AgriCos e-Newsletter
ISSN: 2582-7049
AgriCos e-Newsletter
Open Access Multidisciplinary Monthly Online Magazine
Volume: 06 Issue: 01 January 2025 Article No: 23

Minimal Processing in Food: A Key to Healthier Choices

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SUMMARY

The growing consumer demand for minimally processed foods, which retain their natural nutritional and sensory qualities, has spurred innovation in food processing technologies. This trend is driven by the need for products with high nutritional value, freshness, safety, and extended shelf life, without the use of synthetic additives. To address these challenges, the food industry has adopted minimal processing techniques, including thermal and non-thermal methods, mild preservation technologies, and natural antimicrobials. These techniques aim to preserve food quality while ensuring microbiological safety and convenience. Non-thermal processing methods such as high hydrostatic pressure (HPP), pulsed electric fields (PEF), and natural antimicrobials are particularly effective in maintaining the freshness, flavor, and texture of food products, including fruits, vegetables, meats, and seafood. HPP, for instance, uses high pressure to inactivate microorganisms and enzymes without affecting the sensory and nutritional properties of food. Additionally, natural antimicrobials, derived from plant, animal, and microbial sources, provide safe and effective alternatives to synthetic preservatives. While minimal processing techniques offer significant advantages in preserving the quality of food, careful consideration of factors like temperature, storage conditions, and microbial resistance is necessary to optimize food safety and shelf life. Overall, the implementation of minimal processing methods meets consumer demand for convenient, nutritious, and safe food products.

INTRODUCTION

Over recent decades, there has been an increasing demand among consumers for foods that retain their natural nutritional qualities and sensory properties, such as flavor, aroma, texture, and taste (Huxley et al., 2004). Fresh fruits and vegetables serve as prime examples of convenient and natural food options. This rising preference for minimally processed foods with little to no synthetic additives presents significant challenges for food technologists (Siddiqui et al., 2011). Moreover, there is a growing interest in functional foods aimed at disease prevention and management (Monteiro et al., 2011). These evolving consumer expectations have driven the development of minimally processed, safe food products using innovative techniques (Gilbert, 2000). However, achieving this goal while ensuring an adequate shelf-life remains a complex task. Minimally processed foods can be preserved safely using partial or limited preservation methods, which help minimize changes to their quality (Ohlsson, 1996). As a result, the fresh-cut fruit and vegetable industry is continuously innovating a variety of minimally processed products to cater to consumer demands (Ragaert et al., 2004). Minimal processing has been shown to have a limited impact on quality attributes during storage or shelf life (Allende et al., 2006; HuisIn't Veld,1996; Marechal et al., 1999). In the food industry, the term "mild technologies" is often used to describe processes that cause minimal physicochemical, oxidative, or mechanical damage to food products. The primary goals of minimal processing include: (i) ensuring food is chemically and microbiologically safe, (ii) preserving the desired flavor, color, and texture, and (iii) offering convenience to consumers.

Purposes of Minimal Processing

Minimally processed foods involve essential pre-processing steps like sorting, washing, peeling, and slicing, often followed by value-added techniques such as chopping, husking, coring, low-level irradiation, and individual packaging. These processes aim to retain quality attributes similar to fresh products (e.g., fruits and vegetables) or their intended consumption state (e.g., sous-vide, ready-meals). The methods minimize quality changes while ensuring sufficient shelf life for transport from production to consumers. The primary goal is to simplify and speed up meal preparation. Key benefits include:

- Convenience through quick and easy meal preparation.
- Use of mild, multi-hurdle preservation techniques.

- Retention of fresh-like quality.
- Preservation of nutritional value.
- Flexibility in shelf life based on preservation intensity.

(Dharmabandu et al., 2007; Monteiro et al., 2010; Ohlsson & Bengtsson, 2002).

Applications of Minimal Processing

1. Plant Based Minimally Processed Foods: Fresh Fruits and Vegetables

Minimal processing can be categorized into plant-based products (e.g., fruits and vegetables) and animal-based products (e.g., meat and seafood), with emerging combinations like ready-meals and cook-chill products. Fruits and vegetables, composed of delicate tissues, require careful handling to prevent damage, microbial contamination, and spoilage. Key factors like enzymes (e.g., polyphenol oxidase, polygalacturonase) and high-water activity make them prone to microbial growth, especially at pH levels above 6, where bacteria, yeast, and molds thrive (González-Aguilar et al., 2010).

To maintain quality and extend shelf life, processing must adhere to the following guidelines:

- Use appropriate cultivars and ensure proper pre- and post-harvest handling.
- Follow HACCP protocols and maintain hygiene.
- Process at low temperatures (4–7 °C) and prevent heat abuse to minimize oxidation and browning.
- Wash with mild acids and flowing water.
- Tenderly cut, peel, and shred.
- Keep pH ≤ 5 and use vacuum packaging for storage and distribution.

These measures ensure freshness, minimize spoilage, and maintain product safety.

2. Animal Based Minimal Processed Foods: Meat and Sea Foods

Non-thermal processing techniques such as high hydrostatic pressure, pulsed electric fields (PEF), oscillating magnetic fields, irradiation, and natural antimicrobials are increasingly used for animal-based foods like tender meat, fish, and seafood. These methods effectively preserve texture, flavor, and taste while minimizing damage to delicate tissues. Seafood, being highly susceptible to microbial contamination, benefits significantly from a combination of minimal processing methods, which inactivate microbes while retaining nutritional quality. The quality of animal-based foods depends on consumer-preferred attributes like flavor, taste, color, and aroma. Spoilage often occurs due to protein denaturation, leading to structural dissociation, aggregation, and gelation (Cheftel, 1995). Denaturation is influenced by external factors such as temperature and internal factors like pH and enzymes. While spores are resistant to hydrostatic pressure alone, combining thermal and non-thermal methods with refrigeration offers an effective preservation strategy. High hydrostatic pressure has shown success in maintaining the surface properties, texture, and appearance of fish and meat within acceptable limits.

Impact of Minimal Processing on Nutrition Contents

Beyond sensory attributes, the nutritional value and health-functional components significantly influence the quality of food products. These factors are affected by climatic conditions, harvesting practices, and the specific processing methods employed, such as cutting, shaping, packaging, and operational speeds like churning, cooling, and mixing. The functionality of processed products is primarily determined by their bioactive compounds and antioxidant properties. Post-processing, packaging techniques play a critical role in maintaining quality. Modified atmosphere packaging, with carefully controlled carbon dioxide and oxygen levels, helps prevent undesirable changes in the product (Goswami & Mangaraj, 2011).

Concept of Hurdle Technology

The multi-hurdle approach is an effective and reliable method for controlling microbial growth while minimizing food quality loss. This technique combines preservation methods to ensure food safety (Leistner, 2000). For example, pairing pasteurization with blanching can eliminate microorganisms, while refrigeration slows chemical reactions. Additional hurdles include reducing water activity and lowering pH, achieved by adding agents like glucose, fructose, salts, or acids (e.g., citric, tartaric, or benzoic acid). Preservatives such as sorbates, propionates, and sodium benzoate also inhibit pathogen growth. This combined approach enhances treatment efficiency, maintains product quality, and reduces costs in terms of energy, time, and money. It has shown success in preserving foods like sliced apples, mangoes, banana puree, plums, strawberries, tamarind, and passion fruit.

Fresh-Cut Fruits and Vegetables

1 Washing, Peeling, and Slicing of Fresh-Cut Fruits and Vegetables

The appearance, taste, color, and texture of fresh-cut fruits and vegetables are highly appealing to consumers. These products are in high demand in Europe and North America due to their advantages: (1) convenience, (2) availability in various portion sizes, (3) reduced preparation effort, and (4) retention of nutrients and fresh aroma. These factors drive the rapid growth of the fresh-cut industry globally. Fresh-cut fruits and vegetables must be stored at 0–5 °C to maintain quality. Traditional preservation methods like canning, drying, and steaming have limited impact on extending their shelf life (Kader & Mitcham, 1995; Beaulieu & Gorny, 2001). Common challenges include desiccation, microbial spoilage, browning, discoloration, and off-flavors, which are key factors consumers consider before purchasing. Processing steps such as washing, peeling, cutting, and shredding can damage tissues, leading to wilting, microbial growth, and enzymatic spoilage. These injuries accelerate respiration, ethylene production, senescence, and browning, further impacting product quality.

2. Operations Affecting the Quality of Fresh-Cut Fruits and Vegetables

Processing fresh produce is essential for creating high-quality products (Siddiqui et al., 2011) and involves the following steps:

Sorting: Sorting separates acceptable from defective produce, removing physiological flaws. Manual sorting often delivers superior results compared to machine sorting, as it can better detect minor defects.

Peeling: Commonly performed for fruits like apples and citrus or vegetables like carrots and onions, peeling significantly impacts final product quality (Cantos et al., 2001). Hand peeling produces higher quality results but is labor-intensive, whereas abrasive peelers, though efficient, may cause surface scarring or damage edible portions.

Cutting: Removing unwanted parts like seeds and stems is essential before further processing. Poorly maintained tools can compromise quality, so cutting tools must be clean and well-maintained. Overripe or contaminated areas should also be removed during sorting to prevent microbial growth and contamination.

3. Factors Affecting the Washing of Fresh-Cut Fruits and Vegetables

Washing is a critical step in processing minimally processed fruits and vegetables, requiring attention to several factors:

Washing: Fresh-cut produce must be washed promptly after cutting to remove dirt and surface microbes. Chlorinated water is commonly used, with contact time, pH, and water temperature playing crucial roles in maintaining quality (Sapers, 2003).

Contact Time: Adequate contact time is essential for effective cleaning. Chilled water is typically used, which also helps cool the produce before packaging.

Temperature: Maintaining water temperature near 0 °C is vital to prevent spoilage during this initial step.

Chlorination: Chlorine concentration should be kept between 50–100 ppm to ensure effective cleaning without compromising quality. Chlorine levels must be monitored using appropriate testing kits.

pH: The water's pH must remain below 7.5 to sustain the antibacterial effect of chlorinated water, as higher pH levels reduce its efficacy and risk microbial growth.

Minimal Processing Techniques

Minimally processed foods are commonly treated using thermal methods, non-thermal treatments, low-temperature storage, advanced packaging, and natural antimicrobials, either individually or in combination.

1. Thermal Methods: Thermal treatments can deactivate harmful organisms and enzymes while enhancing aroma and flavor. However, excessive heat may degrade sensitive nutrients like vitamins and health compounds (Bansal et al., 2014). Proper heat treatment, such as High Temperature Short Time (HTST), can ensure food safety and nutrient retention.

2. Coupling with Non-thermal Methods: Non-thermal processing techniques are gaining popularity in the food industry for their ability to preserve foods while maintaining nutritional and sensory qualities. These methods, including high hydrostatic pressure, pulsed electric fields (PEF), high-intensity pulsed light, ultrasonic waves, and irradiation, offer reliable alternatives for processing liquid foods (e.g., beverages, juices) and solid foods (e.g., fruits, vegetables, packaged products). PEF and high hydrostatic pressure are particularly noted for inactivating harmful microorganisms and enzymes, while also being used to extract bioactive compounds like polyphenols and flavonoids. These methods typically keep the processing temperature between 30–55 °C, preserving heat-sensitive components like vitamin C and carotenoids.

Pulsed Electric Fields (PEF): Introduced in the 1960s, PEF uses a high voltage electric field (20–70 kV/cm) applied for microseconds to treat food. Initially used to kill microorganisms, it was later adapted to enhance mass transfer and preserve nutritional content. While PEF effectively inactivates vegetative bacteria, it is less effective against spores at ambient temperatures (Yousef & Zhang, 2006; Park et al., 2014). Recent studies have explored its potential for enhancing the shelf life and quality of fruit juices and even meat products. For instance, O'Dowd et al. (2013) found that while PEF treatments affected beef muscle's weight loss and myofibril size, they did not significantly impact its texture profile.

High Pressure Processing (HPP), also known as high hydrostatic pressure or ultra-high pressure processing, involves applying pressures up to 600 MPa, with or without external heat (up to 120°C), to inactivate microorganisms and enzymes while preserving flavor compounds and vitamins (Park et al., 2014). This method works by exerting pressure that disrupts microbial membranes, preventing them from becoming active (Toepfl et al., 2006). The effectiveness of HPP depends on factors such as pressure, temperature, treatment duration, and the type of microbes. HPP is used for products like jams, sauces, juices, and dairy items (Pasha et al., 2014).

HPP also affects food texture and can cause protein denaturation, aggregation, or gelation. It has been found to inactivate microbial cells and prevent enzymatic browning in fresh-cut fruits and vegetables without compromising their nutritional and sensory qualities. Enzymes like polyphenol oxidase (PPO), peroxidase (POD), and pectin methylesterase (PME) are more resistant to HPP, while enzymes such as polygalacturonase (PG) and lipoxygenase (LOX) are more sensitive and can be significantly inactivated. Interestingly, retaining certain enzymes like PME can enhance the texture and quality of processed products, offering advantages over thermal processing (Terefe et al., 2014).

Natural antimicrobials are gaining popularity as consumers and producers seek safer, effective preservatives over synthetic alternatives. Many countries, especially in Europe and Asia, are turning to natural ingredients to prevent food spoilage. These antimicrobials, derived from animal, plant, and microbial sources, often come from bioactive secondary metabolites found in plants, which are effective alternatives to synthetic additives (Silva-Espinoza et al., 2013; Ortega-Ramirez et al., 2014). Their antimicrobial and antioxidant properties stem from their redox properties, ability to chelate metals, and ability to neutralize reactive oxygen species (Krishnaiah et al., 2011).

These compounds can be applied to various food products, including beverages, sauces, meats (like pork), and fish, to prevent spoilage. They can be coated or sprayed for quick absorption. Maintaining the sensory qualities of food is crucial when using these additives (Skandamis & Nychas, 2000). However, factors like the antimicrobial form, food type, storage conditions, processing methods, and target microorganisms must be carefully considered to ensure their effectiveness (Davidson et al., 2013).

CONCLUSION:

Modern technology and changing consumer demands have led to a shift in food habits, with consumers now seeking products that offer high nutritional value, freshness, safety, and extended shelf life. The market for minimally processed foods is rapidly expanding, driven by their health benefits and convenience. Innovative technologies, such as non-thermal treatments, help preserve food quality and optimize resource use. The growing demand for minimally processed foods highlights the importance of microbiological and physiological quality aspects. Consumer preferences are influenced by factors like nutritional content, simplicity, safety, and convenience, all of which are key considerations in minimal processing. This sector has seen significant investment and research aimed at enhancing the quality and shelf life of perishable agricultural products.

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