Baking

FROZEN PAR-BAKE PRODUCTS

BAKERguide Vol. 1-1

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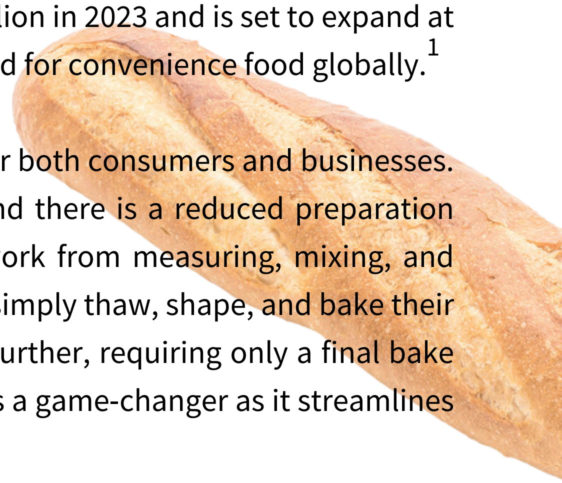
INTRODUCTION

Frozen dough products, including bread, rolls, breadsticks, pizza crusts, cookies, and pastries, are widely sought across both household and commercial sectors due to their extended shelf life, ease of preparation, and ability to deliver consistent quality. Additionally, novel trends such as gluten-free and organic dough varieties are expanding the market further, catering to health-conscious consumers. The global market for frozen dough and par-baked products is experiencing robust growth, fueled by increasing consumer demand for convenient, high-quality baked goods and the expansion of retail and wholesale bakeries. The Frozen Bakery Market is valued at USD 45.8 billion in 2023 and is set to expand at a CAGR of 6.5% between 2024 and 2032, supported by the rising demand for convenience food globally.[1]



Frozen dough and par-baked products offer a wide range of benefits for both consumers and businesses. The significant advantages are that it doesn't require skilled labor and there is a reduced preparation time with a consistent quality. With frozen dough, the bulk of the work from measuring, mixing, and often the initial rising is already done. Without training, operators can simply thaw, shape, and bake their products like a professional. Par-baked baked goods take this a step further, requiring only a final bake to achieve that fresh-out-of-the-oven final product. This convenience is a game-changer as it streamlines operations for many food service establishments.[2]

Another key benefit is the product's extended shelf life due to immediate freezing after pre-production. This freezing significantly slows down spoilage, allowing both frozen dough and par-baked items to be stored for weeks or even months without significant loss of quality and safety. This minimizes waste, enables bulk purchasing for cost savings, and ensures product availability. For businesses, this extended shelf life simplifies inventory management and reduces the risk of unsold products. The ability to have high-quality baked goods readily available, without the daily grind of starting from scratch, makes frozen dough and par-baked products incredibly valuable. [2]

Frozen Dough Market Opportunities

- The Frozen Bakery Market is valued at USD 45.8 billion in 2023 and is set to expand at a CAGR of 6.5% between 2024 and 2032, supported by the rising demand for convenience food globally.
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"Frozen Bakery Market Size, Share & Trends 2024 – 2032." Global Market Insights Inc.. Accessed 31 Mar. 2025.

WHAT IS FROZEN DOUGH AND PAR-BAKED?

It is dough that has been frozen so that skilled labor is not required for it to be baked and consumed. This method allows for the convenient preparation of freshly baked products without the need to make dough from scratch, making it ideal for food outlets without bakery equipment

TYPES OF FROZEN PRODUCTS

1. Freezer to proofer: dough that has been formed but not proofed. Therefore, the customer would need to thaw, proof, and then bake it.

2. Freezer to oven:

- **a) Frozen dough:** dough that has been mixed, formed, proofed, then quick-frozen. Therefore, the customer just needs to finish baking it in the oven.
- **b) Par-bake - dough:** that has been baked to an internal temperature of 82 °C (180°F) without being browned on the outside.

3. Freezer to table: bread that has been fully baked, and just needs thawing or refreshed in a combination (microwave convection) oven, in order to be consumed.

Par-baked products are bakery items that have gone through all the mixing, proofing, and partial baking processes to obtain a product that only requires final baking to consume.

Frozen Dough Types

The main categories of frozen products can be classified according to the particular stage of the baked good production process in which freezing is introduced:

Type	Description	Observations
Freezer to proofer	This type of baked good is the product of mixed ingredients to produce a dough that is frozen after being molded to prevent the development of yeast fermentation	**Thawing:** they are thawed at cooling temperatures of 0 - 5 °C (32 - 41 °F) **Final proofing:** proofed to double its size and then bakedExample: usually sweet rolls, croissants, and sub rolls. **Pros:** cheapest form of frozen dough, because more units can be sold in a case **Cons:** requires training on proofing precision. Lack of training results in smaller-sized products.
Freezer to oven	Two types exist in this category: **Fermented dough:** dough is produced from the conventional direct method, and it is immediately frozen after the dough pieces are fermented. A common example is puff pastry dough. **Par- baked bread:** the pieces of dough are made by the conventional process and partially baked before freezing. Commonly used for baguettes, loaves, pizza crusts, pizza, and cakes.	**Thawing:** they don't need to be thawed before baking. **Preparation:** further preparation is not necessary. Just bake until golden brown **Pros:** minimal training required for bake-off. Has the best product quality results for all frozen dough **Cons:** may require steam during early stages of baking, particularly for large dough pieces. It is more expensive than a freezer to a proofer.
Freezer to table	Baked goods that have been completely baked and frozen.	**Thawing:** they are thawed at room temperature and later consumed. **Examples:** usually pizza, cake, donuts, bagel, waffles, and some gluten-free breads. **Pros:** finished quality is consistently high **Cons:** most expensive to produce

Table 1: Advantages and disadvantages of the different types of frozen dough

Frozen Dough Preparation Process

Frozen dough can be prepared following this general production process:

- **Mixing Ingredients:** combine flour, water, yeast, and other optional ingredients like sugar or salt to form the dough. Usually, the straight dough method is employed in frozen dough production. For freezer to proofer doughs, final dough mixing temperatures must be between 16-21°C (60-70oF), final mixing temperature is crucial for dough quality and stability during freezing and subsequent proofing. This is to minimize yeast fermentation activity. If dough temperatures are too high, the yeast would be activated and some would be exhausted during frozen storage, leaving inadequate yeast vitality to fulfill the proofing process at the customer's facility.
- **Shaping:** the dough is divided into pieces and shaped into the desired size or form.
- **Freezing:** the shaped dough is rapidly frozen using blast freezers to a core temperature ranging from -11 to -9 °C (12 to 16 °F) to -9 to -7 °C (16 to 20 °F), with leaner doughs (i.e. lower sugar) favoring the higher range.
- **Freeze-Thaw Cycles (Optional):** some methods subject the dough to freeze-thaw cycles to enhance its properties, such as fermentation or texture improvement.
- **Storage:** frozen dough can be stored at -18°C (-0.4 °F) for 3-6 months, maintaining its quality for extended periods.

Thermal Profiling for Partially Baked and Frozen Dough Products

IMPORTANCE OF THERMAL PROFILING

The increasing demand for convenience and longer shelf life is fueling the growth of frozen and par-bake dough products in the baking industry. Product consistency quality is essential. A critical factor in this quality control is precise thermal profiling — the measurement of internal dough temperature during baking, cooling, and freezing processes.

CONTROLLED PARTIAL BAKING

Par-baked products undergo 80–90% of the full baking cycle before rapid cooling or freezing halts the process. This method allows bakeries to provide nearly-finished goods that consumers or retailers can complete baking on-site. Critical differences between par-baked and fully baked bread include:

- Lower baking temperatures and shorter bake times (50–75% of standard duration)
- Partial gelatinization and controlled yeast kill phases
- Minimal crust formation and retained moisture due to humidity control
- Immediate cooling to suspend the baking process

Thermal profiling enables bakers to identify exact time/temperature milestones during baking. For example, an S-Curve analysis of par-bake bread shows the absence of a full *"Arrival"* phase — a sign that the baking cycle was stopped before final structure development, allowing the process to resume later at the consumer's site. Accurate data from tools like the M.O.L.E.® profiler ensures repeatability and prevents over- or under-baking.

FROZEN DOUGH: PRECISE FREEZING MANAGEMENT

For dough products that remain frozen until fully baked, the freezing process is as critical as baking. Thermal profiling ensures doughs reach and maintain optimal internal temperatures. Freezing is influenced by:

- Ingredient composition (sugars, fats, salt, proteins)
- Freezing rate and temperature drop
- Final internal temperature
- Freezer set point and cycle duration

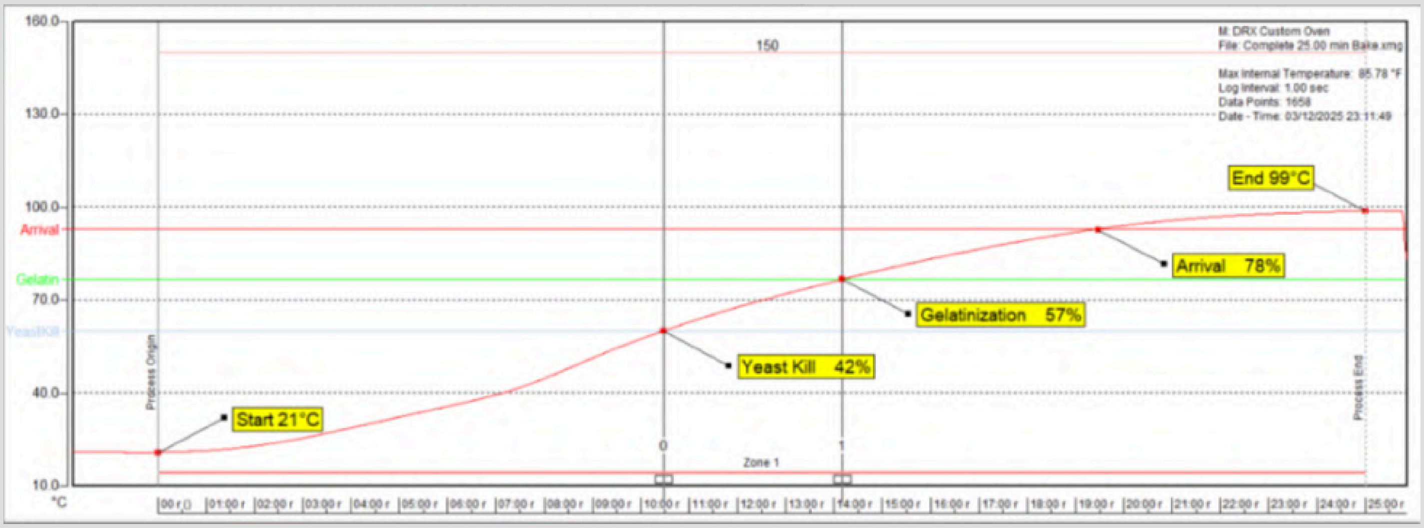


Figure 1. S-Curve for fully baked bread, 25 minute baking cycle: Set point 150° C, completed three baking phases of completing three baking phases of Yeast Kill, Gelatinization and Arrival. Courtesy of ECD

High concentrations of sugars or fats lower the freezing point, requiring more time and energy. Thermal profiling provides real-time insights into how ingredient changes impact freezing behavior. It ensures product stability by managing the transition through the critical temperature zone, where latent heat is released, and the dough reaches its final frozen state.

CONSISTENCY THROUGH DATA

In industrial baking, multiple dough pieces are processed simultaneously, making uniformity across products a challenge. Thermal profiling allows for the comparison of heat transfer and temperature across loaves, identifying inconsistencies and enabling corrections. Tools like the BreadOMETER® sensor paired with the M.O.L.E.® EV6 profiler captures real-time dough response data across environments such as ovens, proofers, and freezers. Making the frozen and par-bake process predictable and repeatable.

Ultimately, thermal profiling empowers bakeries to “know their dough” — controlling key variables to produce consistent, high-quality frozen and par-baked bread products. It is indispensable for optimizing baking and freezing operations, extending shelf life, and ensuring consumer satisfaction.

Stage	Goal	Temp.Range	Time
Dough Prep	Gluten development & fermentation initiation	Dough after mixing target, 22 - 26 °C (72 - 78° F)	
Controlled Rise	Enable limited fermentation before shaping and prep for freezing	22 - 24 °C (72° - 75° F)	Rest dough for 30-60 mins @ room temp or 2- 4 hours in refrigeration 4 °C (39° F). Check dough temp. to ensure no more than slight temp. -17 °C - 4 °C (2-4° F) rise
Shape and pre-freeze	Form individual baguettes and prep for quick freezing	Dough at 20 - 24 °C (68° - 75°)before shaping	Shape, then rest dough for 15-20 minutes
Freezing	Quick freeze to minimize ice crystal formation	-18 °C to - 8°C (0 - 18° F) (or even lower with blast freezer)	Core temp to reach 0° F within 2-4 hours
Storage	Preserve dough viability	Store wrapped baguettes at -18°C (0° F) or below	Can be stored for 1-3 months before thawing, proofing, and baking

Table 1. Typical stages of frozen baguette dough

How well do you know your dough? Capturing dough transformation data is vital for desired results. ECD's M.O.L.E.® EV6, paired with a BreadOMETER® sensor, precisely measures dough milestones in any process – frozen, par-baked, or fully baked – for product perfection. Check out all the details.

INGREDIENTS FOR FROZEN DOUGH PRODUCTION

Flour

Wheat flour is the fundamental building block of most baked goods, particularly bread. It serves as the structural foundation, giving bread its texture and shape. The proteins in wheat flour—glutenin and gliadin—combine to form gluten, which lends elasticity and strength to dough. This gluten network traps gases like carbon dioxide released during fermentation or from leavening agents, allowing the dough to rise. Starch, the largest component of flour, also plays a vital role by contributing to structure and texture and aiding yeast fermentation. Additionally, flour influences the final color of baked goods through its involvement in the Maillard reaction—a process that creates rich browning and flavor.

Choosing the right type of flour is key to achieving the desired bread quality. High-protein flours, typically over 12% protein (14% m.b.) produce doughs that are elastic and cohesive, making them ideal for shaping and handling during breadmaking. These flours result in breads with greater volume and a fine crumb structure. On the other hand, low-protein flours (below 12%) are less effective at forming strong gluten networks, leading to compact breads with coarse or gummy textures. Flours should be checked for excessive damaged starch. Too much damaged starch will artificially increase water absorption, causing increased dough stickiness, which is difficult to process. In addition, excess water that is not bound will be free water that can grow into large crystals that damage the cell and dough structure.

Flour handling for a frozen dough production facility is an important factor. As final dough mixing temperatures are critical, the starting point lies with the temperature of the flour. Flour should not be stored in silos sitting in the hot sun. Instead, these silos should be indoors or sheltered from the sun. If flours are delivered in supersacks or flour bags, it should be stored in the coolest part of the warehouse or the walk-in coolers during the hot summer months. Supersacks or bagged flour should not be stored in their shipping containers sitting in the hot sun. Not only does this increase flour temperature, it increases oxidative reaction with the lipids, creating the rancid off-flavors in bagged flour.

Understanding how freezing affects the different components of flour is crucial for par-baked and frozen baked goods production. The most essential constituents of flour are starch and gluten. Starch, primarily composed of amylose and amylopectin, is essential for the texture and quality of frozen bakery goods. Freezing impacts starch granules by compressing and deforming their surfaces due to ice crystal formation. This structural alteration affects starch's properties, such as solubility, viscosity, and gel firmness, which are critical for dough performance. Advanced freezing techniques like cryogenic refrigeration can rearrange starch molecules internally, further influencing dough behavior. Repeated freeze-thaw cycles exacerbate these changes by breaking down the crystalline structure of starch, leading to visible holes and fractures on the granules' surfaces. These alterations can improve certain properties, such as swelling capacity and viscosity, but also pose challenges for maintaining dough consistency.

While gluten is a protein network formed when flour and water mix, providing elasticity, water retention, and structural integrity to dough. It consists of gliadins and glutenins, which interact through disulfide bonds to create a web-like structure. Freezing disrupts this network as ice crystals form within the dough matrix, damaging gluten's molecular arrangement. Over time, frozen storage leads to protein denaturation and changes in gluten's secondary structure from α-helices to β-sheets and β-turns.

The degradation of gluten during freezing is one of the main factors affecting the quality of thawed bakery products. To mitigate this, additives such as emulsifiers, oxidizers, and enzymes are used to strengthen gluten's structure. These additives promote crosslinking between gluten proteins, enhancing elasticity and stability during freezing. Additionally, flours with stronger gluten networks or high pasting viscosities are preferred for frozen dough to maintain quality.

Water

Water is indispensable in breadmaking, performing multiple essential functions. It hydrates the flour, enabling gluten formation and contributing to both crust (exterior) and crumb (interior) development during baking. Water also activates yeast fermentation, facilitating carbon dioxide production that makes dough rise. The amount of water used varies based on factors like flour type, desired bread texture, and environmental conditions during baking. Medium water hardness is the best for frozen dough production. If hard water is present, use a water softener, as hard water increases yeast activity due to its high mineral content. While water is necessary for creating dough, its evaporation during baking is equally important for transforming dough into bread. Tempered water is important in dough mixing, as it is the chief factor in bringing down the dough temperature.

Yeast

Yeast is a living microorganism that plays a pivotal role in breadmaking by producing gases essential for leavening. When yeast interacts with water and sugars, fermentation occurs, releasing carbon dioxide that causes dough to rise while also producing acids and aromatic compounds that contribute to flavor. Yeast also activates enzymes that break down wheat proteins, enhancing gluten development for better texture and structure.

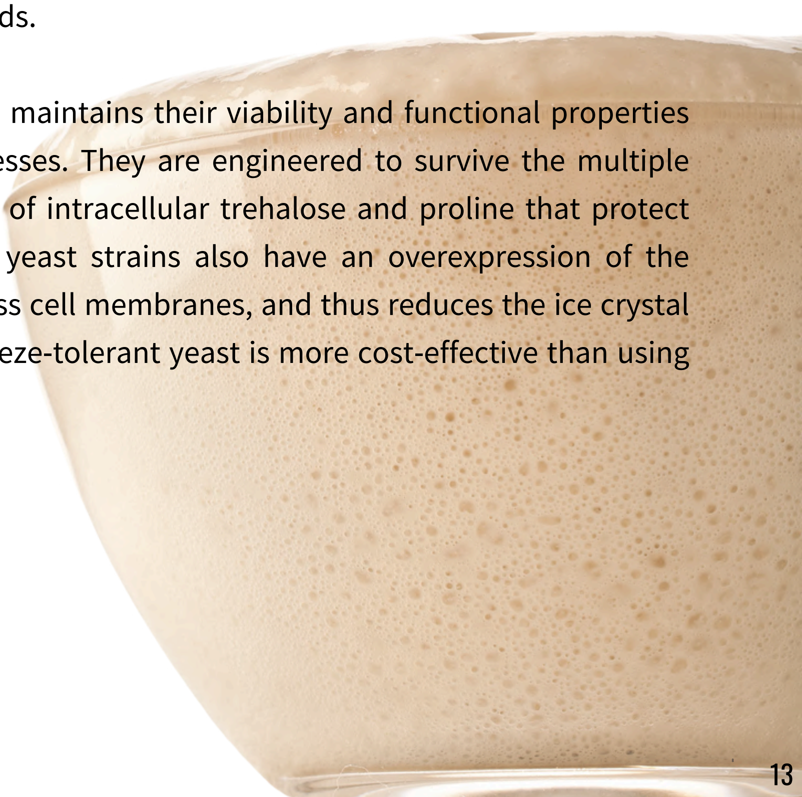
In essence, yeast is responsible for creating bread's light, airy texture and its characteristic aroma.

However, yeast cells are highly sensitive to freezing. Ice crystals can physically damage yeast cells by increasing osmotic pressure or breaching cell membranes, leading to reduced yeast viability. Intracellular freezing further exacerbates yeast degradation by causing dehydration and impairing membrane functions.

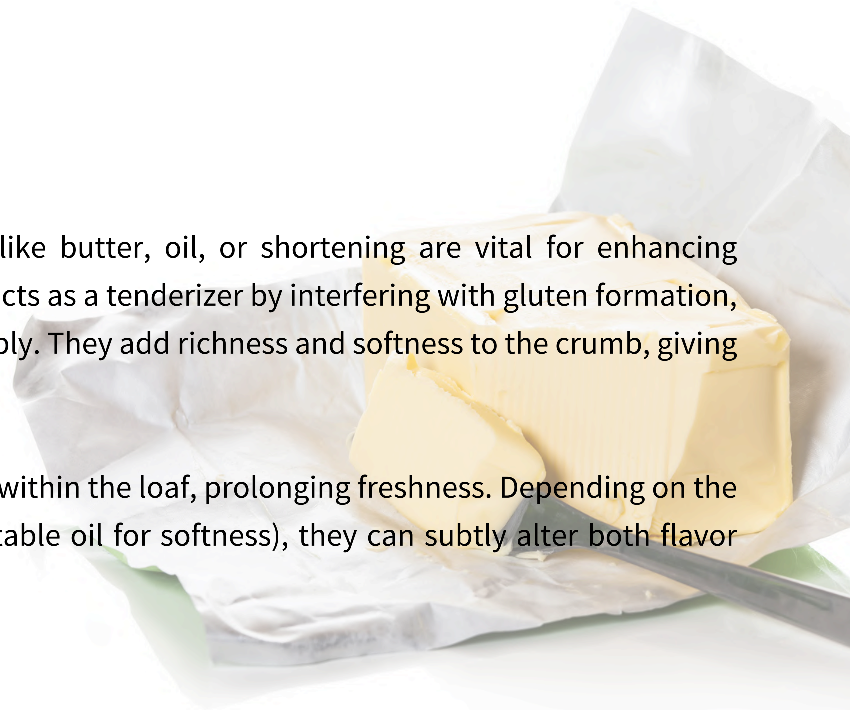
The strain of yeast used is crucial for frozen dough applications. Strains with high levels of cryoprotective compounds like trehalose and proline show better freeze tolerance. These compounds protect yeast cells from ice damage during both short-term and long-term freezing. Additionally, controlling freezing rates and adding cryoprotective agents such as hydrocolloids or antifreeze proteins can help minimize ice crystal formation and preserve yeast activity.

To optimize yeast performance in frozen doughs, reducing fermentation time before freezing is recommended to prevent excessive CO_2 production that could destabilize the crumb structure during storage. Alternatively, using freeze-tolerant yeast strains or adjusting yeast concentration can help maintain product quality over extended storage periods.

Freeze-tolerant yeast strains are a type of yeast that maintains their viability and functional properties after being subjected to freezing and thawing processes. They are engineered to survive the multiple freeze-thaw cycles, and they also have higher levels of intracellular trehalose and proline that protect cells from damage during freezing. Freeze-tolerant yeast strains also have an overexpression of the aquaporin genes that enhances water transport across cell membranes, and thus reduces the ice crystal formation and cell damage during freezing. Using freeze-tolerant yeast is more cost-effective than using regular yeast at a higher concentration.



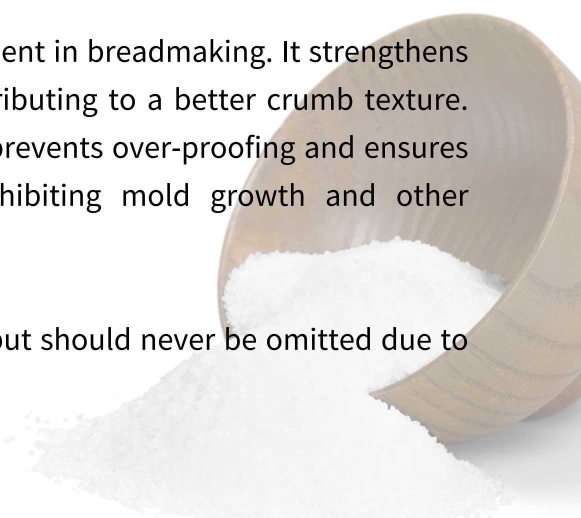
Fat (Oil & Butter)



Though used sparingly—often around 3%—fats like butter, oil, or shortening are vital for enhancing flavor, texture, and shelf life in breadmaking. Fat acts as a tenderizer by interfering with gluten formation, which prevents bread from becoming dry or crumbly. They add richness and softness to the crumb, giving bread a luxurious mouthfeel.

Fat also slows down staling by retaining moisture within the loaf, prolonging freshness. Depending on the type of fat used (e.g., butter for richness or vegetable oil for softness), they can subtly alter both flavor and texture to suit specific recipes.

Salt



Salt is more than just a flavor enhancer—it's a multifunctional ingredient in breadmaking. It strengthens gluten structure, improving dough elasticity and volume while contributing to a better crumb texture. Salt also regulates yeast activity by slowing fermentation rates; this prevents over-proofing and ensures consistent results. Additionally, salt helps preserve bread by inhibiting mold growth and other microorganisms.

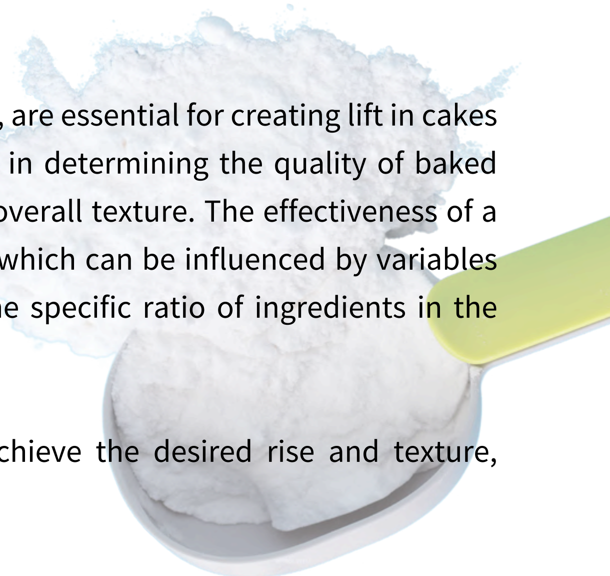
The amount of salt used depends on the type of bread being made, but should never be omitted due to its critical roles in flavor balance and structural integrity.

Sugar

Sugar serves several important purposes in baking. First and foremost, it fuels yeast fermentation by providing a substrate for carbon dioxide production, essential for leavening dough and achieving proper loaf volume. Sugar also enhances flavor and aroma while contributing to browning through its involvement in the Maillard reaction.

Beyond these functions, sugar improves shelf life by retaining moisture within the loaf and lowering water activity, helping keep bread fresher for longer.

Chemical Leavening Agents



Chemical leavening agents, such as baking soda and baking powder, are essential for creating lift in cakes by producing carbon dioxide gas. These agents play a crucial role in determining the quality of baked goods, influencing factors like volume, density, cell structure, and overall texture. The effectiveness of a leavening system depends on how quickly it reacts to release gas, which can be influenced by variables such as the type of acid used, temperature, water activity, and the specific ratio of ingredients in the recipe.

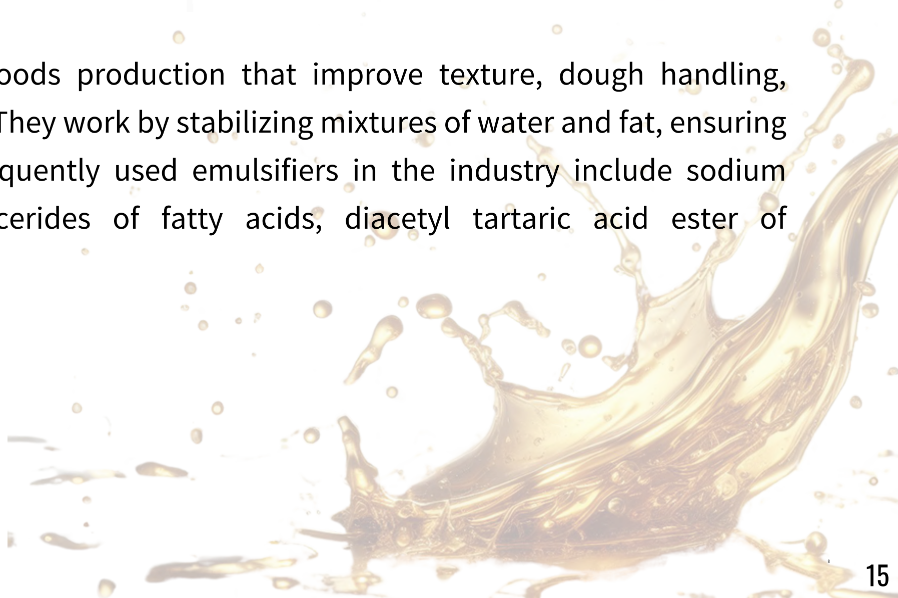
By carefully selecting and balancing these factors, bakers can achieve the desired rise and texture, ensuring consistent results every time.

Eggs

Eggs are a multifunctional ingredient in baked goods. They provide structure by forming a stable foam that supports the cake as it bakes. Eggs also act as binding agents, helping the batter set into a cohesive final product. Additionally, they contribute moisture to the batter, enhancing the cake's softness and tenderness. Eggs even play a role in flavor and browning through their involvement in the Maillard reaction. In certain cakes, eggs may also assist with leavening by incorporating air into the batter.

For vegan or allergy-friendly brioche or sweet breads, eggs can be replaced with common substitutes like applesauce, yogurt, or chia seeds. However, because eggs serve so many purposes in baking, substitutions often require combining multiple ingredients or adding emulsifiers to replicate their unique functions effectively.

Emulsifiers



Emulsifiers are key ingredients in bakery goods production that improve texture, dough handling, enhance overall quality, and extend shelf life. They work by stabilizing mixtures of water and fat, ensuring a smooth and uniform batter. The most frequently used emulsifiers in the industry include sodium stearoyl lactylate (SSL), mono- and diglycerides of fatty acids, diacetyl tartaric acid ester of monoglycerides (DATEM), and lecithin.

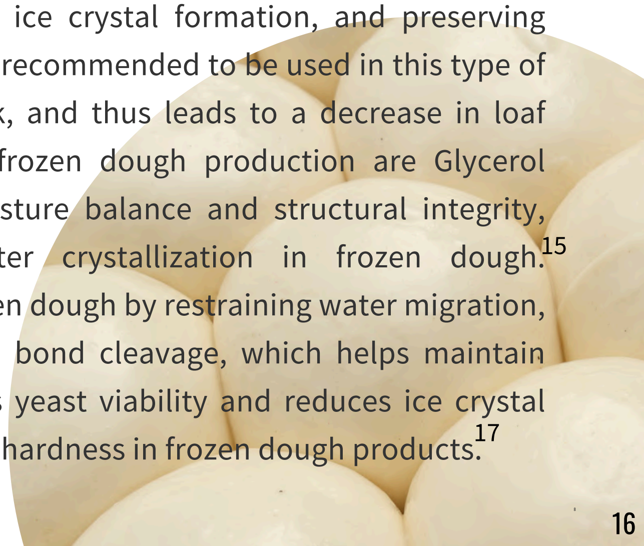
Common Emulsifiers in Bread Making:

- **Sodium Stearoyl Lactylate (SSL):** is the most used emulsifier. It is known for improving dough stability and enhancing bread volume and crumb softness, especially with longer proofing times.
- **Mono- and Diglycerides of Fatty Acids:** are used as dough conditioners and anti-staling agents, contributing to crumb softening and improved texture.
- **Diacetyl Tartaric Acid Ester of Monoglycerides (DATEM):** are used to strengthen dough stability and improve bread volume.
- **Lecithin:** is known for its crumb softening effects. It is used to improve dough handling and bread quality. It is particularly effective in enhancing the sensory qualities of both fresh and frozen dough breads.

Dough Conditioners

- **Enzymes:** enzymes play a crucial role in improving dough quality and stability during freeze-thaw cycles. Some of the best enzymes for freeze-dough production include transglutaminase, glucose oxidase, α-amylase, xylanase, cellulase, and lipase.[12]
    - **Transglutaminase and Glucose Oxidase:** these enzymes, when used together, enhance the dough's extensibility and resistance, reduce syneresis, and maintain a uniform gluten network after freeze-thaw cycles.
    - **α-Amylase and Xylanase:** these enzymes improve the specific volume and texture of bread made from frozen dough. α-Amylase increases bread volume and reduces crumb hardness, while xylanase enhances the gluten network and overall sensory quality. Amylase also improves fermentation time and enhances yeast activity.
    - **Cellulase and Lipase:** cellulase improves the gluten network and dough surface smoothness, while lipase contributes to better dough texture and sensory quality.
    - **Pentosanase:** this enzyme helps in maintaining dough expansion capacity and bread volume during frozen storage by modifying pentosans.

- **Reducing agents:** are dough conditioners used to improve dough quality by aiding in maintaining moisture balance, enhancing structural integrity, reducing ice crystal formation, and preserving protein networks during freeze-thaw cycles. L-cysteine is not recommended to be used in this type of product due to its weakening effect on the gluten network, and thus leads to a decrease in loaf volume.[13] Other reducing agents that can be used in frozen dough production are Glycerol Monooleate (MO), this reducing agent helps maintain moisture balance and structural integrity, reducing mechanical damage and inhibiting free water crystallization in frozen dough.[15] Chitooligosaccharides (COS), COS improve the quality of frozen dough by restraining water migration, reducing freezable water content, and preventing disulfide bond cleavage, which helps maintain rheological properties.[16] Trehalose, this ingredient enhances yeast viability and reduces ice crystal formation, acting as an anti-staling agent by decreasing crust hardness in frozen dough products.[17]



- **Inactivated yeast:** is a yeast cell that does not contribute to fermentation but can be used as a dough conditioner to improve dough texture and handling, as well as to reduce mixing times.[1]
- **Hydrocolloids:** These are increasingly important in the baking industry for their ability to induce structural changes in wheat flour systems. They help maintain the dough's integrity during freezing and improve the texture of the final product. Examples include locust bean gum and gum artemisia.[14]
- **Sucrose Fatty Acid Esters:** Specifically, sucrose fatty acid ester SE-13 is noted for significantly improving the sensory quality of frozen bread. SE-11 is also used but is considered slightly less effective.[14]

Specialty Ingredients for Frozen Doughs

Freezing dough and baked goods can be a challenge for bakers worldwide, however, some technological solutions are available for bakers to preserve texture, structure, and flavor during storage.

NATURAL POLYSACCHARIDES

Polysaccharides, derived from plants, animals, or microbes, are powerful stabilizers that help maintain dough quality during freezing. These natural compounds prevent ice crystals from growing too large and stabilize moisture, ensuring your dough stays soft and elastic even after freezing. Common polysaccharides like guar gum, xanthan gum, and carrageenan are widely used to protect yeast activity and gluten structure in frozen dough.

Gum systems are particularly important for Freezer to oven items, because they trap carbon dioxide generated during proofing. This is necessary to generate oven spring because the yeast in this type of dough die rapidly during frozen storage.

For example, adding rye bran arabinoxylans or konjac glucomannan can improve water distribution and enhance bread volume after thawing.

ANTIFREEZE PROTEINS (AFPS)

Antifreeze proteins, found in plants like carrots and barley, aid frozen dough by controlling ice crystal formation. These proteins help retain yeast activity and CO_2 during fermentation while preventing ice damage. While AFPs have great potential, their high extraction costs limit widespread use.[3]

- **Oat Antifreeze Proteins (AFPs):** these proteins are extracted from cold-induced oats and have been shown to lower the freezable water content in dough, enhancing its fermentation capacity and protecting the gluten matrix, which results in better textural properties in the final product.[18]
- **Barley Antifreeze Protein (BaAFP-1):** this protein helps maintain the dough's gas production ability and protects the gluten network and yeast cells from ice damage during freezing and freeze-thaw cycles. It also reduces the rate of hardness increase in bread crumb.[19]
- **Recombinant Type I Antifreeze Protein (rAFP):** produced by Lactococcus lactis, this protein improves the fermentation capacity of frozen dough and maintains consumer acceptance of bread made from such dough.[20]
- **Recombinant Carrot Antifreeze Protein (rCaAFP):** this protein, produced in Pichia pastoris, exhibits strong ice recrystallization inhibition activity, improving the specific volume and texture properties of bread made from frozen dough.[21]

ICE NUCLEATION AGENTS

Ice nucleation agents like extracellular ice nucleators (ECINs) from microorganisms such as Erwinia herbicola can regulate ice crystal size and shape during freezing. These agents protect yeast cells and reduce crumb hardening after multiple freeze-thaw cycles. Innovative solutions like zein-based films are emerging as packaging options to further preserve frozen dough quality.

By using cryoprotective additives like polysaccharides, antifreeze proteins, or ice nucleation agents, bakers can ensure their frozen goods retain their structure, flavor, and texture even after extended storage.

FREEZING METHODS OF BAKED GOODS

Traditional freezing methods, such as air blast, contact, and immersion freezing, are widely used in the frozen bread industry. Among these, spiral tunnel freezing and cryogenic refrigerator freezing are the most popular due to their ability to enhance heat transfer in dough. However, these methods often result in large, unevenly distributed ice crystals that damage the cellular structure of food.

To address these challenges, emerging technologies like liquid nitrogen spray freezing, high-pressure-assisted freezing, and ultrasonic-assisted freezing have gained attention.

Spiral Tunnel Freezing

Spiral tunnel freezing is a method used in food preservation where products are frozen in a spiral-shaped tunnel. The system consists of a conveyor belt arranged in a spiral configuration within an insulated chamber. As the food moves along the spiral track, it is exposed to cold air generated by refrigeration systems. This design increases the freezing surface area and ensures uniform freezing by maintaining consistent temperatures, typically between -18°C (-0.4 °F) and -34°C (-29 °F). The spiral configuration saves space, improves freezing efficiency, and allows for continuous operation, making it suitable for high-volume food processing. It also reduces energy consumption and labor costs compared to traditional freezing methods.

Cryogenic Refrigerator Freezing

Cryogenic freezing involves the use of extremely low-temperature refrigerants, such as liquid nitrogen or liquid carbon dioxide, to rapidly freeze food products. Unlike mechanical freezing, which cools the surrounding air to freeze the product, cryogenic freezing directly exposes the food to the refrigerant via spraying or immersion. This rapid cooling results in the formation of smaller ice crystals, which minimizes damage to the food's cellular structure and preserves texture, flavor, and nutritional quality. Cryogenic systems are particularly effective for delicate or high-value foods and are widely used in industries requiring precise freezing.

Ultrasonic-assisted freezing

Ultrasonic-assisted freezing has shown promise in regulating ice crystal size and improving heat transfer during freezing. The cavitation motion caused by ultrasound reduces the subcooling temperature and accelerates the freezing process while maintaining the structural integrity of key dough components like starch, gluten, and yeast. This method also helps optimize the quality of frozen bakery products by minimizing damage caused by ice crystal formation. However, its effectiveness depends on factors like ultrasonic frequency and power, which require careful optimization. While research on this technology is still limited, it holds significant potential for improving frozen dough formulations and ensuring high-quality baked goods.

High-pressure-assisted freezing

High-pressure-assisted freezing is a food processing technique that minimizes quality loss in frozen baked goods by chilling dough to its phase transition temperature while applying pressure. This process creates a unique ice structure that is denser than water and exists in a non-crystalline state, which reduces structural damage and results in frozen goods comparable to fresh ones. Studies have demonstrated that wheat starch gels frozen under high pressure have smaller, more uniformly distributed pores due to the reduced size of ice crystals.

The impact of high-pressure freezing on bakery goods necessitates more research. Key areas to explore include its effect on water, gluten, starch, and yeast, and complex structures like bread. Research shows that freezing dough can change the structure of starch, damage gluten, and reduce yeast viability. Utilizing high-pressure freezing can result in the starch maintaining its structure and, therefore, stabilizing the dough. Preserving the original structures of starch, gluten, and yeast can improve the overall quality.

Studies suggest that all freezing techniques impact the internal rearrangement of starch molecules, affecting gelatinization properties. This underscores the importance of understanding how freezing affects starch granules and the overall quality of frozen dough. Beyond starch, gluten and yeast are also affected by freezing, impacting the dough's structural integrity and fermentation capabilities. Managing these effects through cryoprotective agents and optimized freezing rates is crucial for maintaining the quality of frozen bakery products.

HOW DOES THE FREEZING PROCESS WORK?

Freezing is not as simple as packaging up pieces of raw dough into cartons and sending them for a deep freeze. This is usually done when a manufacturer does not truly understand the freezing process. Frozen dough production is a precise process that can produce high quality products.

Faster freezing rates (around 41°C/h (105°F/h) combined with moderate frozen storage temperatures from -15 to -20°C (5 to -4°F) to optimize dough extensibility, yeast viability, and bread loaf volume. Lower storage temperatures (-30 to -35°C) better preserve gluten microstructure but may reduce yeast activity and bread volume. These findings highlight the importance of controlling freezing protocols and storage conditions to maintain frozen dough performance and bread quality during extended frozen storage. This knowledge can guide frozen dough manufacturers in optimizing processing parameters for improved product consistency and consumer acceptance.[24]

Before Freezing

Gluten network is developed

Yeast is active and fermentation has begun

Freezing

Gluten network firms up. Ice crystals begin to form as the water in the dough freezes

Storage

Yeast remains dormant

Dough remains stable. However, the quality can slowly degrade over time due to freezer burn

Quality decreases

Thawing

During thawing, ice melts, and moisture redistributes.

Yeast reactivates as the temperature rises, and the gluten becomes pliable again.The texture of the thawed dough may exhibit slight changes

TROUBLESHOOTING PAR BAKED AND FROZEN DOUGH

Can unproofed pieces of dough be frozen and stored for later use?

Freezing and storing unproved bread and fermented doughs is feasible but requires careful attention from production, processing, storage, and distribution to thawing. Some key aspects to take into account are:

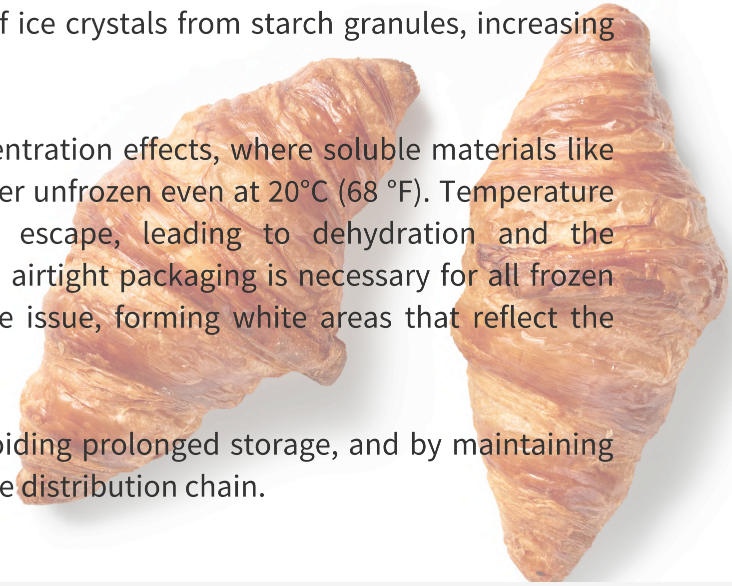
- **Dough Preparation:** use a no-time doughmaking process, as fermentation before freezing negatively impacts quality. Choose high-quality ingredients since freezing cannot enhance product quality.
- **Rework: a**dd it into the dough at the mixing stage, not at the sheeting or forming stage. Up to 10% of rework can be used if frozen shelf life is less than 120 days.
- **Yeast Adjustment:** increase yeast levels to compensate for cell loss during freezing or use a yeast strain that is tolerant to freezing.
- **Freezing Process:** freeze the dough quickly after molding to limit gas production. Avoid air temperatures below -30°C (-22 °F) and ensure the core reaches at least -10°C (14 °F) before storage.
- **Storage and Thawing:** expect reduced product volume over time; adjust proof times accordingly. Thaw it slowly at low temperatures to minimize temperature differences within the dough.
- **Product Selection:** opt for smaller products like rolls or baguettes, which perform better than larger items like pan breads.

When bread rolls and hamburger buns are cut open after being stored in the freezer, a white ring with a hard texture is often observed just beneath the crust. What could be the cause of this issue?

The cause of this issue is a physical phenomenon known as "freezer burn," caused by water movement and oxidation within the product during freezing and storage. It results in a white, dry, and harsh-textured ring beneath the crust due to the sublimation of ice crystals from starch granules, increasing crumb opacity and reducing moisture content.

Factors contributing to freezer burn include freeze concentration effects, where soluble materials like salt and sugar lower the freezing point, leaving some water unfrozen even at 20°C (68 °F). Temperature fluctuations during storage allow unfrozen water to escape, leading to dehydration and the accumulation of "snow" inside the packaging. Therefore, airtight packaging is necessary for all frozen products. Slow refreezing after warming exacerbates the issue, forming white areas that reflect the product's shape.

Freezer burn can be minimized by proper packaging, avoiding prolonged storage, and by maintaining consistent freezer temperature fluctuations throughout the distribution chain.



For small bakeries, what are the key aspects to consider for par-baked and frozen bread products to be used for bake-off at some later date?

The bake-off process for frozen bread products offers flexibility but requires careful attention to minimize moisture loss and staling. Key considerations include:

- **Cooling Before Freezing:** cool the bread to ambient temperature before freezing it to avoid thermal shock and excessive moisture loss. This process can be made precise by using a thermal profilling tool. Covering products can help retain moisture but avoid condensation, which harms crust quality.
- **Freezing Process:** use a blast freezer for faster freezing and reduced moisture loss. Aim for a final core temperature of -10°C (14 °F), as seen with a thermal profiler,
- **Storage and Handling:** minimize freezer door openings to maintain efficiency and prevent moisture loss. Store frozen products in moisture-impermeable bags promptly.
- **Avoid Partial Defrosting:** defrosting and refreezing can cause "freezer burn," resulting in white patches with a harsh texture that are irreversible.
- **Shelling Issue:** crust detachment from the crumb "shelling" can occur due to differing freeze/thaw rates between the crust and crumb, worsened by prolonged storage or improper handling during defrosting and second baking.
- **Bake-Off Guidelines:** defrost products to a core temperature of -5°C (23 °F) before baking. Use higher temperatures with shorter bake times to limit moisture loss during the second bake, as excessive drying accelerates staling.

> *When par-baked products are reheated, it is observed that they remain soft for a short time before hardening and becoming inedible. However, when not reheated, par-baked products are found to stay fresh for several days. What causes the change in the rate of firming? Could it be due to the additional moisture lost during the second bake?*

When par-baked products are reheated, moisture loss occurs during both baking stages, and the combined loss often exceeds that of a single bake. Reduced moisture content contributes to a firmer crumb. However, bread staling is primarily driven by starch retrogradation, where amylose and amylopectin undergo structural changes after baking.

Amylose recrystallizes quickly during cooling, giving initial firmness to the crumb, while amylopectin recrystallizes more slowly over several days, causing progressive firming during storage. Reheating can temporarily reverse amylopectin recrystallization, softening the crumb. However, if the crumb does not reach a critical temperature of 65°C (149 °F) during reheating, un-melted amylopectin crystals act as seeds for accelerated recrystallization, leading to rapid firming upon cooling. This faster staling rate often results from cautious reheating practices that avoid excess surface color but fail to heat the crumb adequately.

Thermal profiling can help understand this process by precisely measuring internal temperatures during both par-baking and reheating, allowing for optimization of time and temperature to control starch gelatinization and moisture retention, ensuring consistency, troubleshooting quality issues, and ultimately extending the softness of the reheated product. For frozen products, a proper thermal profiling with zero time in arrival, and an internal temperature of 65°C (149 °F) is adequate baking. It should not be baked to an arrival of 20% like regular bread.

SUMMARY

This guide explores the rapidly growing market and practical benefits of frozen dough and par-baked products, which include bread, pastries, cookies, pizza crusts, and more. Driven by consumer demand for convenience, consistency, and healthier options like gluten-free and organic varieties, the frozen bakery market is projected to continue to grow through 2032.

Frozen dough products offer major advantages such as reduced preparation time, no need for skilled labor, and consistent results, making them ideal for both home use and commercial kitchens. Par-baked items further enhance convenience by only requiring a final bake. Additionally, their extended shelf life—thanks to immediate freezing—helps minimize waste, streamline inventory management, and ensure product availability. Baker will discover how to enable efficient operations without compromising quality with this guide.

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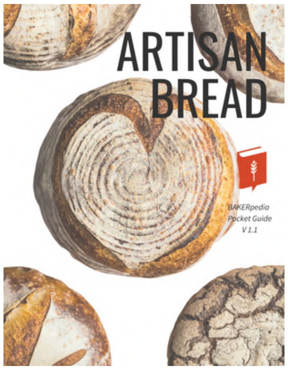

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