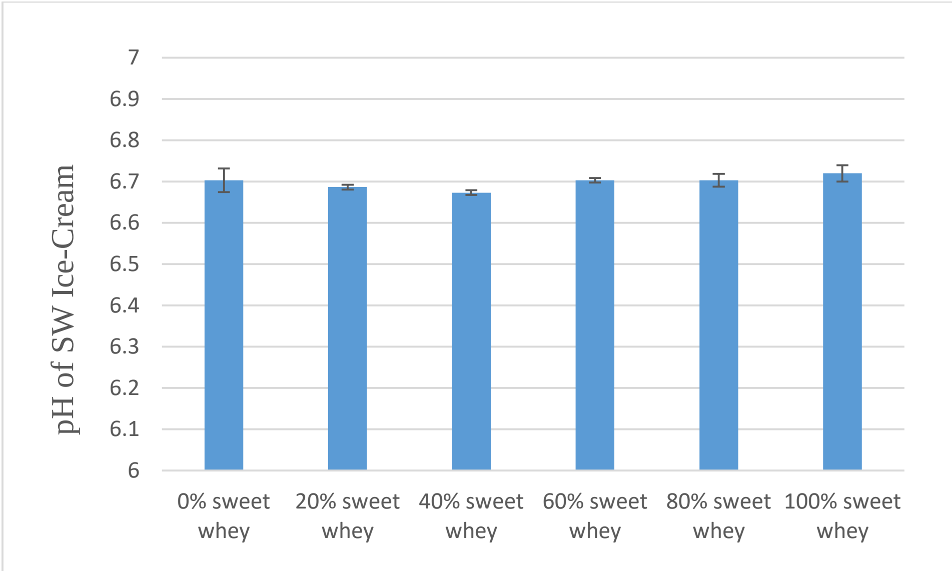
Figure 12: pH measurement in Buttermilk Ice-Cream



4.3.2 pH measurement in Sweet Whey

Figure 13 represents that 40% of the Sweet Whey in the ice-Cream displays a mean pH of 6.67 with a standard variation of 0.006, 20% Sweet Whey's pH measurements reveal a low standard deviation (0.006) and a little decrease to 6.69. While 80% Sweet Whey has a slightly higher standard deviation of 0.015 and a mean pH of 6.70, 60% Sweet Whey displays a consistent mean pH of 6.70. At this concentration, 100% Sweet Whey also shows a consistent pH. Sweet whey's pH, which controls its flavor and consistency in ice cream, stays steady between 6.67 and 6.72. This is because pH measurements from different samples are quite consistent and have minimal standard deviations.

Figure 13: pH measurement in Sweet Whey Ice-Cream



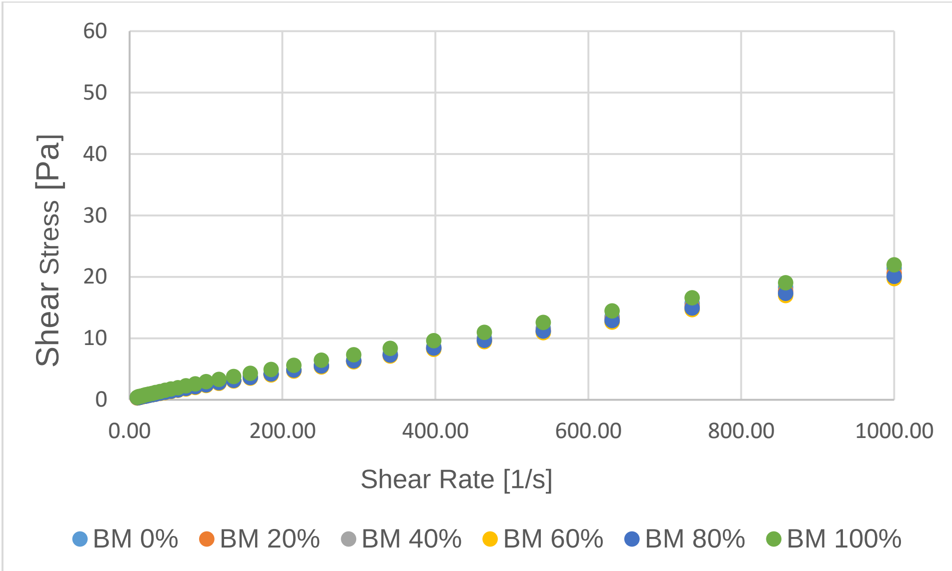
While sweet whey has a slightly greater pH range of 6.67 to 6.72, buttermilk and sweet whey both show stable pH profiles throughout concentrations. While sweet whey's higher pH adds to its flavor and stability and may even add a touch of tang, the lower pH creates a neutral foundation that gives ice cream a moderate, well-balanced flavor.

4.4 Results of Rheological Measurement

4.4.1 Rheology in buttermilk

The relationship between shear stress (resistance to stirring) and shear rate (rate of stirring) for different buttermilk concentrations, ranging from 0% to 100%, is shown in the **figure 14** below. As the shear rate increases (from roughly 10 to 30 1/s), the shear stress decreases more slowly and the values begin to level out. At all concentrations, the shear stress rises in tandem with the shear rate. This pattern suggests that the more quickly the samples are mixed, the more strongly they oppose flow. There is little difference in the patterns of all buttermilk concentrations. This implies that the resistance to flow is not considerably altered by an increase in the percentage of buttermilk. Regardless of the buttermilk content, the close clustering of data points across concentrations demonstrates a homogeneous response to shear. By adding buttermilk at varying quantities, ice cream manufacture maintains a consistent texture and a pleasing mouthfeel while producing stable shear stress values and a useful component without appreciably changing flow properties.

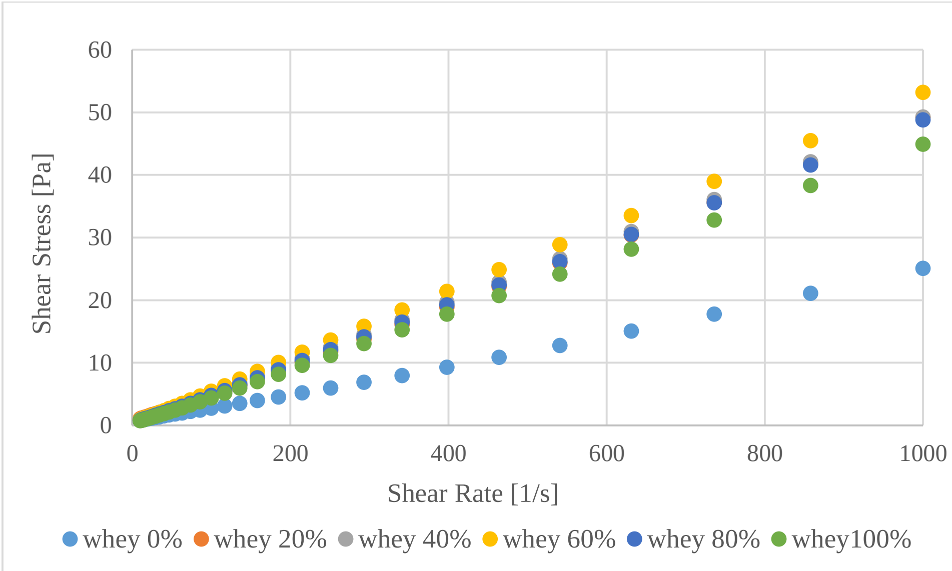
Figure 14: Rheological Measurement of buttermilk Ice-Cream



4.4.2 Rheology in Sweet Whey

Figure 15 illustrates the correlation between shear rate, or the pace at which stirring occurs, and shear stress, or the resistance to stirring, for varying whey concentrations, ranging from 0% to 100%. All whey concentrations show a steady increase in shear stress as the shear rate rises. This pattern indicates that the samples resist flow more and more when they are agitated more quickly. This figure displays a more pronounced variance between whey concentrations than the preceding buttermilk graphic did. At comparable shear rates, larger whey concentrations, especially those of 60% and higher, generally produce higher shear stress values. This implies that the addition of whey raises the flow resistance of the mixture. The shear stress values are more closely grouped at lower shear rates (below about 200 1/s), suggesting that whey content has less of an effect at slower stirring rates. The concentrations grow increasingly separated as the shear rate rises. Whey is a functional ingredient in ice cream, improving texture and mouthfeel, but excessive concentration may increase resistance to flow (Akalın et al., 2007).

Figure 15: Rheological Measurement of Sweet Whey Ice-Cream



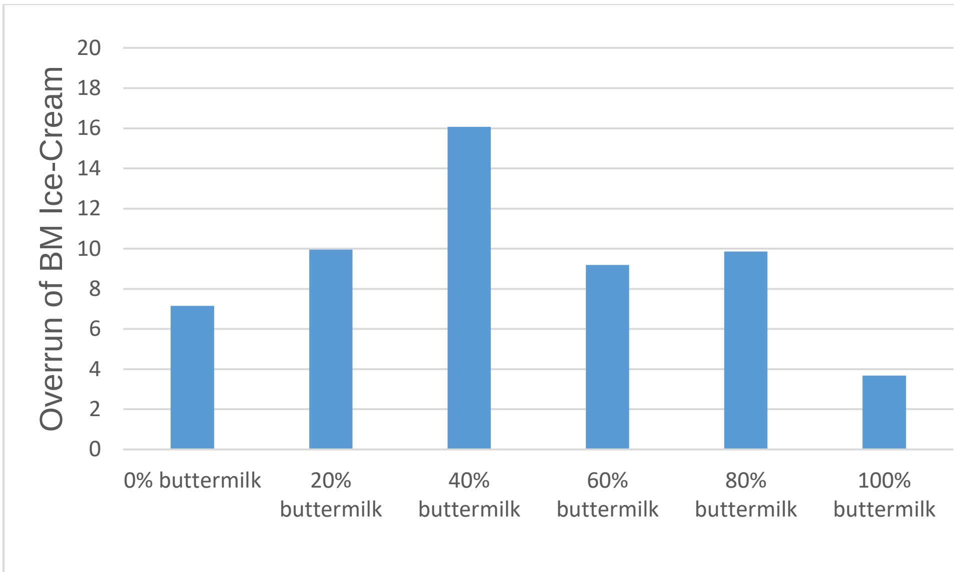
The comparison suggests that buttermilk is a better option for making ice cream. Its consistent reaction to varying concentrations permits formulation flexibility without sacrificing the intended creamy mouthfeel. For making ice cream, a buttermilk content of 40% to 60% would be excellent. Whey is useful for adding creaminess, but at larger amounts, its increased flow resistance may result in an unduly dense texture. Thus, if whey is included, it should not exceed 60% in order to preserve the smoothness of the ice cream.

4.5 Results of Overrun Measurement

4.5.1 Overrun in buttermilk Ice-Cream

In the **Figure 16** the overrun percentage in ice cream varies with the concentration of buttermilk. At 0%, it's low at 7.15%, indicating minimal air incorporation. At 20%, it increases to 9.96%, making the ice cream slightly lighter. At 40%, it rises to 16.06%, indicating higher air incorporation and a lighter texture. At 60%, it drops to 9.18%, resulting in a denser texture. Buttermilk ice cream's overflow percentage changes according to its concentration; denser textures are produced by greater concentrations, while lighter textures are produced by lower concentrations that encourage more air. The texture and overflow of ice cream are influenced by the amount of buttermilk used, lower to moderate amounts (20–40%) provide lighter, airier textures, while higher concentrations (60%) produce thicker ones. My results are in line with studies showing that adding more sweet buttermilk enhances air incorporation, overrun values, and the ice cream's ability to withstand melting. (Ivanova et al., 2024)

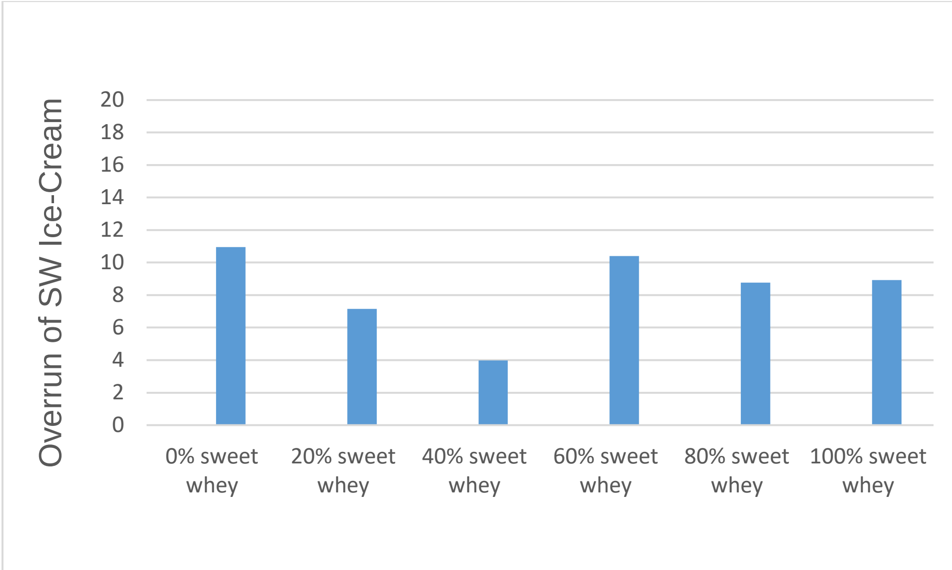
Figure 16: Overrun Measurement in buttermilk Ice-Cream



4.5.2 Overrun in Sweet Whey Ice-Cream

According to the **Figure 17**, the overrun is considerable at 0% sweet whey, suggesting a light mouthfeel. The overflow is thicker and less air-incorporated at 20% sweet whey. The overrun drops to 3.97% with 40% sweet whey, suggesting a thicker ice cream. The overrun increases to 10.41% at 60% sweet whey, suggesting a well-balanced texture with a moderate amount of air. Sweet whey ice cream's overrun percentage varies, with larger percentages at 0% and 60% concentrations and lower at 20% and 40%. Overrun stabilizes at 80% and 100%, ensuring balanced texture, but air absorption is less predictable. By altering the sweet whey content, which can range from low to moderate to higher, manufacturers can create a variety of mouthfeel and texture options for their ice cream. According to the study, sweet whey levels have a big impact on air inclusion and ice cream texture. By varying concentrations from low to higher, manufacturers can alter mouthfeel and textures to accommodate a range of consumer preferences (Young & Steven Young Worldwide, n.d.)

Figure 17: Overrun Measurement in Sweet Whey Ice-Cream



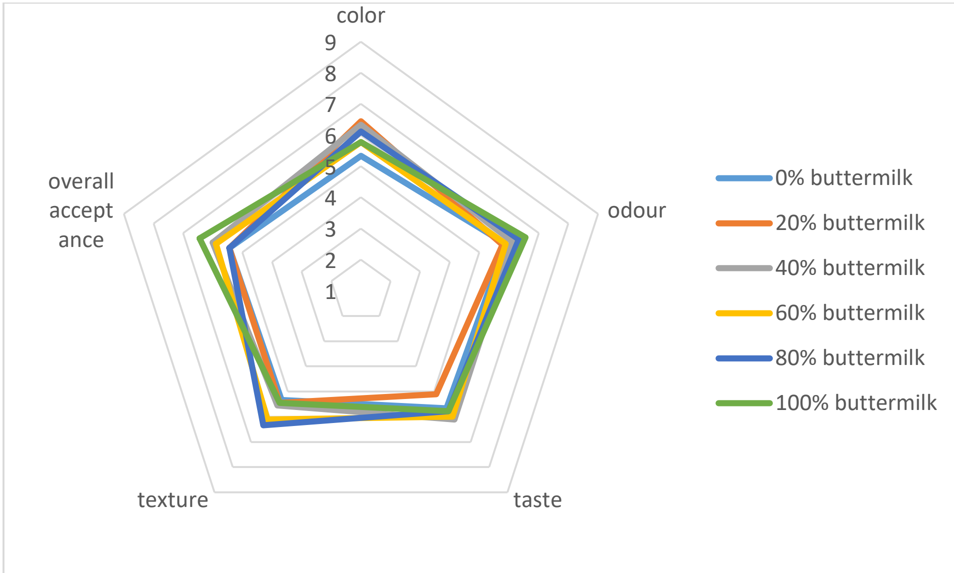
Because of its smooth texture and consistent overrun behavior at moderate concentrations (20% to 40%), buttermilk is a good choice for making ice cream. In contrast, sweet whey provides a variety of texture alternatives but exhibits less consistent behavior at higher concentrations.

4.6 Results of Sensory Analysis

4.6.1 Sensory Analysis of final buttermilk Ice-Cream

As shown in the **Figure 18** that the participants gave the flavor of 0% buttermilk a somewhat acceptable rating, with minor variation. With a mean score of 5.33, the color ratings remained constant at 0% buttermilk. With a mean score of 5.89, the odor ratings at 0% buttermilk were reasonably consistent. With a slight variation, the total acceptance score was 5.44. At 20%, the score dramatically rose to 5.44, indicating that a little larger buttermilk content enhances acceptability. With larger buttermilk contents, acceptance somewhat increased, but overall ratings stayed the same. According to the study, color and acceptability ratings marginally improve with increased buttermilk concentration in ice cream, demonstrating good consistency in sensory characteristics, but odor, taste, and texture stay unchanged. When an ice cream sample was cut with a spoon, the texture's sensory characteristic correlated with whether it crumbled or cut cleanly.

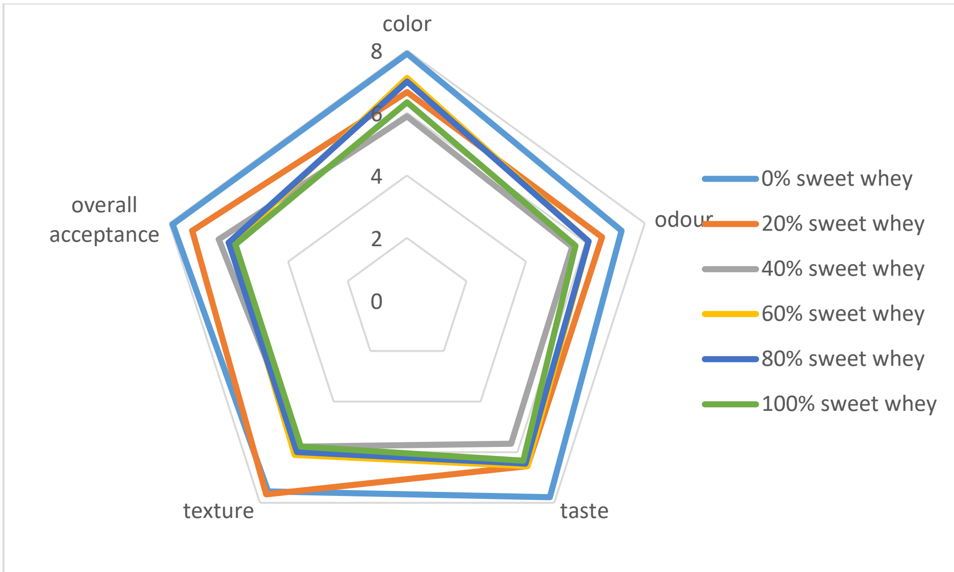
Figure 18: Sensory Analysis of final buttermilk Ice-Cream



4.6.2 Sensory Analysis of final Sweet whey Ice-Cream

Figure 19 shows that the 0% sweet whey color score of 7.89 denotes high acceptance and consistency. At 20% sweet whey, the score falls to 6.67, suggesting greater panelist variance. At 40% sweet whey, the score drops even lower to 5.89, suggesting a drop in color appeal. With an average score of 7.22 for odor, the panelists' responses are generally positive, however there is a significant variation. The score indicates modest but consistent olfactory acceptability as it gradually drops to 6.56 at 20% and remains constant at 40%. Taste scores start at 7.78 and fluctuate a little before falling to 6.56 at 20% and remaining constant at 40%. With a little increase in consistency at increasing concentrations, the texture score stays high at 0% sweet whey. Strong general acceptability and consistency are indicated by the overall acceptance score of 7.89 at 0% sweet whey. According to the study, when the amount of sweet whey in ice cream increases, the color, taste, and overall acceptability ratings fall but texture scores stay high. However, sweet whey ice cream still has a respectable sensory quality, even if panelists often choose lesser percentages.

Figure 19: Sensory Analysis of final Sweet whey Ice-Cream



According to the study, sweet whey ice cream had a significant initial appeal at 0% concentration, with higher evaluations for color, flavor, odor, and general acceptability. It retains its excellent texture but loses color, taste, and general attractiveness as concentration rises. In contrast, buttermilk ice cream is rated moderately for all features with the exception of slight color improvements and overall appeal. Buttermilk's stable character throughout intensities makes its sensory properties more predictable. Sweet whey ice cream may seem appealing at first, but in order to preserve sensory balance, higher concentrations might need to be changed.

5. Conclusion and Suggestions

This study puts focus on how dairy by-products, particularly buttermilk and sweet whey, can be used to make ice cream. In contrast, sweet whey adds more variation in color and texture, providing different sensory qualities that may appeal to customers looking for a variety of ice cream experiences. With buttermilk favoring a more consistent structure and sweet whey having a richer, creamier body at different percentages of concentrations, both additives showed the ability to improve overrun and sensory aspects. All things are considered, using dairy by-products in the manufacturing of ice cream promotes sustainability and provides a practical way to produce a variety of ice cream products with the addition of nutrients.

It is advised to apply buttermilk at concentrations between 20 and 40% for a lighter, airier product or 40 and 60% for a thicker consistency in order to have a balanced texture in ice cream. A creamy texture can be achieved with sweet whey at about 60% without notably raising viscosity. To preserve flavor and color appeal, we think of utilizing sweet whey at lower percentages. For special products that want a fuller, denser texture, higher sweet whey concentrations can be changed. Buttermilk is more dependable when it comes to uniform color and look. When a range of color tones is required or acceptable, sweet whey can be used.

Buttermilk is a dependable basic ingredient for ice cream formulations due to its stability in pH and dry matter, particularly in products where stability and uniformity are important considerations. The functional use of dairy by-products in the food business can be further improved by enhancing their use in frozen desserts beyond traditional ice cream. Consumer trends focus on nutrition and sustainability may be satisfied by experimenting with different flavors and textures.

6. Summary

The probabilities of consuming dairy by-Products are shown in this study, especially in buttermilk and sweet whey Ice-Cream recipes. Both of the buttermilk and sweet whey dairy by-products have special benefits in making Ice-Creams, as they have different effects on the product's final texture, sensory appeal, and overrun. Buttermilk is more inclined towards being used in the ice cream-mmaking process because of its more creamy and mouthfeel texture along with the consistent physical features during a range of varying concentrations, as buttermilk can boost the consistency and uniformity of the ice cream's texture and color. Even at higher concentrations, it continues to behave consistently in terms of pH, dry matter content, and sensory attributes. Buttermilk is a better choice for ice cream as it has uniformity and stability. Buttermilk's ideal concentration range was found to be between 40% and 60%, which has an outcome of well-balanced texture without lowering the sensory attributes or massively raising flow resistance. In comparison, sweet whey elevates mouthfeel and additionally a richer, creamier texture, especially at different concentrations. A high concentration of sweet whey can lead to overflow and textural variation, ultimately resulting in a denser product with increased flow resistance. Consumers seeking a richer, fuller texture are mostly drawn to sweet whey-based ice creams. Around 60% is the best concentration of sweet whey in ice cream because it equalizes the mouthfeel and texture without losing overrun and air conclusion. Taking all the properties into consideration, both sweet whey and buttermilk have special qualities that make them ideal for creative ice cream creations.

In summary, buttermilk is a better choice for the development of ice cream that is consistently smooth and creamy, especially for the recipes that have a goal for a stable and well-balanced texture. If the different concentrations of sweet whey are carefully controlled, it can be helpful for specialist ice creams that prefer a creamier and denser ice cream. Both by-products provide nutrient-dense, sustainable alternatives that enhance the creation of ice cream and empower producers to create a diverse range of textures and sensory experiences.

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