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A Comprehensive Review On Advance Techniques Used For Development Of Frozen Desserts

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Abstract: Frozen dessert has been regarded as a decadent dessert for a long time. Food technologists have been working on making frozen desserts and ice cream better in terms of dietary intake and functioning. Around the world, ice cream and frozen desserts are widely consumed. Even though ice cream is a widely consumed frozen treat worldwide. The advance techniques used for development of frozen desserts includes Low temperature extrusion, cryogenic freezing, and micro fluidization. Ice recrystallization, in which ice crystals progressively get bigger over time according to thermodynamic ripening principles, is one of the main problems with frozen desserts shelf life and causes the texture of the product to become coarse. Therefore, this review comprises of different techniques used for development of frozen desserts.

Keywords: Cold Extrusion Processing, Micro fluidization, frozen dessert, cryogenic freezing

Introduction:
Frozen dessert, also recognized as frozen confections, are created by adding ice to a pasteurized mixture that contains edible vegetable oils, fat from milk, fat with melting point of no more than 37°C, and either milk protein on its own, together with other items high in protein, particularly when combined with nutritive sweets like maltodextrin, dextrose, sugar, fructose, high maltose corn syrup, liquid glucose, chocolate, eggs and egg products, honey, cocoa, condiments, nuts, fruit and fruit products, coffee.
When creating a frozen dessert mix, the freezing point is crucial. For typical ice cream freezers to produce enough ice crystals, products like ice cream and ice milk need to have a high enough freezing point. Too low of a freezing point causes frozen desserts to have less water frozen, which exacerbates heat shock's consequences in standard home freezers and shop freezers. Furthermore, a frozen treat with an excessively low freezing point can be too soft to put in a home freezer or retail cabinet. (Smith & Bradley, 1983)
A key factor influencing the texture of ice cream and other sweets is dependent on size of the ice crystals. If there are enough of these bigger ice crystals (40–55 µ), the texture will be gritty or grainy. Large ice crystals may be the consequence of product management errors, processed in compliance with suboptimal circumstances, or thermal shock that occurs while storing anything frozen food. A precise and dependable technique for quality control, determining the distribution of ice crystal sizes in frozen desserts would be useful, product creation as well as basic research objectives, considering the number of ice crystals plays a significant role in textural qualities. Numerous techniques have been employed to enhance the consistency and composition of ice cream and simulate frozen food chains. (Donhowe *et al.*, 1991) Freezing can raise the standard and functionality of plant meals through the release of bioactive ingredients like phenolic acids and anthocyanins, leading to higher antioxidant activity. (Neri *et al*., 2020)
The phenomenon of shrinkage in frozen desserts has been prominent, although the underlying mechanisms and reasons are elusive. This is distinguished by a reduction in amount while storing, which emerged as production in the middle of the twentieth century expanded to cater to a growing market. The physical characteristics, interfacial composition and the frozen matrix's kinetic stability of the air cells are crucial factors that influence the susceptibility of frozen desserts due to shrinkage. Although precise shrinking mechanism is not fully understood due to the complexity of frozen desserts, it is believed to be linked to the frozen foam's physicochemical characteristics. To prevent shrinkage, it is essential to use functional components and techniques that maximize frozen foam generation and stability. (Samantha R. VanWees, 2021)

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Food freezing involves chilling a product to its freezing point, eliminating latent heat from crystallization, and bringing it down to the temperature needed for ultimate storage. Kinetic variables characterize pace where water turns into ice, apart from thermodynamic parameters that determine equilibrium circumstances of the system. Water crystallization determines efficiency and quality of frozen goods. (Neri *et al*., 2020)

The dairy processing industry has made significant strides in recent years, with the development of cutting-edge, automated equipment capable of processing a wide range of products. These advances have led to significant improvements in product quality, particularly in terms of understanding the useful qualities of components and how they affect product texture and structure. Despite these improvements, foodborne disease outbreaks related to dairy goods are still available, underscoring the importance of rigorous pathogen control measures. In response to this challenge, new analytical techniques have been developed and improved to quickly detect specific types of microorganisms, minimizing the possibility of contamination and ensuring the safety of dairy products. (Goff & Griffiths, 2006)

The challenge in creating desserts lies in maintaining the presence of essential minerals, vitamins, and bioactive substances while incorporating fruit and berry ingredients. To minimize technological and physiological loss of vitamins and organic acids, the most effective strategy is to employ low-temperature processing techniques. The benefits of using shock freezing for food preservation include improved hygiene, reduced weight loss, extended shelf life, and superior product quality in comparison to conventional methods. (Iryna Koretska, 2020)

Maintaining food items quality for a long time is one of the biggest problems facing food scientists. The pace of chemical reactions and microbiological development that cause food quality to deteriorate over time is often decreased by bringing the storage temperature down; thus, freezing is a common method for increasing foods shelf life. Food may be transported and distributed while frozen at almost its ideal quality. Freezing preserves a large assortment of foods types, including fruit and vegetables, dairy products, cattle, poultry, fish, pig, and other meals high in muscle, as well as breads, dough and a large assortment of ready-to-eat items. The microstructure of frozen food is impacted by the ice crystals that develop during the freezing process and the ice crystals that alter while kept in cold storage. (Charoenrein, 2018)

The solutes' freeze-concentration process, which removes water from the mixture by creating ice causes many frozen meals to have a phase that is not frozen and has a low freezing point. Since this, frozen goods have a limited shelf life since various diffusion controlled events, such as ice recrystallization or enzymatic breakdown can take place inside this unfrozen stage even at extremely low temperatures. Recent studies on the stability of food at less temperatures have emphasized on the significance of the freeze-concentrated solution's viscosity or the frequencies of solute occurrence and water diffuse during the unfrozen phase. The formation of a glass or amorphous solid condition within frozen meals can occur tremendous viscosities (> 1012 Pa s), which can significantly reduce the speeds at which molecules diffuse and prolong the stability of the frozen food. (Douglas Goff, 1992)

Types of Frozen desserts

Sr No.	**Name of dessert**	**Characteristics**	**Reference**
1	Ice Cream	Dairy components like milk and nonfat milk are combined with flavoring and sweetening elements including extracts, chocolate chips, fruits, and nuts to make ice cream. Stabilizers and emulsifiers are examples of functional chemicals that are frequently added to food to improve texture and taste. At least 10% milk fat must be present in ice cream before thickening agents are used.	Goff, H.D. (2006)
2	Frozen Custard	Additionally, at least 1.4 percent egg yolk solids and a minimum of 10 percent milk fat must be included in frozen custard.	Kilara & Chandan, (2015)
3	Sherbets	Compared to ice cream, sherbets have a somewhat greater sugar concentration and a milk fat percentage of 1-2 percent. Sherbet is flavor-infused with fruit or other comparable components and weights at least six pounds per gallon.	Marshall & Hartel (2003)
4	Gelato	With a strong flavor and a semi-frozen consistency akin to "soft serve" ice cream, gelato is enjoyed by many. Because it contains less air than ice cream, Italian-style gelato is denser. Gelato usually comprises egg yolks, flavoring, sugars, and more milk than cream	Kanse, Chopde & Shingh, (2020).
5	Sorbet and Water Ices	Sherbets and water ices are comparable, except water ices don't have dairy.	Weir, C., & Weir, R. (2010)
6	Quiescently Frozen	A frozen novelty, such a stick of water ice (popsicles, for example), is referred to as a quiescently frozen confection.	Jana A, Pinto S., & Moorthy,

	Confection		P. R. S. (2016)
7	Frozen Yogurt	A combination of dairy products, including cultured milk and nonfat milk, as well as flavoring and sweetening agents, make up frozen yogurt.	Shin & Yoon (1996)
8	Novelties	Novelties are single portions of frozen desserts (such as juice bars, fudge sticks and ice cream sandwiches,) that are packed individually and may or may not include dairy products.	Goff & Hartel (2013)

Methodology for Frozen desserts

Skim milk

↓

Preheating 40-45°C

↓

Filtration

↓

Heating (50°C)

↓

Mixing of dry ingredients (Maltodextrin, SMP, GMS, Polydextrose, CMC)

↓

Adding the dry ingredients

↓

Addition of sunflower oil coconut oil blend

↓

Sodium alginate addition with sugar

↓

Heat (80°C)

↓

Homogenization (2nd stage)

↓

Chilling (3-4°C)

↓

Ageing (3-4°C for 4-12 h)

↓

Sucralose addition (Vanilla flavour)

↓

Freezing

↓

Filling

↓

Hardening (-18 °C) overnight

↓

Storage (-12 to -15°C)

Fig 1. Flow diagram for preparation of frozen dessert (Pinto S *et al*., 2014)

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Techniques used for development of Frozen Desserts

1. Cold extrusion processing
2. Cryogenic freezing
3. Nitrogen refrigerated hardening tunnels
4. Micro fluidization
5. Microentrapment
6. Fluidized-bed freezing systems
7. Hydro fluidization
8. High pressure freezing
9. Magnetic resonance freezing
10. Air cycle based freezing system

1 **Cold extrusion processing-**

Cold Extrusion processing is also known as Low temperature extrusion (LTE), it improves the quality of frozen desserts (ice cream) by subjecting them to increased shear stress. Ice cream from the freezer is pushed into the extruder. Low temperature extruded ice cream has different microstructural alterations than traditional scraped surface freezing processes. Shear stress reduces the size of air bubbles and ice crystals, making ice cream smoother and creamier overall. This evaluation analyzes quality changes in LTE ice cream and compares it to conventional freezing methods. (Shrivastav & Goswami, 2017)

Ice cream with six distinct emulsification levels was created using a scraped surface freezer and a serial design of a standard freezer and then extruder with low-temperature. The goal was to investigate the impact of emulsifiers on the procedure, as low-temperature extrusion and the inclusion of emulsifiers may both have comparable effects on promoting the structure of colloids in ice cream. Samples of ice cream from each procedures with relation to melting efficiency, microstructure, fat destabilization indices, and stiffness at draw. (Bolliger *et al.*, 2000)

Low-temperature extrusion improved fat instability, when fat extractable by solvent and fat particle size varied at the emulsification stage between the two stages of processing techniques. While Fat levels that can be extracted using a solvent increased via emulsification, data on size of fat particle indicated that mechanical shearing regulated fat agglomeration size. The meltdown test revealed a substantial variations comparing the two systems, with unemulsified and slightly emulsified mixtures resulting in lower melting rates and better form preservation in extruded ice cream. (Bolliger *et al.*, 2000)

lce cream possesses a complicated structure. This is an oil-in-water emulsion containing crystalline oil and water, as well as a foam heavy in fat. Air bubbles with crystals of ice provide a more coarsely dispersed than globules of fat. Ice cream's serum phase, which surrounds the ice crystals and air bubbles, is created by freezing the solution and removing water as ice. Evaluating Ice cream's microscopic composition is challenging due to its fat content and high water, as well as its temperature dependence. Conventional scanning electron microscopy (SEM) uses high vacuum, which can cause sample instability owing to fat and water volatilization. For electron microscopy, samples must be dehydrated or chemically fixed to remove volatile components, water and fat resulting in partly defatted specimens at ambient temperatures. (University of Guelph. COSY Systems Group, 1985)

Traditionally, "wall-scraped freezer" machines are used to continually freeze ice cream. In such processes, primary heterogeneous nucleation occurs at the cooling wall, where it is scraped off and mixed. The watery phase often comprises components that have been solved, such as proteins and sugars or hydro-colloids that have been colloidally disseminated (polysaccharides). A freezing point depression is caused by these chemicals. The residual solution becomes concentrated as water crystallizes, further lowering the freezing point depression. Temperatures of around - 6 to -5°C are often obtained for ice cream, the output of a continuous freezer system. As a result, 40–50% of water in a standard ice cream recipe freezes. (Windhab & Wildmoser, 2002)

With a recently invented low-temperature extrusion device, this may be achieved down to temperatures at the outlets of -15 to -18°C. The homogenous shear treatment is achieved with the application of regionally narrowly dispersed shear stresses, pressures, and residence periods. Ice crystal aggregates de-agglomerate and undergo secondary nucleation to produce new crystal nuclei at low temperatures. Compared to the traditional method, low temperature extrusion yields more finely scattered ice crystals by a ratio of more than 2-3. Additionally, the enhanced viscous forces at low temperature extrusion circumstances lead to a more finely structured ice cream consisting of fat globules and air cells, the other dispersion phases. A tunnel that solidifies over time is no longer required for extruded ice cream made at low temperatures. Both the shelf life and perceptual qualities have greatly enhanced. (Windhab & Wildmoser, 2002)

The LT extruder is comparitively recent technology in the ice cream manufacturing industry. It was developed from the traditional freezing process, where at -5°C, ice cream is added and exits at about -12°C. Because to the strong shear pressures generated during the LTE of air cells, ice crystals, and recently frozen ice cream significantly reduced in size. This may result in a notable improvement in the consistency, cohesion, scoopability, and shape retention of the perceived creaminess. Moreover, LTE can do away with the requirement for traditional tunnel hardening as it permits a

rise in the proportion of frozen water (ice) without causing a noticeable expansion in ice crystals. (Soukoulis & Fisk, 2016)
One of the most inventive developments in ice cream preparation in recent years is cold extrusion. After the slurry leaves the SSF, it is pushed into a low-temperature extruder to lower the temperature rather than being packaged as ice cream. The slurry is rapidly cooled by the extruder to around –12°C. The extruder screw(s) rotate slowly, which reduces air bubble coalescence and ice crystal recrystallization while ensuring consistent cooling. Despite having fewer ice crystals and air cells, the final product somehow still has enough fluidity to fill the envelope entirely. To set it apart from ice cream that is manufactured traditionally, marketers frequently refer to this type of ice cream as "slow-churned." Unfortunately, despite this new technology's clear benefits, its implementation is limited by the cost of installing an extruder at the end of each SSF in commercial production. (Hartel, 2019)

This is a unique technique that combines a low-temperature extrusion (LTE) freezer with a traditional scraped surface freezer (SSF). This frozen product is frozen to low temperatures of around –10°C to –20°C while also undergoing shear treatment. The ice cream mixture passes through the LTE freezer rather than the hardening tunnel after exiting the traditional freezer surface scraped at between -5 and -6°C. Instead of being sent to the hardening tunnel, the mix is sent via the LTE freezer. When the mix comes out of the freezer, the temperature is between -5 and -6°C. At this temperature, approximately 40-50% of the water is frozen. Such a combination will crystallize on the surface of the preexisting crystal and expand in size if it is further deep frozen (at around -20°C) in a hardening tunnel. This will shorten the product's shelf life and lower its quality. The product is then sent to a low temperature extruder and is exposed to shear stress. At this point, the de-aggregation of ice crystal aggregates and secondary nucleation produce new crystal nuclei. Hence, compared to the traditional method, we obtain two to three times as many finely scattered ice crystals. (Shrivastav & Goswami, 2017)

2. Cryogenic Freezing-
Food ingredients are naturally perishable. To extend their storage life, processing or preservation methods are needed. Engineering's field of cryogenics studies the creation of cryogen and the upkeep of low-temperature technology. Liquid nitrogen (LN2) is one such cryogen that has a great deal of promise for usage as a complete loss refrigerant. (Goswami, 2010)
The use of expanding gaseous refrigerants—such as argon, hydrogen, oxygen, carbon dioxide, nitrogen and others—that evaporate or sublime at extremely low temperatures under atmospheric pressure is known as cryogenic refrigeration. Nitrogen and carbon dioxide (CO2) are the most often used cryogenic chemicals in the food sector. Cryogenic freezing and chilling offer several advantages, such as shortened cooling/freezing durations, less dehydration and drip loss, and enhanced product texture from the creation of tiny ice crystals. (Estrada-Flores, 2002)
The ice cream mixture freezes extremely quickly when liquid nitrogen is used in cryogenic freezing because it eliminates the heat required because of this in the meal it comes into contact. At atmospheric pressure, liquid nitrogen boils at -196 °C. For example, it can be used to quickly solidify the ice cream mixture. Additionally, droplets or pellets can be frozen in liquid nitrogen; the quick cooling causes the pellets or droplets to freeze very instantly and create dendritic crystals. The ice cream mixture won't freeze entirely if it is chilled below the glass transition point (-35 °C). Rather, a glassy-like solidified result is produced. Ice crystallization restarts when the temperature increases above the glass transition point. Consequently, the surface could get sticky. (Hidas *et al*., 2021)
Food items with a large ratio of surface area to volume and where the food's thermal diffusivity does not prevent heat from the product from moving to the freezing medium are best suited for cryogens.

3. Micro fluidization
One kind of non-thermal HPH that produces a fine emulsion is microfluidization (MF). Cook & Lagace (1985) were the first to patent the high-shear fluid processing method using a microfluidizer for use in food applications. The microfluidizer was first used by the pharmaceutical and cosmetics sectors to create ultrafine emulsions, and it later gained popularity in culinary applications. (Kumar *et al*., 2022)
Ice cream melting rate was influenced by fat globule size. Meltdown in Fat-free and reduced-fat ice cream produced by using microfluidization as opposed to traditional valve homogenization of the mixtures. (Olson *et al*., 2003)
Certain frozen dairy dessert qualities were impacted by microfluidization at different pressures. The nonfat and low-fat ice creams that underwent microfluidization as opposed to traditional valve homogenization of their mixes frequently exhibited slower meltdown. This could have been attributed to the formation of large chains and aggregates following microfluidization or to an excessive protein covering that shielded the fat and the frozen dairy dessert from melting. (Olson *et al*., 2003)
While extreme processing is known to release unwanted scents, as is known, microfluidization to induce milk fat homogenization under extreme high pressure. However, there is currently no evidence accessible via the quantities of volatile chemicals in milk immediately following microfluidization. When compared to the initial milk, microfluidization frequently had no discernible effect on the volatile levels. (Van Hekken *et al*., 2019)

MF considerably increased the creaminess and other desired textural attributes, such thickness, cohesion, oral and spoon viscosity, and smoothness, for low-fat yoghurts. Rheological characteristics, in particular flow behavior, were somewhat connected to these variations in sensory profiles, notably texture attributes. In comparison to CH yoghurts with comparable fat concentrations, MF of heat-treated milk produced Fat-free and reduced-fat yogurts with greater yield stress, a more noticeable increased viscosity and the hysteresis effect. These results imply that Microfluidization might be used to produce premium yogurt with a lower fat level. (Chr. Ian E. *et al*, 2011)

Conclusion

Food quality is preserved by freezing and the organoleptic qualities of food after thawing are influenced by the quality of the freezing process. Organoleptic features including smell, texture, appearance and taste that are perceived by the senses. Numerous studies have demonstrated that the freezing rate is the key to producing frozen food of the highest calibre; the quicker the freezing rate, the better the quality of food product. This article explains how advance freezing methods can be useful for improving the textural quality of frozen desserts during storage. Low temperature extrusion, cryogenic freezing and Microfluidization, from the three advance techniques cryogenic freezing is most widely used due its advantages and availability. Other two methods are also effective in reduction of ice crystal formation in frozen desserts.

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