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Investigating Innovative Methods for Improving the Shelf Life of Meat

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Abstract:
Over the past few decades, various approaches have been employed for meat preservation. With advancements in technology, the meat industry is actively pursuing modern and cost-effective methods for preserving meat and meat products. In this regard, several unconventional methods, such as Super-chilling, Hydrofluidization freezing, Impingement freezing, electrostatic freezing, and Pressure-shift freezing, have demonstrated their potential for effective meat preservation. Additionally, active and intelligent packaging options will prove beneficial for meat packaging, although their capabilities require further improvement before implementation. Furthermore, these new technologies are more environmentally friendly, requiring reduced energy and water consumption while generating minimal waste. As a result, this article will prove valuable to the meat industry in considering these techniques for more efficient commercial preservation of meat and meat products.

Keywords: Meat preservation methods, Super-chilling, Hydrofluidization freezing, Impingement freezing, environmentally-friendly, active packaging.

INTRODUCTION

With increasing cognizance and demand of consumers for wholesome, fresh and safe meat products, scientists are untiringly engaged in developing and discovering numerous innovative and progressive food preservation techniques for potential commercial application. A vast range of novel thermal and nonthermal meat processing and preservation technologies has gained much attention over the past few years. Several benefits are allied with the use of these techniques which include high process efficiency, enhanced product quality, improved safety, and prolonged shelf stability of meat products.

METHODS

Advancements in Thermal Meat Processing Techniques

Thermal techniques have been preferably used by the food industry to inactivate several spoilage indicators and pathogenic microorganisms and ensure product stability. Nutritional profile of meat and meat-based products attracts microorganisms to grow readily and deteriorate the quality of meat. Therefore, thermal treatment is thought to be the more appropriate method to prevent meat from getting spoiled. However, application of heat to prevent microbial spoilage adversely affects the nutrients present in the muscle foods. Alternatively, low temperature methods have been utilized to slow down or seize the microbial activities. Low temperature preservation methods are claimed to be more beneficial in comparison with the high temperature methods because they usually do not disturb the nutritional contents of food. With the passage

of time, several advancements have been made in low temperature processing techniques for process improvement that are discussed in the following section.

Super-Chilling:

The method of super-chilling is used to describe the process where some portion of the water present in a particular product is frozen. During super-chilling, the product temperature is decreased up to 1–2 ˚C for initial surface freezing. After some time, the product attains the uniform temperature by equilibration of ice distribution which is maintained during the storage and distribution of the product. This process has been mostly used for seafood preservation but unfortunately, the process is not effectively expanded for chilled meat storage. Super-chilling is useful for inhibiting microbial growth and can reduce the use of freezing/thawing thereby reducing energy cost, labor and weight loss. The ice prevents super-chilled meat products from temperature elevation in poor cold chains; though, increased drip loss is recorded during the storage of meat. Super-chilling is claimed to prolong the shelf life of meat products for 1.4–4 times as compared to the conventional meat-chilling.

Freezing:

The size and structure of ice crystals depends on the rate of freezing. Fast freezing leads to the formation of small ice crystals and causes less cellular damage to product being frozen. Reports conclude that cell integrity of muscle foods has better preserved by rapid freezing methods in contrast to slow freezing. Ultra-rapid freezing involves freezing food between -218 up to - 225 ˚C. Temperature of the product is rapidly decreased to desired level which results in the formation of smaller ice crystals; hence, flavor and textural attributes of the food are not disturbed. This is the reason why the fast-freezing technology is increasingly being used in food industry.

Immersion Vacuum Cooling:

Immersion vacuum cooling (IVC) is another method that is claimed to attain high cooling rate and less cooling losses in comparison with traditional cooling methods. Additionally, further advancements have been made in order to improve the competitiveness and safety concerns. These strategies include combining this technology with other cooling methods, pressure control, inclusion of agitation, applying altered condensation temperatures, and using water with different initial temperatures. IVC is mainly used for meat preservation and involves the combination of water evaporation, conduction, and convection.

Hydrofluidization Freezing:

Hydrofluidization freezing (HFF) is a modified form of immersion freezing which involves a circulation system that pump refrigerating liquid in a cooling vessel through nozzles, in a thereby creating agitating jets which forms a fluidized bed having a turbulent liquid and moving products. HFF offers high heat transfer coefficients that provides paced freezing.

Impingement Freezing:

The use of impingement technology is one of the latest techniques that are commercially introduced for the preservation of meat and other food products. The main advantage of this method is higher heat transfer rate through coupling impingement technology with cryogenic freezing system (Winney, 2012). This technique involves directing high speed (50 ms21) jets of fluid to the surface of a solid product that breaks up the static layer of gas surrounding the food surface. This process enhances the efficiency of heat transfer which results in rapid freezing compared to conventional blast freezing systems. Reports have shown that impingement

freezing is more effective for those foods having high surface area to weight ratio, that is, meat cuts and fish fillets

Pressure-Shift Freezing:

Freezing foods using high pressure (200–400 MPa) has attracted researchers in recent years with special reference to pressure-shift freezing (PSF). In PSF, high pressure is applied while cooling the food to subzero temperatures which prevents the phase change and then food is frozen after releasing this pressure. When the pressure of the system is released, uniform and small ice crystals are formed in food due to rapid nucleation.

Comparison of meat thermal preservation methods

Techniques	Advantages	Disadvantages
Super-chilling	Reduced labor and energy cost, less product weight loss, improved meat safety	Complex calculations are required for effective heat transfer and temperature control
Ultrarapid freezing	Less cellular damage, better textural quality	Cause mechanical cracking, higher drip loss
Immersion vacuum cooling	Improved tenderness, less cooling losses,	Safety risks due to inclusion of water
Hydrofluidized freezing	Fast freezing rates, improved quality	No literature available
Impingement freezing	Effective heat transfer	Mechanical damage

Novel Nonthermal Meat Preservation Methods

Apart from the traditional preservation methods that usually involve heat or chemical interventions, many nonthermal preservation techniques have been emerging for preserving solid foods particularly meat products. The most widely used methods include OP, ultraviolet (UV) radiation, ultrasound treatment, HPP, electrolyzed oxidized water with high-pressure carbon dioxide treatment, PEF technology, and plasma technology. The potential of some techniques for meat preservation is summarized in this section.

Acidic Electrolyzed Water Coupled with High Hydrostatic Pressure:

Use of acidic electrolyzed water (AEW) has gained attention of researchers in recent years for effectively controlling the bacterial spoilage of meat-based products. AEW has shown better bactericidal effect in contrast to other conventional sanitizers. Previous studies have depicted that AEW can be used synergistically with other antimicrobial interventions for controlling microbial spoilage of meat and other food products. Used electrolyzed water in combination with other antimicrobial agents on fresh poultry surface and noticed a significant reduction in number of pathogenic bacteria particularly Salmonella. Recently, has reported that using AEW in synergism with high hydrostatic pressure can significantly reduce the bacterial load from shrimp surface without disturbing the quality of meat and can be used as a tool for preservation of other meat-based products.

HPP in Improving Meat Quality and Safety:

Several novel nonthermal techniques have been investigated for effective meat preservation. Literature on these methods highlights that these techniques can assist meat processors to meet the consumer demand of meat with good nutritional value, superior quality, and esteemed safety as well to fulfill the criteria of energy efficient meat processing and preservation. In this regard,

HPP is reported as an effective tool in improving meat safety and quality. Some researchers suggested that HPP (100 MPa) improves texture, color, and water holding capacity of meat in addition to provide microbial safety and extended shelf life. HPP technology has shown its potential for inactivating the growth of microorganisms from meat and meat products during the processing and storage.

Use of UV Treatment in Meat Safety and Preservation:

UV light has wide applications in decontaminating the surface of solid foods by inhibiting the growth of microorganisms and by destructing the pre-existing microbes on the food surface. Short-wave UV light has been deployed to treat the surface of meat fillets and reported to curb the growth of Pseudomonas species.

Plasma Technology in Meat Preservation:

Among various nonthermal processing techniques, plasma technology has also been extensively reviewed to extend shelf life of meat and meat products. Nonthermal plasma is composed of reactive photons comprising ions or free electrons which have significant bactericidal effect Plasma contains charged species, which when applied to the bacterial cell, cause protein denaturation, enzyme inhibition, oxidation of amino acids, breakage of bonds on the cell membrane due to bombardment of radicals, perforation of cell membranes due to the diffusion of ionized species, oxidation of the membranes, DNA damage and reduction of cell membrane resulting in loss of functionality and cell death. Several investigations have affirmed the competence of plasma technology for effective meat decontamination.

Advances in Meat Packaging Technology

With the advent of self-service meat cases for raw chilled and processed meats, the need for meat packaging to fulfill multiple functions has resulted in a variety of materials and systems that are available and each can be tailored to specific needs and applications. Application of several new and more efficient approaches is of no use without proper packaging. Packaging is of prime importance as it protects food from harmful environmental effects by acting as an inert material. So, proper packaging plays a dynamic role in preserving quality, safety, and sensory attributes of the product. Several advancements have been made in packaging technology of which active meat packaging stands out as most important emerging technology.

THE IMPACT OF NON-CONVENTIONAL MEAT STORAGE METHODS ON HEALTH AND THE ENVIRONMENT

These methods not only make it possible to obtain meat and meat products with a longer shelf life, safer for health and without preservatives, but also are more environment-friendly in comparison with traditional methods. With the use of alternative methods, it is possible to obtain meat products that are microbiologically safer, whilst also high quality and free from chemical additives. Moreover, these new technologies are also more ecological, do not require large quantities of energy or water, and generate less waste.

CONCLUSION

It does not seem that using these meat preservation methods would lead to changes that result in the formation of toxic compounds, which could pose health risks. The choice of using the described methods varies depending on the costs and the availability of related technological resources. Innovative meat packaging also plays a significant role in ensuring the safety, convenience, and quality of meat.

Modern approaches to meat processing and preservation have demonstrated the potential benefits of high-quality and long-lasting meat products, aligning with consumer demand. These innovative technologies not only reduce energy and water consumption but also decrease the production of wastewater. However, the widespread adoption of these technologies globally poses challenges for food industry innovators and researchers. Consumer perception of these technologies is not always well-defined, necessitating further clarification and explanation.

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