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Review Article

Preservation Techniques (Natural) and Measures for Enhancing Meat Shelf life Omer, A. Alaa*; Samir, I. Zahran*; Hoda, M. ElZeftawy** and Rania, S. Dewedar**

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Abstract

Food preservation has a vital role in safety insurance, controlling meat spoilage and extending the shelf-life of meat that facilitates its distribution different places. The most common methods of meat preservation include drying, chilling, curing, fermentation, irradiation, chemical treatment and thermal processing (canning). Drying refers to the removal of moisture from the food to be less than 15%. Freezing at chill temperature the meat is cooled to $< 0^{\circ}\text{C}$. Meat starts freezing at -1.5°C . Curing of meat developed as preservation using salt. Salted meat undergoing complex ripening reactions. Eventually other ingredients like nitrate, nitrite, sugar, phosphates, and other materials entered the curing mixture, each with a specific role to play in the curing preservation process. Fermentation is a simple low-tech and inexpensive method of preservation of foods that can be practiced at ambient temperatures.

Thermal processing by Canning of meat products. Sterilized cans Exhausting - 85°C Seaming-can is sealed (seaming) Autoclaving - 121°C . After processing, the cans are cooled in running water-containing chlorine (8 mg/ lit).

Essential oils and natural preservatives contain various content of antimicrobial and antioxidant compounds. So, Essential oils (EOs) have the potential to serve as natural food preservatives.

The present study, carried out to provide information related to the Meat preservation depending on previous studies on food and meat preservation.

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Introduction

Meat and meat products are products that rich in protein, iron, zinc, fatty acids, and many vitamins. Due to its rich nutritional matrix, meat considers the best source of animal protein for many people around the world (**Heinz and Hautzinger, 2007**). As it is known meat is characterized by high nutrient content, high moisture concentrations and close to neutral pH that make it a highly perishable product and more vulnerable to contamination by microorganisms than most other foods, making preserving it a greater challenge. And also because of its chemical composition and enzymatic activities, and availability of factors as temperature, microorganisms, ambient oxygen, and endogenous enzymes make it highly exposed to spoilage this due to breakdown of fat, protein, and other nutrients in meat leading to putrefaction and slime formation that making the meat or its products unsafe for human consumption (**Rahman et al., 2023**). All have an impact on the shelf life and freshness of meat food. Therefore, food safety specialists have resorted to thinking about ways for meat and food preservation.

The principle of food preservation is to create unfavorable conditions for the growth of microorganisms that cause food to spoil (**Rahman et al., 2023**).

So, food preservation is known as the process of handling and treating food to significantly slow down or stop spoilage. Consequently, prevent foodborne illnesses and maintain the nutritional value, taste and texture of food products.

The aim of the present review is to collect recent data about meat preservation, and overview of the different techniques applied to preserve meat around the globe. Therefore, increasing its shelf life and ensuring its safety and quality.

Therefore, this review paper was designed to:

- ◆ Review some techniques that are used to preserve meat.

Review

Meat preservation:

Food industry has become worldwide, leading to an enhanced threat of food contamination by pathogenic microorganisms, chemical residues,

harmful food additives, and toxins. The multiplication of spoilage and pathogenic microorganisms must be controlled to ensure food safety. Therefore, food preservation techniques for protecting food from pathogenic bacteria and extending shelf-life include chemical methods, such as the use of preservatives, physical methods, such as heat treatment, drying, freezing, and packaging; and biological methods using microorganisms that have an antagonistic effect on the pathogenic bacteria and produce bacteriocins (**Hwan Hee Yu, et al., 2021**).

Several techniques can be used to reduce the process of meat spoilage as controlling temperature, controlling water activity and use of chemicals or bio preservatives and also combination of these preservation techniques. The aim of meat preservation is inhibiting the microbial spoilage and minimizing the oxidation and enzymatic spoilage.

There are various methods for meat preservation and we will focus on these methods in this article to illustrate the most common and important technique to apply.

Thermal Method:

Thermal techniques used to eliminate spoilage microorganisms. Like pasteurization that means heating at temperatures between 58 and 75 C⁰, it is also the recommended temperature range for most processed meats. This thermal treatment significantly extends the shelf life of meat or its products. While, sterilization refers to the process that exposures meat to temperatures above 100°C. So, at that point all spoilage-causing microorganisms are destroyed or their microbial cells are permanently damaged (**Rahman et al., 2023**).

Preserving by Drying (Dehydrating):

Drying refers to the elimination of moisture (reduction in aw) from the food. Dried foods are low moisture (LM) food that containing moisture less than 15%. Water activity (aw) of these foods varies between 0.50 and 0.60, and the final moisture content should be around 4%. Usually, it is necessary to use hygienically handled meat with a very low microbial profile for preparing dried meat.

By this way, Dehydrated meat will last 1-2

months in air tight containers without refrigeration (**Steven and Dennis, 2018**). Storage stability of dried meats is extended at ambient temperatures. However, a part from fungal growth and undesirable chemical changes may occur in dried meats during storage.

Canning:

Canning is a common method of preservation for fruits, vegetables and meat. Cans, plastic container and glass jars are suitable for canning. They are dropped in a container with hot water for 10 minutes with the lids and cooled directly to 38⁰C, with removing oxygen during this process (**Berry and Pflug, 2003**).

(**Alpana and Bhagyashree, 2017**) found that some organisms can survive during or after canning process, so other additives or preservatives are also added. Most common examples of food preservatives are sodium benzoate and benzoic acid; sodium ascorbate, and ascorbic acid (vitamin C); calcium, sodium propionate, and propionic acid; calcium, potassium, sodium sorbate, and sorbic acid; butylated hydroxyanisole (BHA) and butylated hydroxytoluene (BHT); lecithin; and sodium and potassium sulphite and sulphur dioxide.

Smoking

(**Rajendran Chellaiah et al., 2020**) mentioned that smoking is an ancient preservative technique as first as human had started consumption of meat. The food is exposed to smoke from burning wood or burning any other plant materials. Smoking causes the outer layer to dry so that the moisture level would be decreased to a stage at which microorganisms cannot enter. This also can be treated in combination with salting method. Common smoking techniques are hot smoking, smoke roasting and cold smoking. And should take care of the smoking by not direct the smoke of wood smoke as it leads to progress food with carcinogenic polycyclic aromatic hydrocarbons. While when the meat is processed through cold smoking, it should be dried quickly to prevent the bacterial growth by making it jerky or by slicing it thinly.

Hot smoking:

Hot smoking is occurred with temperatures ranges from 60°C to 93.33°C. In this tech-

nique, without curing, the meat will be hot smoked with mild addition of salting to prevent bacterial growth during the smoking process. Then, it is hot smoked for several hours lastly before consumption. In addition to flavoring and smoke-based preservatives, hot smoking is used to dry the meat further with the famous double smoked red herring. These meats are completely cured before smoking (**Rajendran Chellaiah et al., 2020**).

Cold smoking

(**Joshua and Brian, 2012**) defined that cold smoking involves saturating the meat to smoke at an optimum temperature range from 23.8°C to 48.88°C after partially or fully cured. In this method, the meat is usually be hung or placed on racks, and allowed to be smoked for days instead of hours which resulted in the product either completely raw or partially cooked. This when combined with salt curing, the product will remain fit for human consumption and tasty for a year or longer without the need of refrigeration. This technology can be applied for all types of meat including poultry, fish and meat cuts.

In both processes, the meat is completely dried at the top of the surface before smoked. In few cases cold smoking is followed by a period of hot smoking. The smoking method, either one process gives best flavors to the meat, which advance the shelf life and can last for 1-2 months in an air tight container (**Rajendran Chellaiah et al., 2020**).

2. Non thermal methods

Low Temperature Methods: The main purpose of cooling techniques is to slow or limit the spoilage rate as temperature below the optimal range can inhibit the microbial growth. Low temperature methods of storage are used in three levels: chilling, super chilling and freezing. All these levels help to inhibit or completely stop bacterial growth (**Zhou, et al., 2010**). Though, the growth of psychrophilic group of bacteria, yeasts and molds is not inhibited by all levels of refrigeration (**Neumeyer et al., 1997**). Also, both enzymatic and non-enzymatic deviations will continue at a significantly slower rate (**Berkel et al., 2004**).

2.1. chilling:

(Coll Cardenas and Olivera, 2016) mentioned that the process of chilling for meat has both advantages and drawbacks on shelf life, hygiene, color, safety and tenderness of meat. Chilling in air decreases the cadaver surface temperature and upgrades remain to dry; and delay the growth of microscopic organisms in meat. At chilled temperature when the time of storage is extended, it will result in an increase of tenderness in meat but may lead to undesirable flavor development and undergo microbial growth.

(Priyanka, P. 2019) documented that chilling can delay the development and metabolic activities of pathogenic bacteria, viruses and toxins in food stuffs unlike higher temperature. Also, certain parasites such as Taenia cysts in beef and all stages of Trichinella spiralis, might be completely destroyed by storing of infected food at 18°C for periods of 20 to 30 days and it occurs by the rate of cold diffusion. Chilling is normally being done at temperature from 0°C to +8°C for preservation of a wide diversity of food products including meat.

(Kerry and Tyuftin, 2017) reported that in chilling, calcium is released from the sarcoplasmic reticulum and mitochondria of meat post mortem leads to activation of calcium-dependent protease, called calpains. Proceeded chilled capacity results in calpains decomposing myofibril proteins, known as proteolysis. The meat becomes tendered and shears force (SF) decreases as proteolysis happens. Also, expanded chilled storing temperature decreases with the stability of color. And additionally expanded anaerobic chilled storing term brings instant discoloration to the presentation of oxygen, which has been found to occur corresponding to lipid oxidation.

2.2. Super chilling:

Super chilling or (Very Fast Chilling) (VFC), in which the temperature of the meat is reduced below the point of solidification of a specific product. Once the primary surface freezing is completed, the distribution of ice equilibrizes, and it is maintained at an even temperature where it is obtained for distribution and storage (Selvaraj Arokiyaraj *et al.*, 2024).

(Kerry and Tyuftin, 2017) mentioned that the low temperature obtained may also outcome in a substantial release of calcium from the sarcoplasmic reticulum of myofibrils.

Super chilling delayed the biochemical aspect of the degradation of salmon filets. The timeframe of accurate usability of super chilled chicken and salmon is half longer compared with chilled items, while super chilled cod 46 % in the longer period of utility compared with the chilled items (Claussen, 2011).

2.3 freezing:

As we know freezing prevents microbial growth and inhibits enzyme activity. The most significant pro of freezing includes the preservation of most of nutrient content of meat at storage, with only a tiny portion of nutrients missing during the thawing procedure. While the abnormal disorder is due to excessive surface dehydration, which concentrates the surface pigments of meat and causing freeze burn. The freezing rate of frozen meat either slow or fast also affects its quality, because fast freezing produces better quality meat than slow freezing. While, slow freezing results in the formation of large ice crystals, that may cause physical damage to muscle tissue results in protein denaturation and change its components and appearance (Rahman *et al.*, 2023).

(Landerslev *et al.*, 2018) reported that the enzymatic activity in meat is reduced by freezing. As transfer of heat constant, cooling temperature, thermodynamic features of meat or quantity determine the rate of freezing of pork in a specific system.

(Rajendran Chellaiah, *et al.*, 2018) described another kind of freezing called Freeze-drying (FD). FD is a technology that is using the physical principle known as sublimation, which is a process in which a solid pass directly to the gaseous phase without melting the ice formed. It considers a best way of preserving food at low temperatures from -10°C to -25°C and in which the chemical reactions will be at very slow stage and the microorganism is difficultly survive. In this technique of preservation, the food items will be frozen first and then sublimates to leave the final moisture content of meat as low as 0.5%.

(Coleen and Louwrens, 2012) reported that

thawing of meat and meat products is very significant to reduce the chance for food-borne illness and it should be done at the refrigerator. Other products such as turkey meats should be thawed by submerging the meat in an air tight packaging by changing cold water every 30 minutes until it is thawed completely.

3. Preservation by curing meat:

(NCHFP, 2025) stated that curing is a general term that include salting, smoking and sugaring. All methods of curing used for all types of food preservation. Curing has been considered an ancient technique for meat preservation.

(Rahman *et al.*, 2023) added that with the advances in the modern techniques of preservation, curing still has been used as an additional step for its effect on the taste and texture of food. However, in poor nations curing is still considered a mean for practicality of meat and its downscale operations as production, transport and access. Historically, meat curing involved of adding rock salt, sea salt, or ground salt to unheated pieces or small cuts of meat to reduce the water activity, prevent microbial growth and chemical spoilage, soften the meat, and convey flavor to the product.

(Rajendran Chellaiah *et al.*, 2020) recorded that Salting occurs by adding of sodium chloride to food, so it preserves the meat by absorbing water and so delaying the growth of microorganisms. In this process, salt in combination with other treatments acts as a preservative in many foods such as butter, cabbage, cheese, cucumber, meat and fish. It also gives a desired flavor to the food. (Curing) Salting can be occurred by rubbing salt on meat or by soaking in brine solution comprising at least 18% salt. Also, the injection of salt solutions into meats also became general method of curing.

(Dave and Ghaly, 2011) mentioned that sodium chloride, sodium nitrate, sodium nitrite, and sugar are the main curing ingredients. In India, they use various methods of curing, including dried cure, pickle cure, injection cure, and direct cure. The preservation of meat through heavy salting is an ancient method. High concentrations of sodium chloride salt have a long history of use in food preservation. The curing is considered the main technique of

preservation as refrigeration methods were unavailable in the past. Curing occurs by increasing osmotic pressure and decreasing water activity in the microenvironment, so sodium chloride inhibits microbial growth.

FAO and Hyfoma, (2018) recorded the methods of curing, as there are four methods of curing meats:

(a) **Dry curing:** Salt mixture is applied on the surface of meat and kept in chill room (2 - 4°C) for 7 - 10 days.

(b) **Pickle curing:** Meat is immersed in pickle solution (salt mixture dissolved in water) at 60 - 65° salinometer and stored in cold room (2 - 4°C) for 5 - 7 days.

(c) **Injection brine:** Pickle solution is prepared by dissolving salt mixture at 60 - 65° salinometer and the solution is then injected into meat and kept in chill room (2 - 4°C) for 5 - 7 days.

(d) **Pickle injection and dry cover:** Meat is injected with pickle solution. This is followed by the application of dry salt mix on the surface of meat. The meat is kept at 2 - 4°C for 5 - 7 days. Ham (thigh portion) and bacon (sides) and sausages of pig are the common cured meat products.

4. Preservation by fermentation:

Fermentation is a simple low-technique and inexpensive method of food preservation that can be practiced at ambient temperatures. fermentation is a method in which chemical reaction in an organic substrate are brought through the action of enzymes liberated by microorganisms. As, during fermentation microorganisms liberate lactic acid, volatile acids (such as acetic acid), bacteriocins and antibiotics that inhibit the growth of undesirable microorganisms and result in preservative effect in foods.

(Pogorzelska-Nowicka *et al.*, 2022 and Mia *et al.*, 2024) reported that meat gets its diverse flavor from the breakdown of proteins in muscles by enzymes like protease, microbial enzymes, and aminopeptidases, that is resulted in tiny peptides and amino acids including alanine, lysine, valine, leucine, arginine, aspartic, and glutamic acid. Certain aroma compounds are resulted from the secondary oxidation products that result from the lipids' lipolysis

and auto-oxidation during the meat's fermentation method. These compounds comprise aldehydes, alcohols, ketones, esters and lactones. Meat proteins create bioactive peptides, which increases their suitability for usage as useful additives.

(**Arghya, 2018**) mentioned that Fermentation and pickling Fermentation used as preservation methods as they control microbial reaction. they result in the production of alcohol and acid by the anaerobic or partially anaerobic oxidation of carbohydrates. Also, high concentration of salt in pickling acts as barrier for pathogens and undesirable microorganisms. The concentrations of the pickling agents and the time needed for pickling are depend on the type of food.

Addition of natural preservatives from essential oils (EO) or plant extracts for meat preservation

Natural preservatives have advanced as substitutions to the synthetic preservative techniques (**Marrone et al., 2021**). Natural preservatives have shown potential to provide effective antimicrobial action with reducing negative health effects. Meat and meat products that containing synthetic additives consider a major concern for human health (**Yong et al., 2021**). Hence, meat manufacturers and researchers have begun to take in consideration the use of natural preservatives rather than synthetic ones.

The replacement of synthetic preservatives with natural ones has major positive effects and is being accepted by customs. However, food producers also meet challenges, including a decrease in price competitiveness due to the comparatively high price of natural preservatives and a decrease in the antibacterial effect due to food ingredients, such as proteins, carbohydrates and lipids. In the case of plant-derived substances, standardization is challenging because of the influence of country of origin, soil, and harvest seasons. Moreover, toxicity evaluation or identification of exact components for several plant-derived compounds contained in extracts and essential oils have been achieved (**Olszewska et al., 2020**). To solve these problems, various studies have been conducted to improve the extraction process, combine other antimicrobial substances, apply active packaging, and encapsulate antibacterial substances to advance their utilization

(**Lee et al., 2020 and Choe, 2020**).

Natural additives are manufactured in a variability of formulations including powder that formed by drying methods and liquid forms as essential oils. Natural preservatives are added directly to meat products and extend the meat shelf-life by inhibiting bacterial growth. As well, it is possible to increase the antibacterial effect of natural additives through a combination of other food processing techniques (**Hwan Hee Yu, et al., 2021**).

The antibacterial effect of plant-derived natural preservatives is closely correlated to phenolics, polyphenols and flavonoids. Plant-derived polyphenols have various classifications and structures, like: phenolic acids (rosmarinic, caffeic, gallic, cinnamic and ellagic acids), flavones (apigenin, luteolin and chrysoeriol), flavanols (catechin, epigallocatechin, epicatechin, galocatechin, and their gallate derivatives), flavanones (heridictyol, hesperidin, hesperetin, naringenin), flavonols (kaempferol, quercetin, myricetin), isoflavones (daidzin, genistein and formononetin), coumarins (warfarin, coumarin, and 7-hydroxycoumarin), anthocyanins (delphinidin, pelargonidin, cyanidin and malvidin), quinones (hypericin and naphthoquinones), alkaloids (caffeine, harmaline and berberine), and terpenoids (thymol, menthol, lycopene, linalool and capsaicin) (**Hwan Hee Yu et al., 2021**).

Some EOs contain cinnamaldehyde, eugenol, thymol, limonene, citronellol, and geraniol, most of these essential oils have antimicrobial as well antioxidant activity (**Rahman et al., 2023**).

phenolic and Terpenoids compounds are the most common active components in EOs (**Oussalah et al., 2007**). At studying different EOs against different microorganisms, the minimum level of inhibition ranged from 1 mM for active compounds to 3% for less active compounds (**Skaltsa et al., 2003**). Inhibiting the growth of pathogenic bacteria and increasing food's shelf life by using EOs as natural antibacterial agents considers a novel impression.

Due to the lipophilic nature of essential oils, the compounds found in EOs have antibacterial properties that can be used to attack the membrane's integrity, reduce the energy supply of bacterial cells, and cause significant damage to

the cell's outer membrane (Rhayour *et al.*, 2003) or plasmic membrane (Lambert *et al.*, 2001).

(Cosentino, *et al.*, 1999) reported that essential oils that are high in phenolic compounds have better antibacterial effects than terpenoids.

Lately, plant and herbal extracts have utilized for increasing shelf life and quality such as Centella leaf (*Centella asiatica*) extracts (Akter *et al.*, 2022), ginger extract (Hossain *et al.*, 2021), lemon extract (Disha *et al.*, 2020), carrot extract (Khatun *et al.*, 2022) pomegranate (*Punica granatum*) extract (Jahan *et al.*, 2018), and synthetic antioxidants (Azad, *et al.*, 2021) might be due to these plant extracts contains natural antioxidant which reduced microbial load.

(Oussalah *et al.*, 2007) mentioned that essential oils have various content of antimicrobial and antioxidant compounds, so essential oils (EOs) have the potential to serve as natural food preservatives.

As well, it was determined that the antioxidative properties of most plant extracts were dependent on the solvent used for their extraction (Yanishlieva *et al.*, 2006).

(Ismail *et al.*, 2001) mentioned that making a solution of 100% sage (*Santolina sp.*) or thyme decreased the number of *Yersinia lipolytica* on chicken. While, Carrots contain phenolic compounds and EOs with considerable anti-listeria activity (Khatun *et al.*, 2022).

Essential oil of rosemary contains approximately fifteen kinds of bioactive compounds this is reported by (Selmi *et al.*, 2017), the principal compound was 1,8-cineole (35.32%) and other major compounds were camphor, α -pinene, trans-caryophyllene, α -thujone, and borneol.

(Soyer *et al.*, 2020) studied the antibacterial effect of rosemary ethanol extracts against *L. monocytogenes* in beef and found that the application of 45% rosemary ethanol extract for *L. monocytogenes* on beef led to a 2-log colony-forming unit (CFU)/g reduction in the incubation at 4 °C for 9 d.

(Moura-Alves *et al.*, 2020) studied the antibacterial effect of sage EO (0.625%) on the survival of *L. monocytogenes* in Sous-vide cook-chill beef that stored in refrigerated storage (2 or 8 °C) for 28 d, and found decrease of 1 log CFU/g of *L. monocytogenes* was detected

in the sage essential oil-treated groups compared to the control at 2 °C. while, exponential growth was observed from day 14, lower *L. monocytogenes* counts of approximately 1 log CFU/g were noticed in sage essential oil-treated samples stored at 8 °C.

Thyme (*Thymus vulgaris*) is a characteristic herb used together with meat and meat products. The application of thyme EO in meat products can raise antioxidant, antibacterial, shelf-life extension, and also sensory properties. In meat sausage, thyme EO inhibited 2.69 log CFU/g of coagulase-positive *Staphylococcus* and 4.41 log CFU/g of aerobic mesophilic bacteria, respectively, at a concentration of 0.95% by mixing with 1% (w/w) powdered beet juice. Moreover, the sensory properties as, flavor, odor and overall acceptability improved (Barboza Mendonça and Gandra, 2021).

(Kiprotich *et al.*, 2020) studied that 1% thyme oil resulted in the reduction in *S. enterica* by 3 log CFU/g during the marination procedure with lemon juice and 0.5% *Yucca schidigera* extract in raw chicken breast. The major components of the thyme oil represented 51.1% and 24.1% thymol and *O*-cymene, respectively.

The antibacterial effects of thyme may be due to additive or synergistic action with its major and/or minor components. Thymol and its synergistic effect with other phenolic compounds, as carvacrol, *p*-cymene, and γ -terpinene, can alterate the permeability of the bacterial cell wall, leading to cell death (Marchese *et al.*, 2016).

Oregano EO acts by inhibition the growth of bacteria by releasing volatile components during the drying method. (Hernandez *et al.*, 2017) reported that the addition of oregano EO that composed of carvacrol (64.5%), *p*-cymene (5.2%), and thymol (2.9%) inhibited *S. Enteritidis* and *E. coli* in the beef drying method.

Also, (Yu *et al.*, 2019) described that Grapefruit Seed Extract (GSE) have a wide-range spectrum antimicrobial, antiparasitic, and antifungal activities.

(Khaleque *et al.*, 2016) reported that cinnamon (*Cinnamomum cassia*) EO could inhibit *L. monocytogenes* in ground beef at refrigerated (0 and 8 °C) and at frozen (-18 °C) conditions. The concentration of 5.0% cinnamon EO to decrease by 3.5–4.0 log CFU/g of *L. mono-*

cytogenes at 0 and 8°C for 7 d. While, under frozen conditions, *L. monocytogenes* was reduced by 3.5–4.0 log CFU/g over 60 d.

(Kotra *et al.*, 2019) mentioned that Turmeric (*Curcuma longa* L.) has been used as a flavor and color agent in food and traditional medicine to treat several diseases, mainly in South and East Asia. The main active components of turmeric originate from its constituents, called curcuminoids.

Curcuminoids (demethoxycurcumin, bis-demethoxycurcumin and curcumin) content of turmeric varies between about 2–9% depending on its growth environments, such as soil, and climatic conditions.

(Das *et al.*, 2022) reported that mustard EO also used for meat preservation to extend the shelf life of refrigerated meat rather than soybean and flax seed oils. The pattern of EOs in the mustard oil reduce the microbial load and it is recommended that mustard oil be used in the preservation of raw chicken meat in refrigerated storage.

Essential oil, chitosan, lactic acid, phytochemical extracts, nisin, lysozymes, and so on are some natural compounds that can be used for meat preservation technology (Zhou *et al.*, 2010 and Lim *et al.*, 2013). Spices and herbs turned out to be generally preferred for food application for all the reasons and their utilization as preservatives for a considerable length of time prompted the improvement of ethnic dishes, that are still in the presence of today's world.

(Dutta, *et al.*, 2009) reported that Chitosan is a sugar that is obtained from the hard outer skeleton of shrimp, lobster and crab. Chitosan can be used as a preservative of food in materials used for packaging as chitosan has the ability of forming a film with antimicrobial properties. The growth of microorganisms as bacteria, yeast, and fungi is inhibited by chitosan in the storage of meat products due to its broad spectrum of antimicrobial activity.

Conclusion

This review aimed to describe ancient and current methods and technologies for fresh meat preservation and their developments. As we know Meat is a highly nutritious food rich in proteins, essential amino acids, vitamins, and

minerals, but it is also highly perishable due to its high-water activity and nutrient content. Traditional preservation methods such as chilling, freezing, and irradiation are well-established, while modern technologies, both thermal and non-thermal, are being developed to improve shelf life and maintain meat quality. As consumer awareness of health concerns related to synthetic preservatives increases, natural preservatives derived from plants, animals, and microorganisms have emerged as promising alternatives, despite challenges related to cost, sensory impact, and standardization. Additionally, pre-slaughter handling and storage conditions significantly affect meat quality. With increasing global demand for meat and the environmental and economic burden of spoilage, the implementation of effective preservation and handling techniques is more critical than ever.

Recommendations

Improve pre-slaughter animal handling by minimizing stress factors such as long transport times, unfamiliar environments, and inadequate feeding, in order to maintain optimal muscle glycogen levels and meat quality.

Provide specific training for slaughterhouse workers in animal welfare, stress indicators, proper restraint, and humane slaughter practices to ensure high-quality meat and ethical treatment.

Encourage the use of natural preservatives as safer alternatives to synthetic chemicals, and enhance their effectiveness through combination with physical treatments, encapsulation, or active packaging.

Ensure strict control over storage and transport conditions, especially temperature and humidity, to reduce microbial spoilage and oxidation.

Invest in research and development of advanced preservation techniques (e.g. superchilling, non-thermal plasma, natural bio preservatives, ect..) to facilitate industrial-scale application.

Raise consumer awareness about the importance of proper meat storage, handling, and timely consumption to minimize spoilage and food waste.

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