AMERICAN FROZEN FOOD INSTITUTE

FARM TO FREEZER

Exploring the Science and Benefits of Frozen Foods

AUTHORED BY **KANTHA SHELKE, PHD, CFS**

Introduction

In the realm of nutrition and food preservation, freezing stands out as a preferred method for maintaining the integrity, nutritional value, and quality of foods.

As society gravitates toward healthier, more sustainable eating habits, understanding the benefits of frozen fruits, vegetables, and meals becomes increasingly important. This paper delves into the science of freezing to maintain the quality of color, flavor, and texture in our everyday foods. Through exploring the freezing process, packaging, and other factors influencing quality and shelf life, we show that freezing is a natural, efficient way to preserve food, making it an essential tool in the dietitian's arsenal for promoting a nutritious and wholesome diet.

THE NUTRITIONAL PLUSES OF FREEZING

- **Modern freezing processes do not affect nutrient content negatively.**
- **Freezing prevents post-harvest decline of nutrients in produce.**
- **Freezing protects protein, vitamins A and D, or other nutrients in meat, seafood, and poultry.**
- **Freezing preserves macro- and micronutrients in prepared foods.**
- **Freezing locks in nutrients in the peak of ripeness of fruits and vegetables and immediately upon preparation of multi-ingredient meals.**

Freezing Fundamentals

Freezing preserves food by solidifying naturally-occurring water in foods. The solid water pauses nutrient degradation, bacterial growth, and enzyme activity. When done right, this preserves flavor, texture, and color—all the things we love about the food we eat.

The concept of freezing is straightforward, it simply consists of using low temperature to remove heat. While the concept is easy, the process of freezing food to ensure high quality can be extremely complex with fats, fiber, protein, carbohydrates interacting with salts and sugars, creating a matrix of frozen and partially frozen components. University researchers and frozen food processors work to fine-tune the temperature and the rate of freezing for different types of food to optimize the moisture, texture, color, and flavor of the foods we eat.

The speed at which food is frozen is critical to product quality. Rapid freezing processes reduce the temperature of food from ambient to -20°F in a few minutes to form the smallest ice crystals possible. Small ice crystals are less likely to damage the cellular structure of meats, fruits, and vegetables, which preserves texture, flavor, and nutritional value better than larger ice crystals. While there is no universal target for the size of ice crystals to best preserve foods, the universally accepted axiom is “the smaller the better.” The larger ice crystals formed during slow freezing tend to affect a food’s microstructure in ways that become evident during thawing, such as cell tissues softening or rupturing with accompanying loss of moisture, flavor, aroma, color, and texture. Since the goal in freezing is to avoid large ice crystals, it is crucial to minimize the time it takes for the product to pass quickly through the temperature range where water crystallizes. This means freezing food in minutes instead of hours.

One method to control the speed of freezing is adjusting the size and thickness of food pieces. Smaller, thinner pieces freeze more rapidly than larger, thicker ones, allowing for quicker temperature reduction through freezing temperatures.

Commercial operators today use a range of freezing technologies, with Individual Quick Freezing (IQF) being the most common method for extracting heat from food. IQF uses extremely cold temperature (-40°F) and turbulent air flow over and around the food. IQF is excellent at maintaining piece identity in products like blueberries, corn, or shrimp. While IQF offers a range of benefits, including preserving the texture, color, and nutritional value of foods, it must be carefully managed across different food types, including fruits, vegetables, proteins, and complex meals. The challenge for producers lies in balancing the speed of freezing to minimize ice crystal formation without inducing other types of damage, such as cellular damage or moisture loss. This delicate balance ensures the benefits of rapid freezing to maintain food quality without compromising safety or organoleptic properties.

- **Fruits and Vegetables:** Water makes up more than 80% of the composition of fruits and vegetables and IQF's rapid freezing capabilities allow for individual piece identity and outstanding texture.
- **Proteins:** Water content is 60-70% on a wet basis and the small ice crystals formed through rapid freezing help retain the cellular structure of proteins making this process ideal for meat, poultry, seafoods, and other proteins. Protein producers may use a sauce or marinade that freezes around the protein, acting as a protective barrier to reduce freezer burn and oxidation.
- **Grains:** Starches such as rice, pasta, and quinoa also benefit from IQF as the smaller ice crystals prevent these foods from becoming mushy when thawed. Producers of grains such as pastas or rice will blanch or par-cook the grains to stabilize the moisture and enzymes of grains to ensure even freezing and texture.
- **Combined meals:** Pizzas, lasagna, and multi-ingredient meals benefit from rapid freezing as the smaller ice crystals lock down the individual distinct flavors, textures, and colors. Producers of multi-component meals face the challenge of managing the freezing requirements of individual food items—each with its own optimal freezing conditions. They not only address individual ingredient freezing challenges to preserve texture, flavor, and nutritional quality, but also manage how these components interact when frozen together. Strategies include staging the freezing process or using sauces (like a tomato sauce on pasta) to protect components during the rapid freezing process. This special care ensures the final product maintains desired qualities, offering consumers a satisfying and consistent eating experience after reheating.

DON'T GET BURNED

For optimum quality and nutrition, it is essential to follow directions for storing frozen product, to use it within suggested storage times and to follow directions for preparation / cooking to ensure full palatability and sensory qualities.[9]

Frozen foods exposed to air inside the freezer will suffer damage from oxidation and dehydration. The colder the temperature of the air, the lower its moisture-carrying capacity. This dryness in the surrounding air can cause the moisture inside the food to sublimate—change directly from its solid (i.e., frozen) state to its gaseous state and dissipate. The result, called "freezer burn," compromises the color, texture, and flavor of foods.

Freezer burn can even occur in tightly wrapped foods because air with water vapor is exchanged through the layers of packaging in the container. The best ways to avoid freezer burn is to vacuum wrap or tightly seal the food and store it in a container with an airtight seal before freezing.

Food with freezer burn is still safe to eat, although palatability suffers. Rather than throwing the food away, just remove the "burned" portion, and then proceed with your normal preparation.

Freezing and Nutrition

Freezing is like a pause button. Modern freezing helps maximize the nutritional value of frozen foods.

Research consistently shows that freezing produce within hours of harvest preserves its nutrient content.[1] Studies also have shown that freezing maintains the levels of protein, vitamins A and D in meat, seafood, and poultry. In essence, freezing locks in the nutrient value at the point of freezing.[2]

Produce intended for freezing is typically harvested at the peak of ripeness and frozen within hours to lock in flavor, color, and nutritive quality. The journey for ambient temperature produce from the farm to supermarket can take days or weeks. Once in the supermarket, it can be stored for several days longer. During that time, exposure to air, light, and warm temperatures, the amount and quality of nutrients can decline.[3] After purchase, consumers may then store produce in their homes or refrigerators for another week or so prior to eating it. All of this can lead to a significant drop in vitamin content.[4] For example, vegetables generally lose 15-77% of vitamin C a week after harvest; spinach can lose up to 80% of its vitamin C in just three days.[5,6] Studies of a variety of produce types, including strawberries, corn, green beans, green peas, spinach, broccoli, and cauliflower highlight that frozen fruits and vegetables are nutritionally equal to, and in some cases superior to, their fresh-stored counterparts.[7]

Ensuring Quality and Safety

All fruits, vegetables and proteins are in a constant state of degradation from the moment they are harvested, due to enzyme activity, microbiological spoilage organisms, oxidation, and dehydration that drive changes in flavor, texture, color, and a break down nutritional quality.

To ensure high-quality foods, manufacturers carefully manage processes to prevent quality degradation. Rapid freezing is an extremely effective way to manage this degradation.

1. **Managing Enzyme Activity:** Enzyme activity in food can lead to undesirable changes in color, flavor, and nutritional value. To inhibit these enzymes, manufacturers use blanching techniques for vegetables, rice, and pasta, and some fruits before freezing. Blanching involves briefly exposing food to boiling water or steam, which effectively inactivates enzymes. This process not only preserves the food's color, texture, and nutritional content, but stabilizes the product prior to freezing.
2. **Controlling Microbiological Spoilage Organisms:** Microbiological spoilage is a significant concern for food safety and quality. Freezing does not kill microorganisms but halts their growth by making their environment uninhabitable. To ensure safety, foods are processed and handled in clean facilities, and blanching is used to reduce microbial loads. Rigorous hygiene practices and proper handling before and after freezing are crucial to minimize the risk of contamination and spoilage.

3. **Limiting Oxidation:** Oxidation can affect the flavor, color, and nutritional quality of food. To combat this, food producers limit the food's exposure to oxygen, water, and light during processing and packaging. By controlling the environment around the food, manufacturers can significantly reduce degradation due to oxidation, extending the shelf life of the food and reducing food waste.

4. **Preventing Dehydration and Freezer Burn** Freezer burn is a condition that affects the quality of frozen foods, primarily due to dehydration that occurs when food is not properly sealed. It results from air reaching the food's surface, leading to moisture loss and oxidation. The areas affected by freezer burn may appear dry, leathery, and discolored, and while the food remains safe to eat, these changes can impact its texture and flavor negatively. Freezer burn is more likely to occur in food that is stored in the freezer for extended periods and not wrapped and sealed tightly. Preventing freezer burn involves using air-tight packaging materials, using moisture-vapor resistant packaging, adding sauces to protect product surfaces, and ensuring that food is stored at a constant freezing temperature of 0°±5°F.

5. **Food Safety and Facility Operations:** Sanitation forms the backbone of effective food safety and quality management during freezing. Sanitation involves the systematic cleaning and disinfection of equipment, surfaces, and the entire production environment to prevent the contamination of food with pathogens, spoilage organisms, and foreign materials. This is critical not only before the freezing step begins but also throughout the handling and packaging stages to ensure that the food remains safe and of high quality.

   Rigorous sanitation practices ensure that the integrity of the food is maintained from production through to freezing and storage. By minimizing the risk of contamination and spoilage, these practices play a vital role in protecting consumer health and maintaining the organoleptic and nutritional quality of frozen foods.

FRESH OR FROZEN?

Contrary to popular misconceptions, fresh produce is not nutritionally superior to frozen produce. Generally, produce is sorted, cleaned, prepped, and flash-frozen immediately after being picked. Fresh produce, however, can spend days or weeks in cold storage and transit before arriving at the supermarket (as is often the case with potatoes and apples, for example).

Scientific research has verified that frozen produce (broccoli, cauliflower, corn, green beans, green peas, spinach, blueberries, and strawberries) can outperform "ambient-stored" in nutritional value.

At the end of the day, most Americans need to eat MORE fruits and vegetables, regardless of frozen or fresh, and should choose the forms that best fit their schedules, preferences, and price points.

Why Frozen?

In conclusion, freezing uses temperature to preserve food. Attention to detail ensures the safety, nutritional integrity, and sensory qualities of food.

The combination of rapid freezing techniques, packaging, and sanitation is paramount. In the realm of nutrition and food preservation, freezing stands out as the preferred method for maintaining the integrity, nutritional value, and freshness of foods. Freezing foods delivers year-round quality and availability, and evidence supports that frozen food is equal in nutrition to fresh and local food.[8] Furthermore, once a food is frozen, it stays preserved and safe for a long time, minimizing consumers' food waste and extending their food dollar. Freezing is a natural, efficient way to preserve food, making it an essential tool in the consumers arsenal for promoting a nutritious, wholesome diet.

CAN ANY FOOD BE FROZEN?

Almost any food can be frozen. But the challenge is ensuring its food quality remains. Foods with extremely high levels of water (95%+) such as lettuce, whole tomatoes, mushrooms, or whole eggs (in shell) do not freeze well.

FROZEN IS THE NEW GREEN

With sustainability high on the list of consumer demands these days, a significant advantage of freezing foods is the reduction of food loss and waste. This is not only an advantage in production and distribution but carries through to the supermarket and at home.

A recent survey by MITRE-Gallup,[10] "The State of Food Waste in America by the Numbers" disclosed that:

The average household wastes an average of 6.2 cups of food per week, or 322 cups per year—enough to fill 360 medium-sized take-out containers.

87% of households reported wasting edible food the prior week.

Despite 81% of households citing price as the top food-related issue, only 33% are aware the average American household could save at least $1,500 per year by eliminating food waste, and almost half (49%) underestimate potential cost savings.

More than 8 in 10 shoppers agree that buying frozen food helps them limit the amount of food wasted at home thanks to the longer shelf life and ability to portion what they need.[11]

References

1. Linshan Li, Ronald B. Pegg, Ronald R. Eitenmiller, Ji-Yeon Chun, Adrian L. Kerrihard, Selected nutrient analyses of fresh, fresh-stored, and frozen fruits and vegetables, Journal of Food Composition and Analysis, Volume 59, 2017. ISSN 0889-1575, https://doi.org/10.1016/j.jfca.2017.02.002.

2. D.P. Attrey, Chapter 44 - Safety and quality of frozen foods, Editor(s): Rajul Kumar Gupta, Dudeja, Singh Minhas, Food Safety in the 21st Century, Academic Press,2017, Pages 527-539, ISBN 9780128017739, https://doi.org/10.1016/B978-0-12-801773-9.00044-3.

3. Neri, L.; Faieta, M.; Di Mattia, C.; Sacchetti, G.; Mastrocola, D.; Pittia, P. Antioxidant Activity in Frozen Plant Foods: Effect of Cryoprotectants, Freezing Process and Frozen Storage. Foods 2020, 9, 1886. https://doi.org/10.3390/foods9121886.

4. Elhadi M. Yahia, Armando Carrillo-Lopez. Postharvest Physiology and Biochemistry of Fruits and Vegetables. Woodhead Publishing; 1st edition. 1st Edition, 2018. eBook ISBN: 9780128132791.

5. Rickman, Joy C., Diane M. Barrett, and Christine M. Bruhn. "Nutritional comparison of fresh, frozen and canned fruits and vegetables. Part 1. Vitamins C and B and phenolic compounds." *Journal of the Science of Food and Agriculture* 87.6 (2007): 930-944.

6. Rickman, Joy C., Christine M. Bruhn, and Diane M. Barrett. "Nutritional comparison of fresh, frozen, and canned fruits and vegetables II. Vitamin A and carotenoids, vitamin E, minerals and fiber." *Journal of the Science of Food and Agriculture* 87.7 (2007): 1185-1196.

7. Bouzari A, Holstege D, Barrett DM. Vitamin retention in eight fruits and vegetables: a comparison of refrigerated and frozen storage. J Agric Food Chem. 2015 Jan 28;63(3):957-62. doi: 10.1021/jf5058793. Epub 2015 Jan 13. PMID: 25526594.

8. Graham, A., Bonwick., Catherine, S., Birch. (2013). Antioxidants in fresh and frozen fruit and vegetables: Impact study of varying storage conditions.

9. Stephen J. James, Christian James, Chapter 23 - Chilling and Freezing, Editor(s): Veslemøy Andersen, Huub Lelieveld, Yasmine Motarjemi, Food Safety Management (Second Edition), Academic Press, 2023, Pages 453-474, ISBN 9780128200131, https://doi.org/10.1016/B978-0-12-820013-1.00005-X.

10. MITRE-Gallup Survey Finds U.S. Households Waste 6.2 Cups of Edible Food Every Week on Average https://www.mitre.org/news-insights/news-release/mitre-gallup-survey-finds-us-households-waste-62-cups-edible-food-every#:~:text=

    Hammad H., Ma M., Damaka A., Elkhedir A., Jin G. Effect of freeze and re-freeze on chemical composition of beef and poultry meat at storage period 4.5 months (SP4. 5) J. Food Process. Technol. 2019;10:2. [Google Scholar]

    Dang DS, Bastarrachea LJ, Martini S, Matarneh SK. Crystallization Behavior and Quality of Frozen Meat. Foods. 2021 Nov 5;10(11):2707. doi: 10.3390/foods10112707. PMID: 34828989; PMCID: PMC8620417.

11. "Freezing Prepared Foods," PM 799, Iowa State University Cooperative Extension Service, September 1977 https://frozenadvantage.org/wp-content/uploads/2023/05/Consumer-Food-Waste-Survey.pdf

AFFI AMERICAN FROZEN FOOD INSTITUTE

The American Frozen Food Institute (AFFI) represents America's frozen food and beverage makers. Our members are farmers, fruit and vegetable growers, makers of prepared meals, suppliers and distributors that provide over 670,000 American jobs.

www.affi.org