Baking
SHELF STABLE PRODUCTS

BAKERguide Vol. 1-2

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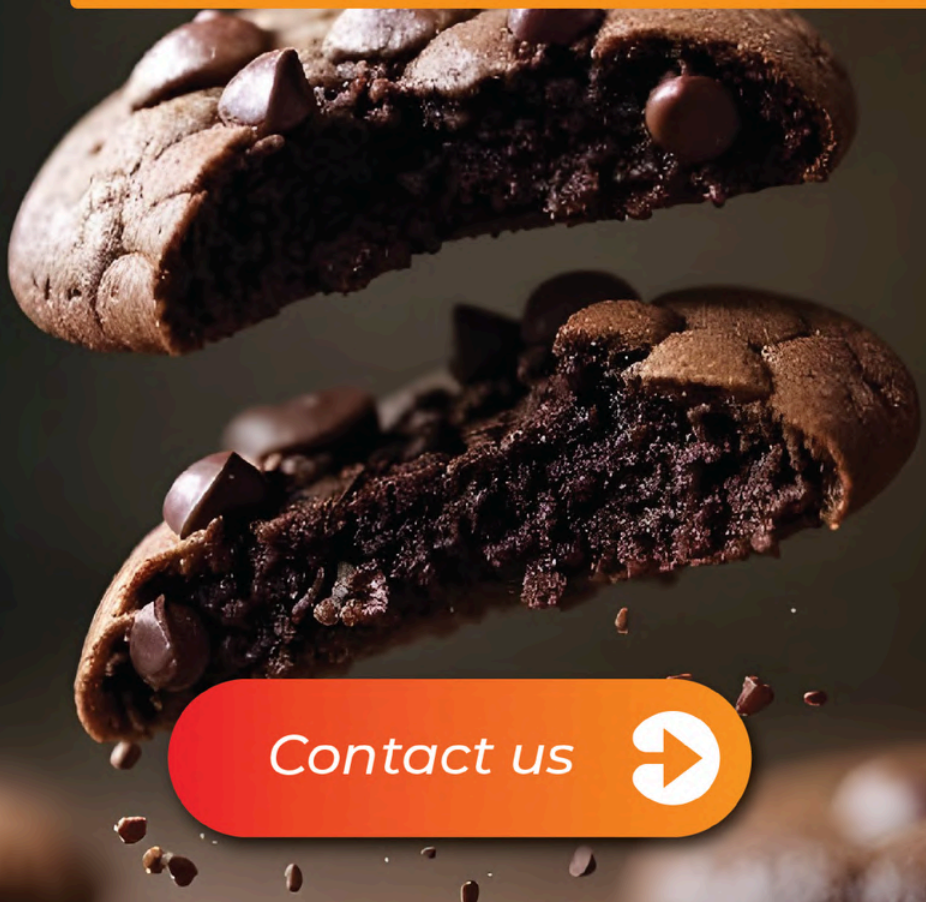

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Table of Contents

INTRODUCTION

Today's high-speed bakeries have to provide consumers with delicious and nutritious products and make these products accessible for long periods. Shelf-life in baked goods refers to the time after baking that the product can be consumed before it should be discarded, usually indicated by the "best-before" label. This means the period for consumption, based on quality, has passed. Going past the recommended date does not necessarily mean that the product cannot be eaten, but instead, it means that the product may no longer meet quality standards for its organoleptic properties, depending on the type of food product.[1]

Shelf-life extension is a multifaceted concern for bakers worldwide. Keeping them fresh entails preserving their original organoleptic properties from day one. This requires the use of shelf-life-enhancing ingredients, proper manufacturing practices, air-tight packaging, and temperature-controlled transportation to preserve the quality of the product. It can have an impact on the economic effectiveness of the bakery and product safety.[1]

Extending shelf-life can significantly impact production and distribution by affecting the size of production batches and economies of scale. Longer runs of a certain product reduce changeovers, reducing overhead costs. Additionally, a longer shelf-life reduces the need for frequent deliveries to retail chains, which can streamline logistics. It also plays a crucial role in minimizing product wastage by reducing spoilage from mold growth or moisture loss. Furthermore, maintaining a longer shelf-life helps prevent or reduce product quality losses, ensuring they remain fresh and appealing to consumers for a longer period.[1]

Shelf-Life Extension Importance

- Food waste produced worldwide is a global concern. According to the UNEP Food Waste Index Report 2024, over 1.05 billion tonnes of food waste was produced in 2022. Of that, 19% is wasted at the retail level. The actual number of bakery product loss is not estimated in the report.

Environment, UN. "Food Waste Index Report 2024." UNEP,. Accessed 15 Apr. 2025.

WHAT IS SHELF-LIFE EXTENSION?

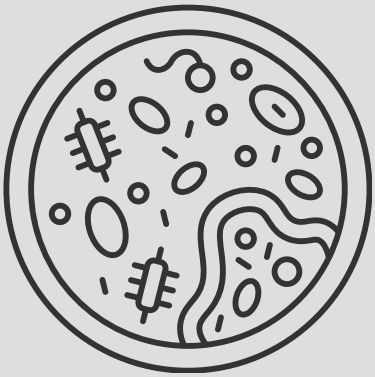
As mentioned previously, a product's shelf-life *"is the period in which the baked good is suitable for consumption based on quality and not necessarily safety"*. Baked goods' shelf-life is influenced by a combination of sensory, chemical, physical, and microbiological factors.[1]

Sensory characteristics like taste, smell, and texture are the most immediate indicators of freshness, while chemical processes such as oxidation and moisture loss contribute to long-term changes in flavor and texture. The physical characteristics, including packaging and storage conditions, play a significant role in retaining freshness, and microbiological growth, particularly mold and yeast, is a critical factor in spoilage. Proper handling, storage, and packaging can help extend the shelf-life of baked goods and maintain their quality for as long as possible.[1]

WHAT DEFINES A PRODUCT'S SHELF-LIFE?

SENSORY CHARACTERISTICS

MICROBIOLOGICAL CHARACTERISTICS



PHYSIO-CHEMICAL PROPERTIES

Sensory Characteristics

Sensory characteristics are essential in determining the consumer's perception of baked goods over time. As baked products age, their sensory attributes can change, which impacts their overall appeal and shelf-life.[3]

- **Taste:** over time, the flavor of baked goods can degrade due to the breakdown of fats and sugars, leading to stale, rancid, or off-flavors. For example, cookies and cakes may taste metallic, and bread may taste sour or overly yeasty after a few days.

- **Smell:** freshly baked goods have a pleasant aroma, but as they age, this aroma diminishes or becomes unpleasant. The breakdown of fats (e.g., butter) can result in a rancid smell, and mold growth can cause a musty odor, signaling spoilage.

- **Appearance:** baked goods can undergo color changes as they lose moisture, especially in products like bread. For instance, crusty bread may become soft, and pastries may become dry and dull in color. Also, any visible mold or discoloration can make the product less appealing. Golden brown products can also pale up to be yellow over shelf-life.

- **Texture:** as starch retrogrades, bread may become dry and hard, and cakes or muffins may become crumbly. Additionally, products like cookies or pastries may lose their crispness, affecting their overall texture and appeal.

Physio-chemical Properties

The chemical stability of baked goods significantly affects their shelf-life. Various chemical processes affect the flavor, texture, and freshness during storage.[4,5]

- **Water activity (a_w):** refers to the availability of free water for microbial growth and chemical reactions. This parameter has a key influence on product safety, quality, and shelf-life. Lower aw products like biscuits have a lower risk of microbial spoilage than high aw products like cream-filled snack cakes. Water activity directly affects chemical reactions as well. The Maillard browning reaction has a peak performance at aw=0.6 due to enough solubilization of reactants and ideal concentration for interaction. Lipid oxidation is also influenced by water activity; intermediate water activity levels prevent lipid oxidation, while high or low water activity values increase the rate of this reaction.[5]

Food Product	Typical Water Activity (aw)
Corn Flakes	0.2
Breakfast Cereals (e.g., Corn Flakes)	0.20–0.30
Crackers	0.20–0.30
Cookies	0.30–0.50
Dried Noodles	0.45–0.50
Pastries	0.60–0.90
Filled Cookies (e.g., Fig Newtons)	0.70–0.75
Nutritional Bars	0.70–0.75
Snack Cakes (e.g., Twinkies)	0.82–0.85
Muffins	0.85–0.90
Waffles	0.85–0.90
Hamburger Buns	0.90–0.94
Sliced Bread	0.94–0.96
Artisan Ciabatta or Focaccia	0.94–0.96

Table 1: Water activity of various food product

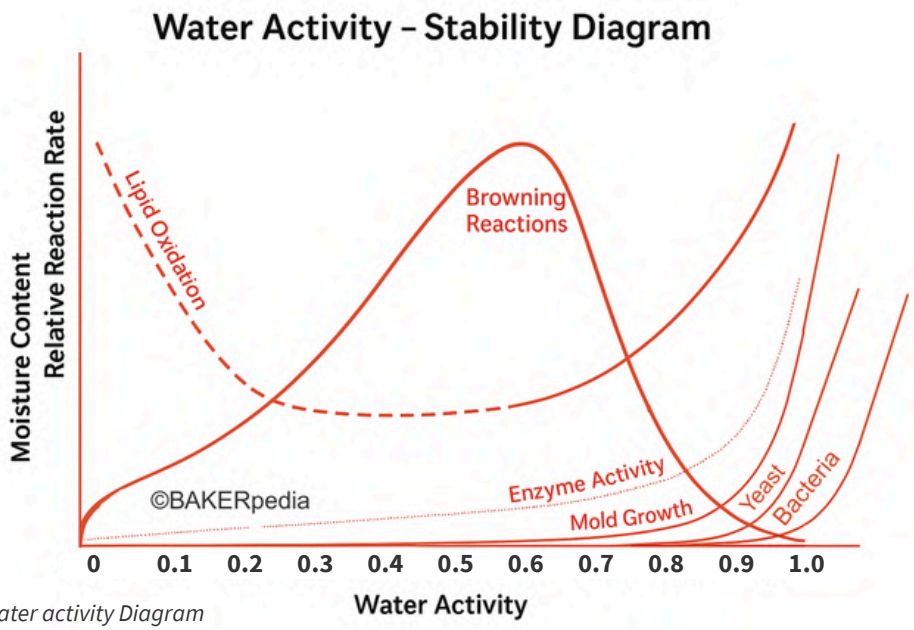


Figure 1: Water activity Diagram

- **Oxidation:** fats and oils in baked goods (such as butter, vegetable oils, or shortening) are prone to oxidation, which leads to rancidity. Rancid fats create off-flavors and smells and can make baked goods less enjoyable. For example, croissants or cakes that contain butter can spoil due to oxidation. Exposure to metals can also enhance oxidative effects, causing a metallic or chemical aroma. Lipid oxidation increases at 0.3 aw, this happens a lot in crackers, cereals, and dried noodles as a shelf-life issue. [1,3]

- **Staling:** is a major issue in baked goods, especially bread, due to a lower sugar and fat content as compared to cakes and cookies. It involves a physical change called starch retrogradation. During baking, starch absorbs water and swells. As the product cools, starch molecules, particularly amylopectin, reorganize into a crystalline structure, expelling water. This process increases firmness, dryness, and creates a crumbly texture. Staling starts almost immediately after baking and occurs even with minimal moisture loss, leading to a decline in the product's sensory qualities.[1,3]

- **Moisture Content:** a significant factor affecting the freshness of baked goods is moisture. As moisture evaporates, bread becomes firmer, and crackers or cookies become harder or more friable. On the other hand, too much moisture can lead to sogginess or mold growth. For instance, a cake with high moisture content will typically mold faster. [1,3]

- **Packaging:** plays a crucial role in maintaining the physical integrity of baked goods. Products like bread and cakes are often packaged in plastic to retain moisture, whereas dry goods such as cookies and crackers are packaged in packaging materials that block light and moisture migration, keeping them crisp.[1,3]

- **Temperature and Humidity:** shelf-life of baked goods is also affected by storage conditions. Higher temperatures can promote staleness, while high humidity can encourage microbial growth and spoilage. Conversely, refrigeration can extend the shelf-life of products like cakes or pastries, but it may alter the texture, causing them to stale faster or dry out during storage in the refrigerator.[1,3]

Microbiological Characteristics

The growth of microorganisms is one of the key factors influencing the shelf-life of baked goods. Baked goods are often high in moisture, which can support the growth of bacteria, molds, and yeasts.

- **Mold:** thrives in moist environments, and products such as bread, cakes, and pastries can develop visible mold spots if not stored correctly. Molds not only affect the visual appeal and texture but can also produce mycotoxins that are harmful to health. Mold spores are abundant in bakeries, especially in bakeries that do not exhaust the air in the mixing room, have a flour reclamation system, and/or do not sanitize their surfaces regularly. Accumulation of flour dust in the air and on horizontal surfaces provides a food source for the mold to grow and produce more spores. In addition, the longer the cooling time and/or fans are used in these environments, the greater the likelihood of mold contamination.[1,3]

- **Bacterial Growth:** while baking creates a kill step that eliminates harmful bacteria, improperly stored or undercooked products can be susceptible to contamination by bacteria like Rope, especially if the moisture content is high and products are re-contaminated after the kill step. These bacteria can cause foodborne illnesses and reduce the shelf-life of the product.[1,3]

FACTORS AFFECTING SHELF-LIFE

Ingredient composition

Ingredient composition plays a key role in determining the shelf-life of baked goods. The specific ingredients used can influence moisture content, water activity, texture, flavor, and susceptibility to spoilage. Some of the most important ingredients are:[1,3,5,6]

- **Flour and Starch:** the type and quality of flour, as well as the starch content, influences moisture retention. Higher starch content, like gluten-free products, can contribute to staleness over time as starch retrogrades, leading to a firmer, drier texture. [5,6]

- **Fat and Oil:** fat like butter, oils, and shortenings acts like a lubricant, contributing to a soft and 'moist' texture. It helps improve texture by creating a tender crumb and coating starch molecules to delay starch retrogradation. preventing excessive drying. However, they are prone to oxidation, which can cause rancidity and off-flavors, shortening the shelf-life of products. Products with higher fat and oil in the formulation would need to have emulsifiers and antioxidants to keep the system stable.[5,6]

- **Sugar:** in the form of sucrose, honey, and syrups is are humectant and acts as a preservative by binding moisture. Creating a hygroscopic environment that reduces water activity, thus reducing microbial growth. However, excessive sugar can also lead to overly sweet products that may cause sugar recrystallization.[5,6]

- **Honey, glycerin and other humectants:** play a role in reducing water activity, thus lowering the risk of microbial growth and extending shelf-life. Humectants attract moisture, keeping the baked goods soft and fresh for a longer time. By reducing water activity, they help preserve the product's texture and taste while also preventing issues like mold growth, a common concern in shelf-life extension. These ingredient innovations not only enhance the eating experience but also provide natural solutions for extending the freshness and safety of baked goods.[5,6]

- **Fiber:** enhances water absorption and moisture retention, preventing staling and extending shelf-life. Fiber binds water, reducing syneresis and improving textural properties. It also mimics fat, contributing to a moist crumb while enhancing nutritional quality.[5,6]

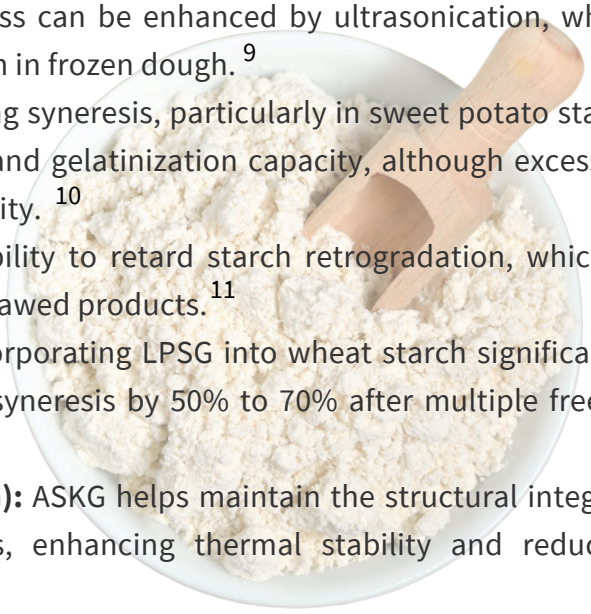
- **Emulsifiers:** stabilize air bubbles in batter and dough, retain moisture, and inhibit starch retrogradation. Lecithin enhances dough elasticity while polysorbates stabilize fat-water emulsions in frostings and fillings and improve fat dispersion in doughs and batters. Mono- and diglycerides inhibit starch retrogradation by forming complexes with amylose, thus preventing crystallization and staling. Propylene glycol monoesters (PGME) improve aeration and volume retention, thus improving texture. Alpha-dextrin stabilizes the structural integrity of the baked good during storage and improves moisture retention, thus retarding staling. [5,6]

- **Chelating Agents:** prevent color discoloration and off-flavors by binding pro-oxidative metals. Chelators like Ethylenediaminetetraacetic acid (EDTA) and citric acid bind metals like iron (in flour) and other metals to prevent lipid oxidation and off-flavors. Many times, the food product comes into contact with metal machinery or metals within the packaging material, which makes it unstable over shelf-life and causes a change in color. Although not as effective, natural chelating agents can be found in certain amino acids such as glycine, alanine, and lysine, with promising results.[5,6]

- **Antioxidants:** prevent lipid oxidation and rancidity in baked goods. Antioxidant ingredients like butylated hydroxyanisole (BHA), butylated hydroxytoluene (BHT), tert-butylhydroquinone (TBHQ), and propyl gallate (PG) are highly effective but face concerns regarding safety. Natural alternatives such as rosemary extract,ß-carotene, and vitamin E are increasingly used for clean-label products. Encapsulation techniques can improve thermal stability during baking.[7]

- **Hydrocolloids:** prevent syneresis (water separation) and enhance water retention in frostings. Gellan gum and agar are particularly effective in donut frostings to prevent drying or cracking.[8]

    - **Xanthan Gum:** xanthan gum is highly effective in reducing syneresis in various starch gels, including sweet potato and tapioca starch. It performs well at different concentrations and pH levels, particularly at neutral pH, and can maintain textural properties during freeze-thaw cycles. Additionally, xanthan gum's effectiveness can be enhanced by ultrasonication, which reduces its viscosity and improves its application in frozen dough. [9]
    - **Guar Gum:** guar gum is also effective in reducing syneresis, particularly in sweet potato starch gels. It helps in maintaining water absorption and gelatinization capacity, although excessive amounts can increase hardness and reduce quality. [10]
    - **Sodium Alginate:** this gum is noted for its ability to retard starch retrogradation, which is beneficial in maintaining the quality of freeze-thawed products.[11]
    - **Lepidium perfoliatum Seed Gum (LPSG):** Incorporating LPSG into wheat starch significantly reduces syneresis, with a notable decrease in syneresis by 50% to 70% after multiple freeze-thaw cycles.[12]
    - **Artemisia sphaerocephala Krasch Gum (ASKG):** ASKG helps maintain the structural integrity of starch granules during freeze-thaw cycles, enhancing thermal stability and reducing syneresis.[13]



- **Leavening Agents:** type of leavening agents (properly neutralized) can impact texture and the rate of staling. The higher the gas production, will result in a softer texture.

- **Acids:** propionic or sorbic acids can extend shelf-life by preventing microbial growth. Calcium propionate or its naturally occurring counterpart in cultured wheat, rice, or dextrose alternatives can be used in yeasted dough. Potassium sorbate or its naturally occurring rowanberry extract can be more effective in chemically leavened baked products. Sodium Benzoate can also be used in pH ranges from 2.5 to 4.0, they are not recommended for use above pH 4. Acidity levels for calcium propionate have pH values up to 5.5 for yeasted doughs. Potassium Sorbate works at low pH conditions up to 6.5 for chemically leavened systems. In the product, they can also help inhibit mold growth and slow spoilage, especially in products with fruit fillings or acidic ingredients.[8]

Natural Extenders

Natural preservatives, such as vinegar and cultured wheat, are increasingly used in the baking industry to extend the shelf-life of baked goods while meeting consumer demand for clean-label products. The most commonly used natural preservatives in baked goods are:

- **Vinegar (Acetic Acid):** inhibits microbial growth by increasing acidity, thereby extending shelf-life.
- **Cultured Wheat:** produced through fermentation, it contains natural antimicrobials that combat spoilage organisms.
- **Plant Extracts:** substances like rosemary, thyme, cinnamon, clove, lemongrass, capsicum, bay leaf, ginger, garlic, and basil possess antimicrobial properties that help preserve baked goods.
- **Vitamin C (Ascorbic Acid):** acts as an antioxidant, preventing oxidative spoilage and maintaining product quality.
- **Rosemary Extract:** rich in carnosic acid, it serves as a potent natural antioxidant, preserving flavor and extending shelf-life. Rosemary extract, which has diterpenes and rosmarinic acid, inhibits rancidity in fat-rich components such as fillings and frostings by reducing oxidative stress.
- **Cultured Starches:** fermented starches from sources like wheat or corn produce acids and peptides that inhibit mold growth.
- **Tea Extracts:** contain tannins and polyphenolic compounds with bactericidal properties, contributing to the preservation of baked goods.
- **Chitosan:** derived from crustacean shells or mushrooms, it forms a protective barrier against microbial contamination and oxidation.
- **Fruit Concentrates:** ingredients like raisin or prune juice concentrates contain natural acids that act as preservatives while also serving as humectants.

- **Natamycin:** a natural antifungal agent effective against yeasts and molds, commonly used as a surface treatment post-baking.

Consumers are particularly attracted to these natural preservatives as they prefer simple, recognizable ingredients. Clean-label products, free from artificial additives, align with the growing trend of health-conscious and ingredient-aware buyers. Natural alternatives like bamboo leaves, tea polyphenols, and vitamin E are also being explored.

Novel Ingredients

- **Enzymes:** enzymes help improve dough handling and bread texture by breaking down starches and sugars, reducing staling, and maintaining moisture, which delays the retrogradation of starch and helps maintain softness.

- **Emulsifiers** improve the structure of the dough by stabilizing the mixture of water and fat, improving crumb structure, and enhancing product freshness. Alpha dextrin specifically, extends the shelf-life of baked goods by stabilizing emulsions and preventing physical spoilage. Its unique cyclodextrin structure, with a lipophilic cavity and hydrophilic outer layer, interacts with fatty acids to act as an emulsifier, reducing moisture loss and staling. By slowing starch retrogradation and maintaining product softness, alpha-dextrin helps baked goods retain their texture and freshness over time. Additionally, its stabilizing properties improve resilience under temperature fluctuations, ensuring baked goods remain stable and appealing during storage and transport. They can be produced from acidic hydrolysis from starch or by enzymatic means.

- **High-quality flour** and **vital wheat gluten in yeasted doughs:** further enhance the texture by providing better dough elasticity and gas retention, which can lead to a finer, softer crumb. These ingredients help improve the dough's strength, contributing to improved volume and texture, making the baked goods lighter and less prone to drying out.

Environmental conditions

- **Storage Temperature:** lowering the storage temperature of baked goods slows mold growth and extends shelf-life. However, moisture loss and quality changes can still occur, so proper packaging is necessary.

- **Effects of pH:** the pH of a product can also influence shelf-life by inhibiting mold growth. Molds thrive within certain pH ranges from 4.5 to 8.0, and adjusting the pH outside their "comfort zone" can slow growth. Preferably, calcium propionate works at lower pH values up to 5.5 for yeasted doughs. Potassium Sorbate works at low pH conditions up to 6.5 for chemically leavened systems. Increasing fermentation time, and/or adding vinegar, acetic, citric, malic, or fumaric acids can reduce the pH in yeasted doughs. However, decreasing pH in a chemically leavened system is tricky, as it neutralizes the baking soda. In these situations, encapsulation of the acids, such as baking powder.

- **Humidity:** humidity significantly affects the shelf-life of baked goods. High humidity can lead to mold growth, spoilage, and a loss of texture, causing products like crusty bread, pastries, crisp cookies, and biscuits to become soggy or soft. On the other hand, low humidity can result in dryness and staleness, making items like cakes and soft bread, and rolls hard and dry. While dry products like crackers may fare better in low humidity, a balance is essential for maintaining freshness. Proper humidity control during storage helps preserve the quality, texture, and longevity of baked goods.

Packaging methods

- **Packaging Before Baking:** packaging before baking involves depositing baked products, such as steamed or Christmas puddings, into containers before they are fully baked or steamed. These products are part-sealed, then baked or steamed, and the final sealing occurs immediately after baking while the product is still hot. This method helps preserve the shelf-life by preventing contamination and ensuring that the product is sealed in an optimal condition before cooling. It is particularly useful for products where crust color and surface condensation are less critical, as staling is often reversed when the product is reheated before consumption.

- **Packaging Directly After Baking:** packaging directly after baking involves quickly cooling the baked product and sealing it in a clean, hygienic environment to prevent contamination. Sealing the product at the correct temperature reduces the risk of moisture buildup inside the packaging, which could otherwise lead to mold growth and spoilage. Proper cooling and sealing immediately after baking help maintain the product's freshness, prevent contamination, and extend its shelf-life by reducing the factors that contribute to spoilage. This can often be achieved with vacuum cooling methods. Care must be taken to avoid localized condensation within the packaging, which can also encourage mold growth.

ADVANCED TECHNIQUES FOR SHELF-LIFE EXTENSION

Freezing

Freezing is an effective method for preserving the quality and extending the shelf-life of baked goods. The freezing process works by lowering the temperature of baked items to below **0°C (32°F),** slowing down or halting microbial growth and enzymatic activity that can lead to spoilage. When baked goods are frozen, water molecules form ice crystals, which can help preserve their texture, flavor, and moisture content. This is particularly beneficial for products like bread, cakes, and pastries. Freezing helps maintain the freshness of these items for months, offering convenience and reducing food waste by extending shelf-life.

Cooling

For optimal results, proper packaging is key when freezing baked goods. Packaging should be airtight to prevent freezer burn, moisture loss, and the absorption of unwanted odors from the freezer. Vacuum-sealed bags or tightly wrapped plastic films are ideal choices for packaging. For products like bread, slicing before freezing can help with easier portioning when thawing. When thawing, it's important to allow baked goods to come back to room temperature gradually, typically by leaving them out on a countertop. For items like pastries or bread, reheating them in an oven for a few minutes can help restore their original texture and flavor. Avoid thawing in a microwave as it can cause a soggy texture in some products.

Baking Process Optimization

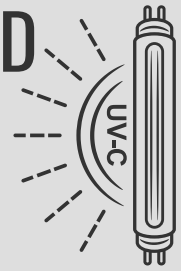
Baking process optimization plays a significant role in extending the shelf-life of baked goods. The baking temperature and time are critical factors that affect not only the texture and flavor of baked products but also their freshness and shelf-life. If the baking temperature is too high or low, it can lead to uneven moisture distribution, which affects the product's texture, making it either too dry or undercooked. This inconsistency can result in faster staling and spoilage, reducing shelf-life. Conversely, optimizing both temperature and time ensures the product is cooked thoroughly, preserving moisture and texture, which contributes to longer shelf-life by preventing rapid staling.

An essential technique in process optimization is following the internal S-curve profile for baking, which refers to a controlled baking process where the product's internal temperature gradually rises in a consistent manner. This ensures uniform heat distribution throughout the baked good, leading to better moisture retention, reduced staling, and a longer shelf-life. The internal S-curve profile helps prevent uneven cooking, reduces excess moisture loss, and limits overbaking, which can accelerate staling or microbial growth. By controlling the internal temperature rise, bakers can ensure products remain fresh longer, stay softer, and resist spoilage, providing a natural extension to shelf-life while maintaining the desired organoleptic properties.

UV Treatment

UV light treatment has emerged as an innovative solution for extending the shelf-life of baked goods while adhering to the increasing consumer demand for clean-label, chemical-free, and environmentally friendly food preservation methods. UV-C light, which operates within the 200-280 nm wavelength range, helps to reduce microbial contamination, including mold and bacteria, without affecting the organoleptic properties of the product, such as taste, texture, and aroma. This non-thermal process is FDA-approved, making it a safer alternative to traditional chemical preservatives. It is particularly effective in controlling microbial hazards in the later stages of the baking process, such as during cooling, slicing, and packaging.[18]

WHY IS UV LIGHT TREATMENT AN ADVANCED SHELF-LIFE EXTENSION PROCESS?



- **Consumer Demand:** growing preference for clean-label, chemical-free, and environmentally-friendly food preservation methods.
- **UV Light Process:** Uses UV-C light (200-280 nm) to reduce microbial contamination without affecting taste or texture. It is FDA-approved.
- **Effectiveness:** Reduces microbial loads on products, especially after baking during stages like cooling, slicing, and packaging. Effective against mold growth and foodborne pathogens.
- **Environmental and Economic Impact:** UV light treatment supports sustainability by reducing food waste and extending shelf-life while maintaining product quality.

Baked Good	UV-C Dose	shelf-life Extension
Par-baked Pizza	1000 V for 10 min	Up to 40-day extension in shelf-life
Wholemeal, Rye, and Six-Grain Bread	2.50 J/cm^2	Wholemeal: 6 days, Rye: 8 days, Six-Grain: 9 days

Table 2: UV Treatment of Bakery Products

Packaging Solutions

Packaging plays a crucial role in extending the shelf-life of baked goods, ensuring they remain fresh, safe, and of high quality for longer periods. Effective packaging solutions help prevent contamination, moisture loss, and spoilage, which are essential factors in maintaining the taste and texture of products. By utilizing various packaging techniques, manufacturers can significantly improve the longevity of baked goods and enhance consumer satisfaction.[1]

Packaging Solution	Mechanism	Benefits
Modified Atmosphere Packaging (MAP)	Replaces air with a mix of gases (e.g., nitrogen, carbon dioxide) to inhibit microbial growth.	Reduces mold and bacteria growth, retains moisture, and slows down staling.
Vacuum Packaging	Removes air before sealing, preventing oxygen contact.	Prevents microbial growth and reduces staling by minimizing exposure to oxygen.
Active Packaging (Oxygen Scavengers, Moisture Control)	Uses materials that absorb excess oxygen or moisture inside the packaging.	Prevents mold growth, maintains texture, and prevents staleness.
Intelligent Packaging	Includes sensors or indicators to monitor product condition, such as spoilage or moisture content.	Allows real-time monitoring of freshness, ensuring the product remains optimal until consumption.

Table 3: Pacakging Solutions for Bakery Products

Packaging Solution	Mechanism	Benefits
Anti-microbial packaging*	Anti-microbial packaging technology embeds natural, food-grade organic extracts into packaging materials that release antimicrobial vapors inside the package. These vapors inhibit mold growth by slowing mold metabolism and preventing colony formation without affecting taste, smell, or leaving residue. The packaging integrates seamlessly with existing production lines and targets mold inhibition specifically for baked goods like whole grain breads, allowing the food to last longer at ambient temperatures without refrigeration.	Extends shelf-life of baked goods by 5 to 30 days, significantly reducing spoilage and food waste. Enables clean-label products by eliminating the need for chemical preservatives and dough conditioners, meeting consumer demand for healthier foods. Lowers logistics and refrigeration costs for producers and retailers. Contributes to reducing food waste from 40% to less than 10%, promoting environmental sustainability and potentially lowering food prices for consumers.

Table 3 (continuation): Pacakging Solutions for Bakery Products
**Nov 6, 2019 - SoFresh. "Blown Film Materials and Processes for Manufacturing Thereof and Uses Thereof." Justia,. Accessed 15 Apr. 2025.*

TYPES OF PACKAGING MATERIALS

Different packaging materials are used for baked goods to ensure the best preservation while considering factors such as moisture control, protection, and cost-effectiveness. Below is a comparison of the most common types of packaging materials:

Packaging Material	Description	Advantages	Disadvantages
Plastic Packaging	Flexible, lightweight materials such as polyethylene and polypropylene (1-2 mils). Often used for individual packs or bags.	Affordable, versatile, provides a good moisture barrier, and has easy-to-print branding and information.	Can be prone to environmental concerns (non-biodegradable), may affect the product's taste if not properly sealed.
Plastic Packaging	Flexible, lightweight materials such as polyethylene and polypropylene (1-2 mils). Often used for individual packs or bags.	Affordable, versatile, provides a good moisture barrier, and has easy-to-print branding and information.	Can be prone to environmental concerns (non-biodegradable), may affect the product's taste if not properly sealed.
Biodegradable plastic (Polylactic Acid)	Plant-based plastic is made from corn starch or sugarcane. Used for transparent films and containers.	- Renewable and compostable in industrial facilities.- Transparent and moisture-resistant.	- Requires industrial composting (not home-compostable).- Can soften under high temperatures.
Paper Packaging	Includes kraft paper, wax-coated paper, and cardboard, typically used for loaf bread, pastries, and wraps.	Eco-friendly (biodegradable), good for presentation and branding, and provides breathability for certain products.	Less effective at moisture retention, prone to tearing, and may not provide the best barrier to oxygen.
Vacuum-Sealed Packaging	Involves removing air from the package before sealing, typically used for individual portions or bulk packaging.	Maximizes shelf-life by removing oxygen, prevents staling, retains moisture, and prevents microbial growth.	More expensive than plastic or paper packaging, it requires specialized equipment, and is not suitable for all baked goods.

Table 4 (continue): Pacakging Material for Bakery Products

Each type of packaging material comes with its advantages and drawbacks, depending on the product type, shelf-life requirements, and environmental considerations. The best packaging choice is often a balance between the product's specific needs and the cost-effectiveness of the packaging solution.

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*International Food Information Council, 2023 Food & Health Survey.

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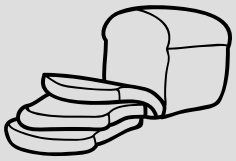
MORE THAN YEAST

EXTENSION OF SHELF-LIFE BY CATEGORIES

YEASTED DOUGH



Extending bread's shelf-life requires a multifaceted approach, addressing both textural degradation and microbial spoilage. Bread shelf-life is characterized by the staling rate, which mainly affects the acceptability of the product.

Several strategies are being employed to extend the shelf-life of bread:

- **Fat Selection for Oxidative Stability:** choice of fat significantly impacts bread's shelf-life, particularly in preventing rancidity. Saturated fats like palm oil, shortening, or lard, due to their chemical structure, offer superior oxidative stability compared to unsaturated fats. This stability minimizes the development of off-flavors and odors caused by oxidation, maintaining the bread's desired taste and aroma for a longer period. Therefore, opting for saturated fats, when formulation allows, is a key strategy for extending bread shelf-life.
- **Emulsifier Optimization:** emulsifiers play a crucial role in enhancing bread texture and moisture retention. By facilitating the interaction between water and fat, emulsifiers contribute to a softer crumb and delay staling. Optimizing emulsifier usage, aiming for approximately 4% based on fat content, ensures effective distribution and functionality. This precise application helps maintain bread softness, resiliency, and overall quality throughout its shelf-life.
- **Sugar Incorporation:** sugars are not merely for sweetness; they also contribute to bread shelf-life by binding moisture and reducing water activity. This moisture-binding property slows down staling, keeping the bread softer for longer. Furthermore, by lowering water activity, sugars create an environment less conducive to microbial growth, thus extending the bread's freshness and preventing spoilage.
- **Enzyme Application:** enzymes are powerful tools for tailoring bread texture and delaying staling. Selecting enzymes based on their specific functionalities, such as amylases for crumb softness or xylanases for dough handling, allows bakers to fine-tune bread characteristics. This targeted application of enzymes ensures that the bread maintains its desired texture and quality throughout its shelf-life.

- **Proper Processing and Hydration:** consistent and thorough dough processing, particularly proper hydration, is fundamental for optimal bread shelf-life. Adequate hydration ensures that gluten develops correctly, resulting in a well-structured crumb that retains volume and moisture. Proper processing throughout the mixing, fermentation, and baking stages contributes to a consistent product, minimizing variations that could affect shelf-life.
- **Sanitation and Environmental Control:** maintaining a clean and sanitized environment is essential for preventing microbial contamination and extending bread shelf-life. Implementing strict sanitation protocols, including regular cleaning and disinfection of equipment and surfaces, minimizes the risk of mold and bacterial growth. Air filtration systems help remove flour particles and other airborne contaminants, further reducing the potential for spoilage.
- **pH Management:** controlling dough pH is a critical strategy for inhibiting mold growth. By maintaining an acidic environment, mold proliferation is significantly reduced. If traditional mold inhibitors are ineffective, lowering the dough pH with vinegar or other food-grade acids can provide an effective alternative. This pH management is a strong tool for maintaining bread safety.
- **Adequate Bake-Out:** sufficient bake-out is crucial for reducing moisture content and minimizing microbial activity. Using thermal profiling, a thorough bake-out, or staying 20% in the arrival zone ensures a proper bake.. Increasing arrivals to 22-25% significantly evaporates the water in the bread, reducing the amount of cooling time. This technique can be used in the summertime to reduce cooling time, when it is humid and hot.
- **Appropriate Packaging:** packaging plays a vital role in protecting bread from environmental factors that can accelerate spoilage. Specialized packaging, such as modified atmosphere packaging (MAP) or barrier films, creates a protective shield against moisture, oxygen, and other contaminants. This packaging helps maintain the bread's freshness and extends its shelf-life by preventing staling and microbial growth.
- **Cooling Before Packaging:** allowing bread to cool completely 32–43°C (90–110°F) before packaging is essential for preventing condensation and mold growth. Packaging warm bread traps moisture, creating an environment conducive to microbial proliferation. Cooling allows excess moisture to evaporate, minimizing the risk of condensation and ensuring a longer shelf-life.

- **Alternative Mold Inhibitors:** when traditional mold inhibitors prove insufficient, exploring natural alternatives becomes essential. Researching and implementing natural mold inhibitors like cinnamon, cloves, or onion extract can provide effective protection against mold growth. These natural options can offer a solution when chemical preservatives are undesirable while still ensuring product safety.

- **Specific Volume Monitoring:** monitoring the specific volume of bread provides critical data about the product's consistency and quality. Specific volume is related to the amount of air that is incorporated into the dough. This is greatly affected by the mixing process. Monitoring this helps to ensure that the product is uniform and that the proper mixing techniques are being used.

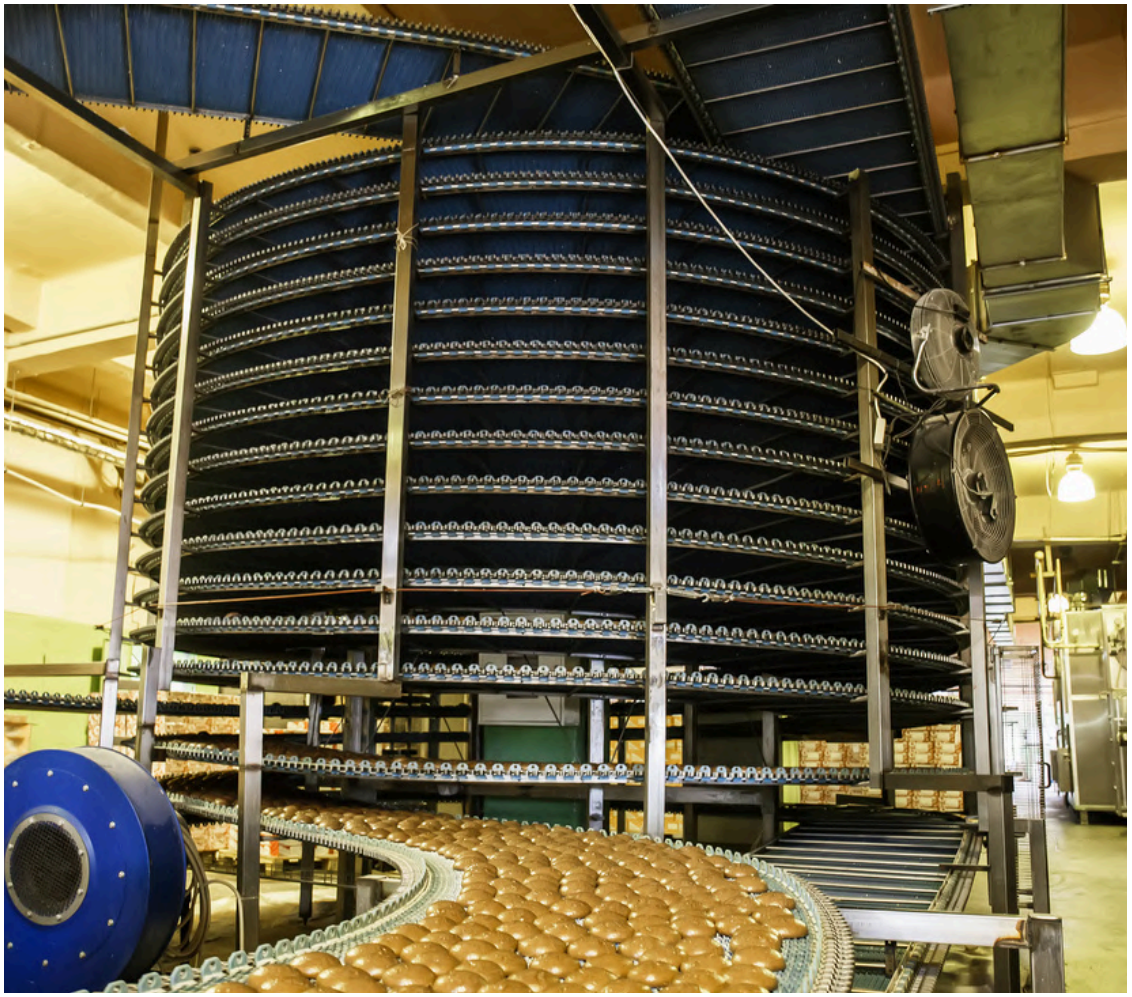
SNACK CAKES

Cakes, snack cakes, madeleines, brownies, and cake donuts have an incredible shelf-life due to their high fat and sugar content. Achieving a moist product necessitates controlling moisture loss during baking rather than simply increasing water content. Fat and emulsifiers play a crucial role in providing a perception of moistness and improving texture. Extended shelf-life is contingent on mitigating microbial activity and staling.

Several strategies are being employed to extend the shelf-life of cakes:

- **Control Water Activity (a_w)**: minimizing aw is essential for extending shelf-life. This involves reducing the amount of free water available for microbial growth, particularly molds and yeasts. Strategies include incorporating humectants like glycerin or sorbitol, which bind water molecules, formulating with ingredients that naturally have lower moisture content, and utilizing packaging that creates a barrier against moisture ingress. Achieving a water activity level below 0.7 is generally recommended for inhibiting mold growth.
- **Optimize Fat and Emulsifiers:** the strategic use of fats and emulsifiers significantly impacts cake moistness and shelf-life. Fat acts as a lubricant, creating a perception of moistness and slowing down the staling process. Emulsifiers, on the other hand, stabilize emulsions, preventing water and fat separation and ensuring a uniform texture. This results in a more cohesive crumb that doesn't crumble when sliced. Incorporating fat-based fillings and icings can further contribute to moisture retention and extend shelf-life. Achieving the correct balance of fat and emulsifiers is crucial for a desirable texture and prolonged freshness.
- **Utilize Enzymes:** enzymes, especially amylases, play a vital role in preventing starch retrogradation, which is the primary cause of staling in cakes. By breaking down starch chains, these enzymes hinder recrystallization, maintaining a soft and tender crumb. This enzymatic action extends the perceived freshness and softness of the cake, making it a valuable tool for extending shelf-life.
- **Proper Mixing and Aeration:** effective mixing and aeration are fundamental for creating a stable cake structure. Proper mixing incorporates air, increasing volume and resulting in a light and airy crumb. Conversely, overmixing can develop excessive gluten, leading to a tough cake, while undermixing can produce a dense and uneven texture. Achieving the right level of aeration is essential for maintaining moisture and preventing the cake from becoming dry or crumbly.

- **Balanced Leavening System:** a well-balanced leavening system, using the correct leavening acid with a base, is critical for achieving a consistent and appropriate rise. Proper leavening creates a porous structure that effectively retains moisture, contributing to a soft and tender crumb. An imbalanced leavening system can result in unreacted acid or base that will cause an off color, an uneven rise, collapse, or undesirable texture, affecting both the appearance and shelf-life of the cake.
- **Employ Mold Inhibitors:** mold inhibitors, such as potassium sorbate or sodium benzoate, are crucial for preventing the growth of molds and yeasts, which are the primary causes of spoilage in baked goods. These preservatives extend shelf-life by inhibiting microbial activity. It is essential to choose and use mold inhibitors in compliance with regulatory requirements, ensuring both effectiveness and safety.
- **Precise Specific Gravity Measurement:** specific gravity measurement provides valuable information about batter density and air incorporation. Maintaining a consistent specific gravity ensures uniform baking and product quality. This consistency helps maintain consistent moisture levels and texture throughout the cake, contributing to a longer and more predictable shelf-life.



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COOKIE

Cookies, bars, and crackers are primarily influenced by awand fat oxidation. The inherently low water activity in cookies, often further reduced by ingredients like sugars and fats, inhibits microbial spoilage. However, fats are susceptible to rancidity, necessitating the use of antioxidants. Staling, the gradual loss of freshness, is also affected by fat content and starch interactions. Additionally, environmental factors like temperature fluctuations can lead to fat bloom, impacting visual appeal and perceived quality.

The main factors affecting cookie shelf-life are:

- **a_w:** are characterized by low moisture and aw in the range of 0.30 - 0.50, which is a key factor in their shelf stability. Ingredients like sugar (especially powdered sugar), honey, and high fructose corn syrup act as humectants, retaining moisture and thus aiding in improving microbial deterioration.
- **Fat Oxidation (Rancidity):** fat is a crucial ingredient, but its oxidation can lead to rancidity, reducing shelf-life. Chelating agents and antioxidantslike BHA, BHT, and TBHQ are used to retard fat oxidation.
- **Microbial Growth:** high sugar content and low moisture generally inhibit microbial growth by reducing water activity. Spices like cinnamon, ground ginger, nutmeg, and cloves have natural anti-mold properties. Reducing or replacing sugar can increase water activity, therefore,anti-mold ingredients might be needed when replacing sugar with allulose, stevia, or acesulfame-K.
- **Staling:** fat delays staling by delaying the starch gelatinization process.
- **Fat Bloom:** temperature changes can cause fat bloom, where fat migrates to the surface, causing a paler appearance. Storing cookies in a temperature-controlled environment or using emulsifiers can help prevent this, especially in chocolate chip cookies.
- **Ingredient Choices:** the type and amount of flour, sugar, fat, and emulsifiers significantly impact texture and shelf-life. Emulsifiers like mono- and diglycerides and lecithin help distribute fat and water, improving texture and potentially extending shelf-life. Flour type and enzymes like proteases, hemicellulases, and amylases can modify texture and spread, indirectly affecting shelf-life.

BakeShure® preservation and acidulant technology enables you to build a system that works to meet your needs, while maintaining finished product quality by preventing inhibition of baker's yeast, gluten degradation and interaction with chemical leavening systems. Contact us: HNH-info@balchem.com

TORTILLA

Tortillas are growing in popularity, driven by increasing consumer demand for healthier, gluten-free, non-GMO, and clean-label options. The global tortilla market is growing at 3.4% per year. As tortillas are often consumed as convenience food, extending their shelf-life without compromising quality is a priority. However, staling is a common issue for fresh tortillas, leading to a loss of flavor, texture, and moisture, which results in a drier and breakable product.

Several strategies are being employed to extend the shelf-life of tortillas:

- **Enzymes:** maltogenic amylase enzymes slow down starch retrogradation, which is a primary cause of staling. By breaking down amylose and amylopectin, these enzymes reduce moisture loss and help maintain freshness.
- **Wheat Proteins:** Adding wheat proteins, such as gliadin, increases dough extensibility and water retention, improving the texture and moisture of tortillas, thus extending shelf-life.
- **Packaging Solutions:** Specialized packaging materials with moisture barrier capabilities, along with inert gas flushing, help to maintain freshness by preventing moisture migration and product contamination.
- **Oils:** oils play a crucial role in extending the shelf-life of tortillas by maintaining texture and freshness over time. Stable fats, such as saturated oils, are particularly effective due to their resistance to oxidation, which delays spoilage and off-flavors caused by rancidity. Additionally, oils contribute to moisture retention and dough lubrication, ensuring tortillas stay pliable and fresh throughout their storage period.6
- **Mono-and diglycerides:** mono- and diglycerides are widely used in tortilla production to extend shelf-life by improving flexibility, texture, and moisture retention. These emulsifiers interact with starch molecules, preventing retrogradation and staling, which helps tortillas remain soft and pliable for longer periods. By stabilizing the dough structure and retaining moisture, mono- and diglycerides reduce dryness and cracking, enhance rollability, and maintain a fresh feel even after several days of storage. They also contribute to freeze-thaw stability, ensuring quality is preserved when tortillas are frozen and thawed.6

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SUMMARY

Shelf-life extension is extremely important for today's high-output bakeries, where maintaining freshness and quality is key to satisfying consumer expectations and minimizing food waste. In this Pocket Guide, we dive into the essential strategies for extending the shelf-life of baked goods, helping bakeries keep products fresh for longer without compromising on taste or texture. From the role of natural preservatives, such as vinegar and cultured wheat, to the use of enzymes, emulsifiers, and high-quality ingredients like vital wheat gluten, we explore how smart ingredient choices can help preserve freshness.

We also uncovered the impact of packaging to safeguard against contaminants and moisture loss. Beyond ingredients and packaging, we examine advanced techniques like UV light treatment and freezing, which are gaining traction for their ability to prevent microbial growth and spoilage. Lastly, we discuss how optimizing the baking process through careful control of temperature, time, and internal profiles can make a significant difference in product longevity. With a growing shift toward clean-label and natural solutions, this guide provides bakers with the tools and knowledge needed to extend shelf-life, reduce waste, and deliver high-quality baked goods that keep customers coming back.

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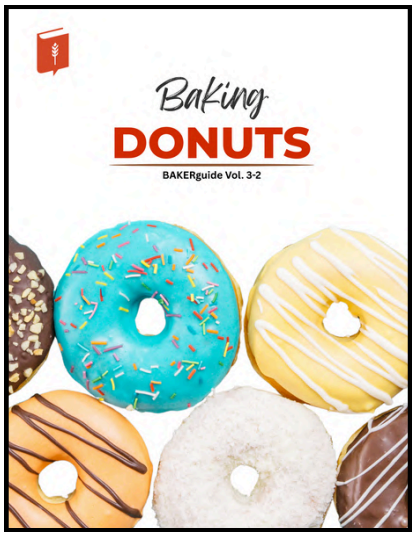

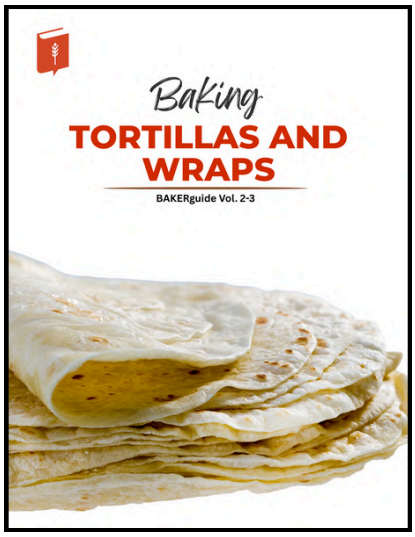

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