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Neelesh Kumar Maurya *

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Review Article

Nutrient Loss During Food Preservation

Neelesh Kumar Maurya [1]*, Bhawini [2], Riya Chauhan [3], Anshu Thapa [3], Diana Gao Nino [3]

[1]Assistant Professor, Department of Nutrition and Dietetics, School of Allied Health Science, Sharda University, Greater Noida, U.P, India.

[2]M. Sc Students, Department of Nutrition and Dietetics, School of Allied Health Science, Sharda University, Greater Noida, U.P, India.

[3]B. Sc Students, Department of Nutrition and Dietetics, School of Allied Health Science, Sharda University, Greater Noida, U.P, India.

Corresponding author: Neelesh Kumar Maurya, Assistant Professor, Department of Nutrition and Dietetics, School of Allied Health Science, Sharda University, Greater Noida, U.P, India.

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Abstract:

Food preservation techniques are essential in supporting global food security by extending the shelf life of perishable products, reducing waste, and ensuring year-round availability. However, these processes can result in the degradation of essential nutrients, affecting the nutritional quality of preserved foods. This chapter explores the dynamics of nutrient loss during food preservation and highlights the varying impacts of common methods such as canning, freezing, drying, pasteurization, fermentation, and pickling. Nutrient loss occurs due to thermal exposure, oxidation, light sensitivity, water leaching, and prolonged storage, particularly impacting vitamins, minerals, proteins, and fats. Heat-sensitive nutrients like Vitamin C and B-vitamins are significantly diminished during high-temperature treatments, while fat oxidation compromises the integrity of unsaturated fats. Although minerals are more stable, they can still leach into water during blanching or cooking processes. Freezing retains most nutrients but may cause minor losses during pre-freezing steps like blanching. Strategies to minimize these losses include improving processing temperature and time, using light-blocking and oxygen-reducing packaging, and employing antioxidants. Packaging innovations and less invasive techniques such as vacuum sealing and cold preservation are becoming increasingly vital in protecting nutrient integrity. This chapter also evaluates comparative data across preservation methods and food types, revealing that nutrient retention varies widely based on the method used and the specific nutrient in question. By understanding the mechanisms of nutrient degradation and implementing evidence-based preservation strategies, food scientists and producers can better ensure the nutritional quality of preserved foods. Ultimately, this chapter underscores the importance of developing balanced preservation systems that prioritize both shelf life and nutritional value to support long-term health and food sustainability.

Key words: nutrient degradation; food preservation; vitamin loss; oxidation; canning freezing; nutritional retention

Introduction

Food preservation is essential for prolonging the shelf life of perishable food items and maintaining food security worldwide. With global populations rising and agricultural practices facing challenges like climate change, food preservation methods have become increasingly critical. They help reduce food waste, ensure a stable food supply, and prevent the loss of essential nutrients due to spoilage or contamination [1]. The various techniques employed for food preservation include refrigeration, freezing, canning, drying, fermentation, and the use of preservatives. Each of these methods contributes to extending the usability of food by slowing down spoilage, inhibiting microbial growth, and preventing the oxidation of fats and vitamins. However, while these methods are invaluable for keeping food safe and available, they may inadvertently lead to nutrient loss, affecting the nutritional quality of preserved foods. In the context of modern food systems, the importance of preserving food goes beyond just keeping it edible. It is an essential part of the global effort to mitigate food insecurity, particularly in regions where fresh food is not readily available year-round. This is especially crucial for providing essential nutrients to populations that rely on preserved foods as their primary source of nutrition. Despite the many benefits of food preservation, the unintended loss of nutrients during these processes can be a significant challenge. In particular, the effects on vitamins, minerals, proteins, fats, and carbohydrates are of concern. Understanding how these preservation processes impact nutrient retention and developing methods to reduce nutrient degradation is critical to maximizing the health benefits of preserved foods [2-4].

Nutrient Loss in Preservation Processes

The preservation of food inevitably involves alterations to its composition, and nutrient loss is one such consequence. Each preservation method affects different nutrients to varying degrees, and the

impact can be both immediate and cumulative. Nutrient loss occurs due to physical, chemical, and biological changes that take place during processing, storage, and handling [6,7]. For instance, thermal treatments like pasteurization and canning are known to cause significant losses of sensitive vitamins, especially those that are water-soluble, such as Vitamin C and the B-vitamins. These vitamins are highly susceptible to heat and can degrade quickly when exposed to high temperatures, reducing the nutritional value of the preserved food. On the other hand, some preservation techniques, such as freezing or drying, have a less pronounced impact on nutrient levels. Freezing, for example, preserves most vitamins and minerals, though it can still cause some degradation, particularly in vegetables that are blanched before freezing. Drying, while effective at prolonging shelf life, can lead to losses of vitamins, especially Vitamin A and B-vitamins, due to the elevated temperatures used in the drying process. Additionally, dehydration can also reduce the bioavailability of certain minerals by altering the food's chemical structure [8-10].

2.Types of Nutrients Affected by Preservation

The nutrients most commonly affected by preservation processes include vitamins, minerals, proteins, fats, and carbohydrates. Each of these macronutrients and micronutrients plays a crucial role in maintaining human health, and their degradation during food preservation can undermine the nutritional quality of the food [8-12].

Vitamins: Water-soluble vitamins, such as Vitamin C, Vitamin B1 (thiamine), Vitamin B2 (riboflavin), Vitamin B6, and folic acid, are particularly vulnerable to nutrient loss during food preservation. These vitamins are sensitive to heat, light, and oxygen, and are often lost during processes such as blanching, boiling, canning, and pasteurization. Fat-soluble vitamins, like Vitamin A, D, E, and K, tend to be more stable during preservation processes, but they can still degrade if exposed to extreme heat or prolonged light exposure [8,10-13].

Minerals: Unlike vitamins, minerals are relatively stable during food preservation, but they can be lost in the water during cooking or canning, particularly when the food is immersed in water. For example, when vegetables are blanched before freezing, minerals like potassium and magnesium may leach into the water and be discarded. Additionally, the processing of grains and legumes can reduce the mineral content by removing the outer layers, which contain many of the minerals [12-14].

Proteins: Proteins, being made up of long chains of amino acids, are generally more stable during food preservation compared to vitamins. However, certain methods like drying or high-heat cooking can cause protein denaturation, where the protein structure is altered, leading to changes in texture and reduced digestibility. Freezing may also lead to some loss of protein quality as it can cause the formation of ice crystals that break down the cell structure, leading to a slight reduction in the protein content [15-16].

Fats: The preservation process can have a significant impact on the fat content of food, particularly when it comes to the oxidation of unsaturated fats. Oxidation is the process by which fats react with oxygen, leading to the formation of rancid compounds, which not only degrade the quality of the fat but also reduce its nutritional value. Preservation methods that involve high temperatures, such as deep-frying, can accelerate fat oxidation. On the other hand, freezing can help preserve fats by slowing down oxidation, but some loss may still occur over time, especially if the food is not stored properly [17].

Carbohydrates: Carbohydrates, being the most stable macronutrient during preservation, are generally less affected by preservation processes. However, some methods like drying and fermentation can alter the carbohydrate composition, particularly in grains, fruits, and vegetables. During fermentation, some sugars are converted into alcohol or lactic acid, reducing the overall carbohydrate content. Additionally, certain processing methods may cause a loss of dietary fiber, which is an important component of carbohydrates in many foods [15-19].

3. Factors Influencing Nutrient Loss During Preservation

Food preservation is essential for extending self-life, ensuring food safety, and maintaining supply chains. However, the methods used to preserve food can significantly impact its nutritional value. Several factors influence nutrient retention or loss during preservation and understanding them is crucial to optimizing processing techniques for better health outcomes. Among these factors, temperature, exposure to light, oxygen, duration of preservation, and water involvement play significant roles in determining the extent of nutrient degradation [20-21].

Temperature is one of the most critical determinants in nutrient stability during food preservation. High heat used in methods such as canning, sterilization, drying, or pasteurization can degrade heat-sensitive nutrients, particularly vitamin C and several B-complex vitamins like thiamine and folate. These nutrients are thermolabile, meaning they break down rapidly at elevated temperatures. For example, vitamin C (ascorbic acid) is particularly unstable and can be lost in significant amounts during thermal processing, sometimes as much as 50–80%. Similarly, thiamine and riboflavin experience notable degradation in cooked or heat-preserved foods. In contrast, other nutrients, such as some minerals or fat-soluble vitamins like vitamin A and D, may be more heat-stable but can still suffer from structural changes when exposed to high temperatures for prolonged periods. Thus, careful temperature control and the use of alternative methods like cold preservation or minimal processing can help mitigate these losses [1,3, 20-21].

Exposure to light, particularly ultraviolet (UV) and visible light, is another potent factor contributing to nutrient degradation. Some nutrients are photolabile, breaking down or losing their effectiveness when exposed to light. For instance, vitamin A, vitamin D, and certain B vitamins (e.g., riboflavin) are highly sensitive to light and can degrade during storage if not properly shielded. This issue is especially relevant in the storage of milk, oils, and other packaged foods in transparent containers. Riboflavin degradation under light can occur within hours, reducing the vitamin's bioavailability. Moreover, degradation often leads to the development of off-flavors and undesirable changes in color, affecting not just the nutritional quality but also consumer acceptance. Packaging technologies such as the use of opaque or UV-blocking containers have been developed to counteract this effect and are commonly applied in the dairy and beverage industries [20-21].

Oxygen, while essential for life, poses a significant threat to food nutrients when it acts as a catalyst in oxidation reactions. Oxidative degradation can affect both lipids and vitamins, particularly fatty acids, vitamin C, and vitamin E. Lipid oxidation leads to rancidity, producing off-odors and potentially harmful compounds, while vitamin oxidation renders the nutrients biologically inactive. For instance, vitamin C oxidizes to dehydroascorbic acid, which eventually becomes inactive and is lost from the food matrix. Similarly, vitamin E, a natural antioxidant, also deteriorates in the presence of oxygen, especially when combined with

light or heat exposure. Preservation techniques that minimize oxygen exposure—such as vacuum sealing, modified atmosphere packaging (MAP), or inert gas flushing—are thus essential to maintain the stability of oxygen-sensitive nutrients during storage and distribution [20-21].

Time is another crucial variable that affects nutrient retention. The longer food is exposed to preservation environments—whether thermal, oxidative, or involving light or water—the greater the potential for nutrient degradation. Time interacts synergistically with other factors; for example, the duration of heat application or length of oxygen exposure significantly magnifies nutrient loss. Nutritional decline is not always immediate but can occur gradually over time, especially in stored foods. Even refrigerated or frozen items experience some loss of labile vitamins over extended storage periods. Research has shown that vitamin C can continue to degrade in frozen vegetables over time, albeit at a slower rate compared to fresh or thermally preserved items. Therefore, reducing preservation time, or limiting storage duration post-processing, is key to preserving the maximum nutrient content [20-21].

Water, particularly in processes involving washing, soaking, blanching, or boiling, can lead to the leaching of water-soluble nutrients, notably vitamin C, B vitamins, and certain minerals like potassium and magnesium. Water-soluble vitamins are highly susceptible to being washed away during rinsing or cooking in large volumes of water. Blanching, a common step before freezing vegetables, often results in a 10–40% loss of vitamin C, depending on time and temperature. Similarly, boiling vegetables without retaining the cooking water can significantly reduce the final nutrient intake. To mitigate water-related nutrient losses, methods like steaming, pressure cooking, or microwave processing are preferred since they reduce direct water contact and minimize leaching. Additionally, reuse of cooking water in soups or stews can help conserve the nutrients that dissolve into the water phase [20-21].

4. Common Preservation Methods and Their Impact on Nutrients

Food preservation plays a vital role in extending the shelf life of produce, ensuring nutritional value, and enhancing food safety. Different preservation methods affect the nutritional content of foods in varying degrees. Below are some common preservation techniques and their impact on nutrients, along with solutions to minimize nutrient loss [22].

Canning: Canning involves heating food in airtight containers to destroy microorganisms and prevent spoilage. This process generally entails placing food in jars or cans, followed by heating to high temperatures, which eliminates bacteria, yeasts, and molds that could cause spoilage. However, the high temperatures used in canning have an impact on the nutritional content of the food [22].

Nutrients Affected: Heat-sensitive nutrients such as Vitamin C, B vitamins (especially B1, B6, and folate), and some antioxidants are particularly vulnerable to degradation during the canning process. Vitamin C, being water-soluble, leaches into the canning liquid, causing substantial losses. Folate, another water-soluble vitamin, is also affected by heat, as are several B vitamins, which are essential for energy metabolism and nervous system function [20-23].

Solutions to Minimize Loss: To reduce nutrient loss during canning, it is crucial to minimize the exposure to excessive heat. Using lower temperatures and shorter heating times can help preserve more nutrients. Additionally, storing canned goods in a cool, dark place away from light and heat will help prevent the degradation of nutrients, such as vitamin C, which is sensitive to light exposure [22,23].

Freezing: Freezing is one of the most widely used preservation methods, primarily because it inhibits microbial growth while maintaining the texture, flavor, and nutritional value of many foods. The process involves lowering the temperature to below freezing (usually around -18°C or lower), which prevents the growth of bacteria, molds, and yeasts. However, the freezing process can lead to some nutrient loss, especially during the preparation phase [23,26]

Solutions to Minimize Loss: Using lower temperatures and shorter drying times can help retain more of the nutrients in the food. Additionally, protecting dried foods from light and oxygen during storage is critical to prevent further nutrient degradation. Vacuum-sealing dried foods or storing them in airtight containers can minimize their exposure to air and light, preserving their nutritional value for longer periods [23,26].

Fermentation: Fermentation is a preservation method that uses microorganisms—such as bacteria, yeast, and molds—to ferment food and enhance its shelf life. The process not only helps preserve food but also adds beneficial probiotics, which promote gut health. Common examples of fermented foods include sauerkraut, kimchi, and yogurt. While fermentation can have positive effects on the nutritional profile of food, it also causes some nutrient loss.

Nutrients Affected: Fermentation can have mixed effects on nutrients. Some B vitamins, such as B12 and folate, may be synthesized by the microorganisms during fermentation, enhancing the nutritional value of the food. However, there is some loss of vitamins A and C during the early stages of fermentation, as heat and microbial activity can degrade these nutrients. Despite this, the overall health benefits of fermented foods, such as the increased bioavailability of certain nutrients, outweigh the nutrient losses.

Solutions to Minimize Loss: To minimize nutrient loss during fermentation, it is important to maintain controlled conditions, such as appropriate temperature and humidity, to ensure optimal fermentation. Using starter cultures with high probiotic production can also improve nutrient retention. Careful monitoring of fermentation time can further help preserve the integrity of vitamins, particularly in the early stages when the food is most vulnerable.

Pickling: Pickling is another preservation method in which food is stored in a vinegar or salt solution. The high acidity of the solution creates an inhospitable environment for harmful microorganisms, thereby preserving the food for longer periods. Pickling is often used for vegetables, fruits, and even meats. However, the pickling process can lead to some loss of nutrients [22-27].

5. Strategies to Minimize Nutrient Loss

To mitigate the loss of nutrients during food preservation, several strategies can be employed to optimize processing conditions and preserve the nutritional integrity of foods.

Optimizing Preservation Conditions: One of the most effective strategies for minimizing nutrient loss is to control the key factors of preservation, namely temperature, time, and light exposure. By reducing the temperature and processing time during preservation, the degradation of heat-sensitive vitamins like Vitamin C and the oxidation of fats can be

minimized. Moreover, reducing the exposure of foods to light and air during storage and processing helps protect against nutrient degradation, particularly for vitamins and fats. For example, vacuum sealing or using airtight containers can significantly reduce oxygen exposure, helping to preserve both fat-soluble and water-soluble nutrients [25-30].

Use of Antioxidants: The addition of natural preservatives such as ascorbic acid (Vitamin C) can help prevent oxidation during preservation, particularly for sensitive nutrients like Vitamin C and fats. Antioxidants inhibit the oxidative processes that lead to the destruction of vitamins and the rancidity of fats. Natural antioxidants, such as rosemary extract or ascorbic acid, can be added to food during the preservation process to help maintain their nutritional content. This strategy is particularly beneficial for extending the shelf life of foods that undergo drying, canning, or freezing, where oxidation is a primary concern [21,25-30].

Minimizing Water Usage: Reducing the amount of water used in food processing is an important strategy for preserving water-soluble nutrients like B vitamins and Vitamin C. Water leaching is one of the major causes of nutrient loss during food preparation and processing. To minimize this, blanching and washing times should be kept to a minimum, and steaming or microwaving can be used as alternatives to boiling. Additionally, using less water in cooking processes ensures that fewer nutrients are lost, as these vitamins are less likely to leach into the cooking liquid [22.27-30].

Packaging Innovations: Innovative packaging technologies, such as vacuum sealing and airtight packaging, can significantly reduce the exposure of food to oxygen and light, two factors that contribute to the degradation of vitamins and fats. Vacuum sealing, in particular, is highly effective at preventing oxidation and maintaining the quality of fats and vitamins during storage. Moreover, the use of opaque or dark-colored packaging can protect light-sensitive nutrients like Vitamin A from degradation. By combining optimal packaging with temperature control, food preservation can be significantly improved, leading to a more nutrient-dense final product [28-30].

Preservation Method	Nutrient(s) Affected	Key Findings	Reference
Canning	Vitamin C, B Vitamins	Significant loss of Vitamin C and B vitamins due to heat and water exposure. Vitamin A also deteriorates.	10-13
Freezing	Vitamin C, B Vitamins	Freezing helps preserve most vitamins, but some, like Vitamin C, can degrade slightly over time.	12-14
Drying	Vitamin C, B Vitamins, Fats	Loss of water-soluble vitamins, including Vitamin C and B vitamins, and potential fat oxidation leading to rancidity.	8,9
Blanching	Vitamin C, B Vitamins	Some loss of Vitamin C and B vitamins, though less than in boiling. It is less severe if blanching times are short.	20,21
Fermentation	Vitamin C, B Vitamins	Fermentation generally retains most nutrients, but Vitamin C may be degraded in some fermenting environments.	23
Vacuum Sealing	Fats, Water-soluble Vitamins	Preserves nutrients effectively by reducing oxygen exposure, which helps in minimizing oxidation of fats and vitamins.	31
Pickling	Vitamin C, B Vitamins	Retains most nutrients, but Vitamin C can be lost during the pickling process, especially when exposed to heat.	32

Table 1: Nutrient Loss in Common Food Preservation Methods

Institutional Study Board Statement

Not applicable.

Informed Consent Statement

Not applicable.

Conflicts of Interest

The authors declare no conflicts of interest.

6. Conclusion

Food preservation methods play a crucial role in extending the shelf life of perishable items and reducing food waste, making them an essential part of the modern food system. However, despite their benefits, these methods can lead to significant nutrient loss, especially for sensitive vitamins, minerals, proteins, and fats. The degradation of nutrients during preservation can impact on the nutritional quality of the food and, consequently, its health benefits. Understanding the effects of various preservation techniques, such as heat, drying, freezing, and canning, is key to developing strategies that minimize nutrient degradation. By optimizing factors such as temperature, time, water usage, and light exposure, and by employing antioxidants and innovative packaging, it is possible to mitigate nutrient losses and preserve the food's nutritional integrity. Moreover, ongoing research into new and improved preservation methods holds promise for further minimizing nutrient loss. Advancements in food science may lead to the development of more efficient techniques that retain the nutritional content of preserved foods, thereby improving the overall quality and healthfulness of preserved food products. As such, balancing the need for effective preservation with the desire to maintain food's nutritional value is essential in shaping the future of food preservation.

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