International Journal of Veterinary Sciences and Animal Husbandry

ISSN: 2456-2912
NAAS Rating (2025): 4.61
VET 2025; SP-10(12): 23-33

www.veterinarypaper.com
Received: 12-10-2025
Accepted: 15-11-2025

TA Sabalpara
Department of Livestock Products Technology, College of Veterinary Science and Animal Husbandry, Kamdhenu University, Junagadh, Gujarat, India

SH Sindhi
Department of Veterinary Public Health and Epidemiology, College of Veterinary Science and Animal Husbandry, Kamdhenu University, Junagadh, Gujarat, India

AR Bariya
Department of Livestock Products Technology, College of Veterinary Science and Animal Husbandry, Kamdhenu University, Junagadh, Gujarat, India

AS Patel
Department of Livestock Products Technology, College of Veterinary Science and Animal Husbandry, Kamdhenu University, Sardarkrushinagar, Gujarat, India

JB Kathiriya
Department of Veterinary Microbiology, College of Veterinary Science and Animal Husbandry, Kamdhenu University, Junagadh, Gujarat, India.

Corresponding Author:
TA Sabalpara
Department of Livestock Products Technology, College of Veterinary Science and Animal Husbandry, Kamdhenu University, Junagadh, Gujarat, India

Essential oil and plant extract as natural preservatives in meat and meat products

TA Sabalpara, SH Sindhi, AR Bariya, AS Patel and JB Kathiriya

DOI: https://www.doi.org/10.22271/veterinary.2025.v10.i12Sa.2815

Abstract
Meat and meat products are rich in nutrients, but are highly perishable due to microbial growth and lipid oxidation, leading to spoilage. Growing consumer awareness and health-related risks associated with synthetic preservatives such as nitrites, BHA, and BHT have stimulated the exploration of natural compounds for food preservation. Essential oils and plant extracts, containing bioactive compounds like phenols, flavonoids, tannins, alkaloids, and terpenes, exhibit strong antioxidant and antimicrobial activities. These natural agents can be incorporated directly into meat or applied as edible coatings, nanoencapsulation, or integrated into active packaging materials to enhance oxidative stability and microbial safety. Research findings indicate their ability to improve storage stability and maintain sensory attributes such as flavour, colour, and texture. Their practical application remains limited due to challenges such as pronounced aroma, variation in bioactive content, greater expense, and absence of standardized regulations. Incorporating natural preservatives offers a sustainable strategy to extend shelf life while maintaining the safety and acceptability of meat products.

Keywords: Essential oil, natural preservatives, meat products, meat products, acceptability

Introduction

India having a largest livestock sector with 535.78 million total livestock population, which is increase of 4.6% over 90th livestock census (Anonymus, 2019) [8]. The contribution of livestock in total agriculture GDP (Gross domestic products) and Indian GVA (Gross value added) is 30.23% and 5.5%, respectively. India ranks 5th in the world in term of total meat production with 10.25 MT total meat produce during year 2023-24, which increased by 4.95% as compared to previous year. The poultry industry is the largest contributor to meat production in India, accounting 48.96% followed by Buffalo, Goat, Sheep, Pig and Cattle which contribute 18.09%, 15.50%, 11.13%, 3.72% and 2.60%, respectively to the total meat production. India is the largest exporter of buffalo meat in the world and stands 5th for poultry meat production. The per capita availability of meat is reached 7.1 kg/annum in year 2023-24 from 6.82 kg/annum (BAHS, 2024) [11]. "Meat" defines as an all-edible part (including edible offal) of any food animal slaughtered in an abattoir and have been judged as safe and suitable for human consumption (FSSAI, 2011). Meat and meat products are a vital component of human diet because they are excellent source of proteins, amino acids, lipids, minerals (zinc, iron, copper, cobalt and phosphorus), vitamins (thiamine, riboflavin, niacin and vit B_{12}), and other necessary nutrients (Manessis *et al*., 2020) [43]. Meat shelf life is affected by various factors including storage temperature, enzymatic activity, oxygen, humidity, light, and microbes. These elements have a significant impact on food quality. It affects nutrition as well as sensory aspects of products. Nutrient and moisture content of meat makes it more susceptible to spoilage. Meat and meat products, that originating from cattle, pig, poultry are extremely perishable to lipid peroxidation and vulnerable to variable microorganism (Campolina *et al*., 2023) [17]. The primary causes of quality loss in meat and meat products are microbial deterioration and auto-oxidation, which leads to development of undesirable flavours, odours, and toxic compounds such as Reactive Oxygen Species (ROS) and Reactive Nitrogen Species (RNS) that are harmful to human health (Aguirre *et al*., 2023) [3].

Oxidation is a common process that occurs in meat and meat products during storage. The sensory and nutritional qualities of the meat product are directly impacted by the oxidation of lipids, proteins, and pigments. In addition, the pathogenic bacteria such as a *Campylobacter spp*., *Listeria monocytogenes*, *Staphylococcus aureus*, *Salmonella enterica*, and *Escherichia coli* are the predominant spoilage and pathogenic microorganisms found in meat and meat products, that are responsible for foodborne outbreaks (Campolina *et al*., 2023) [17].

There are certain methods used to maintain quality as well as increase the shelf life of meat and meat products. It including traditional method such as salting, curing, smoking, fermentation and drying. Nowadays, ohmic heating, dielectric heating, irradiation, ultrarapid freezing and retorting like temperature control method, while advance packaging such as modified atmospheric packaging, vacuum packaging, smart and intelligent packaging are also used in preservation of meat and meat products (Beya *et al.*, 2021) [15]. The food industry has been utilizing synthetic chemical preservatives since the industrial revolution. Synthetic preservative such as nitrites, nitrates, ascorbates, monosodium glutamate, butyl-hydroxy anisole (BHA), sulphur dioxide, butyl-hydroxy toluene (BHT), tert-butyl-hydroquinone (TBHQ), and propyl-gallate (PG) are inhibiting and preventing the growth of spoilage microbes along with slow down auto-oxidation of lipids and proteins (Aguirre *et al.*, 2023) [3]. However, synthetic preservative having a negative effect on consumer health, these can induce food poisoning, liver damage, carcinogenesis, allergy, and mutation. Consumers are now more aware about severe health risks which caused by consumption of meat and meat products with synthetic additives. It's raised demand for food products prepared with natural component (Batiha *et al*., 2021) [12].

The meat industry turning its attention towards antioxidants that are innovative, effective, affordable, environmentally friendly, or natural substitutes to replace toxic synthetic preservatives (Hassani *et al*., 2025) [34]. Plant extracts and essential oils are the primary natural sources of bioactive compound used in meat and meat products. These compounds are classified into phenolic acids (hydroxybenzoic, hydroxycinnamic acids), flavonoids (flavanol, flavones, anthocyanins), tannins (hydrolysable and condensed tannins), terpenes, catechins, alkaloids, saponins, and coumarins, which having an antibacterial and antioxidant properties (Awad *et al*., 2022) [10]. In addition, plant extracts and essential oil are considered as a GRAS (Generally Recognized as Safe) therefore, they are suitable for use in meat and meat products without any harmful effect to consumers (Campolina *et al*., 2023) [17].

Mechanism of lipid peroxidation

Lipid peroxidation is a chemical reaction in which unsaturated fatty acids react with oxygen or free radicals present in meat and causing a deteriorative change including change in flavour, colour, texture, appearance which have an effect on consumer acceptance. Meat lipids are susceptible to lipid peroxidation due to meat and meat products are lack of antioxidant molecules (Awad *et al*., 2022) [10]. Lipid oxidation is the primary non-microbial cause of quality deterioration in meat and meat products. Additionally, lipid oxidation produces a number of toxic substances. These compounds are linked to a number of human diseases such as cancer, atherosclerosis, inflammation, and aging as well as it also associate with cytotoxic and mutagenic effects (Domínguez *et al*., 2019) [26]. The lipid oxidation is a complicated process, which involving multiple mechanisms that interact with each other. Lipid peroxidation is differentiated by a chain radical mechanism and comprise of a discrete phases of initiation, propagation, and termination in the chain reaction (Dragoev, 2024) [27].

- **Initiation**

Lipid oxidation is initiated by the interaction of oxygen molecules or reactive oxygen species (ROS) for example superoxide ($O_2^{\bullet-}$), hydrogen peroxide (H_2O_2), hydroxyl radical ($^{\bullet}OH$), and hydroxyl ion (OH^-) with phospholipids and unsaturated fatty acids, which produces highly reactive and unstable free radicals (Awad *et al.*, 2022) [10]. Hydrogen present adjustcent to double bond in unsaturated fatty acids is abstracted as a H_2O (Valgimigli, 2023) [68].

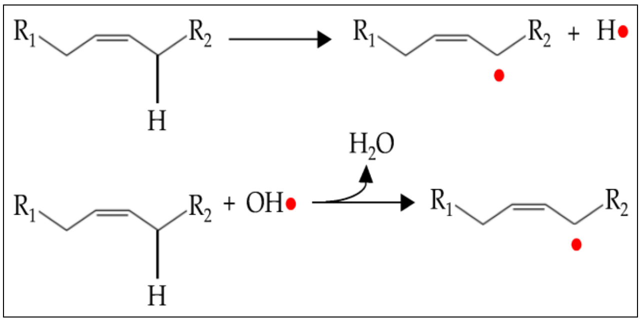


Fig 1: Initiation of lipid peroxidation (Domínguez *et al*., 2019) [26]

- **Propagation**

Propagating stage followed by the initiation stage, which produces activated peroxide by oxidizing free radicals. After that activated peroxide react with another unsaturated fatty acid by shifting hydrogen ion of unsaturated fatty acid, that unite with activated peroxide and forming hydroperoxide and another free radical, which is further oxidize to form new activated peroxide. Hydroperoxides are primary end products of lipid oxidation (Domínguez *et al.*, 2019) [26]. A magnification phase also exists alongside the propagation phase. The process by which hydroperoxides produced during propagation is broken down to produce additional hydroxyl, peroxyl, and alkoxy radicals that is referred to as secondary initiation. This process repeated again and again until termination (Chaijan & Panpipat, 2017) [18].

Adverse condition in meat or surrounding environment as well as metal ion present in meat, leading to further radical chain rection such as an isomerization and decomposition. The hydroperoxide fragments as a result of the metal ion giving it an electron. Thus, both heme and non-heme iron found in meat serve as a significant catalyst for the breakdown of hydroperoxides (Domínguez *et al*., 2019) [26]. This process results in the production of secondary compounds including volatile fatty acids, aldehydes, and ketones that have shorter carbon chains. These substances give a characteristic rancid odour or flavour. In addition, the primary aroma compounds produced by lipid oxidation are aldehydes such as malonaldehyde and ketones (Reitznerová *et al*., 2017; Ye *et al*., 2024) [55, 70].

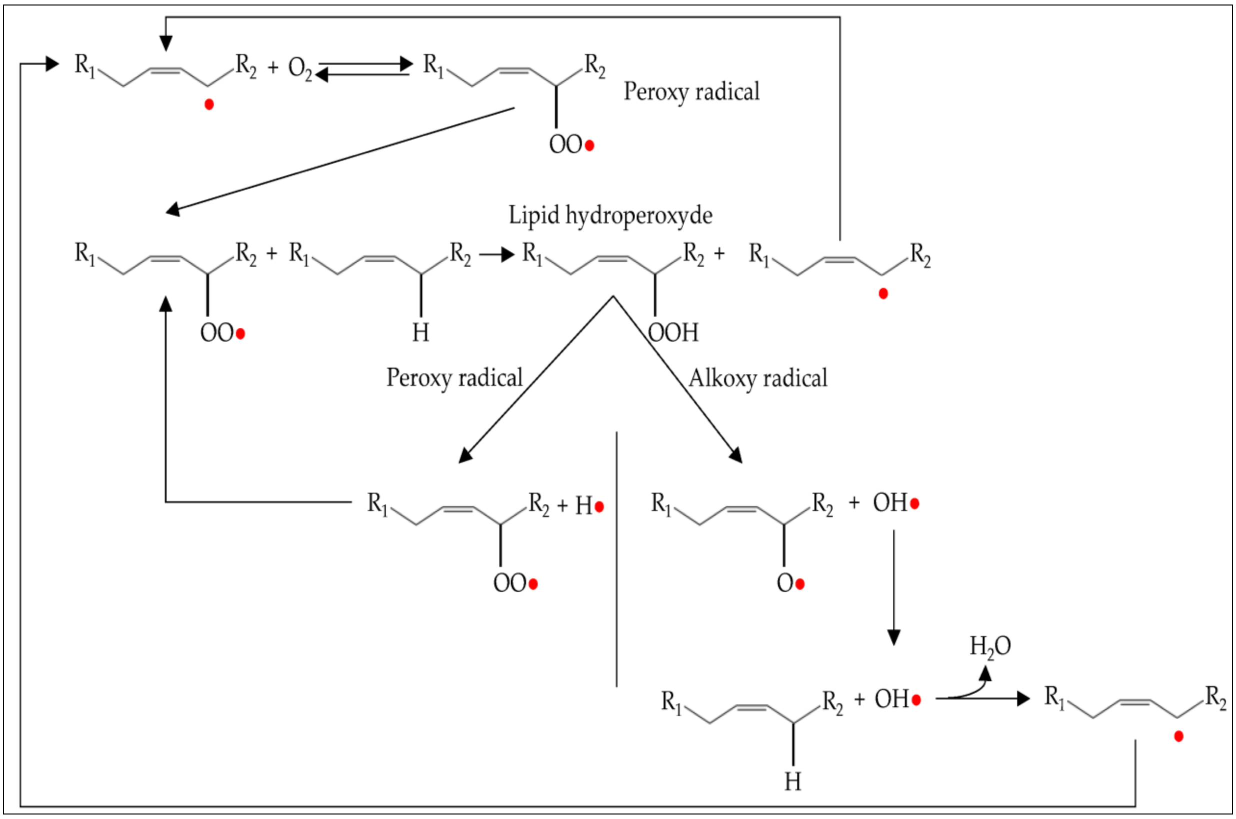


Fig 2: Propagation and magnification phase (Domínguez *et al*., 2019) [26]

- **Termination**

In termination stage free radicals react with each other or with antioxidants compound to form stable and non-radical products. When two free radicals interact with each other, radical-radical coupling and disproportionation can occur (Amaral *et al*., 2018) [7]. While, antioxidant react with radicals by donating hydrogen ion to free radicals, which is less reactive and more stable (Prasetyo *et al*., 2024) [51].

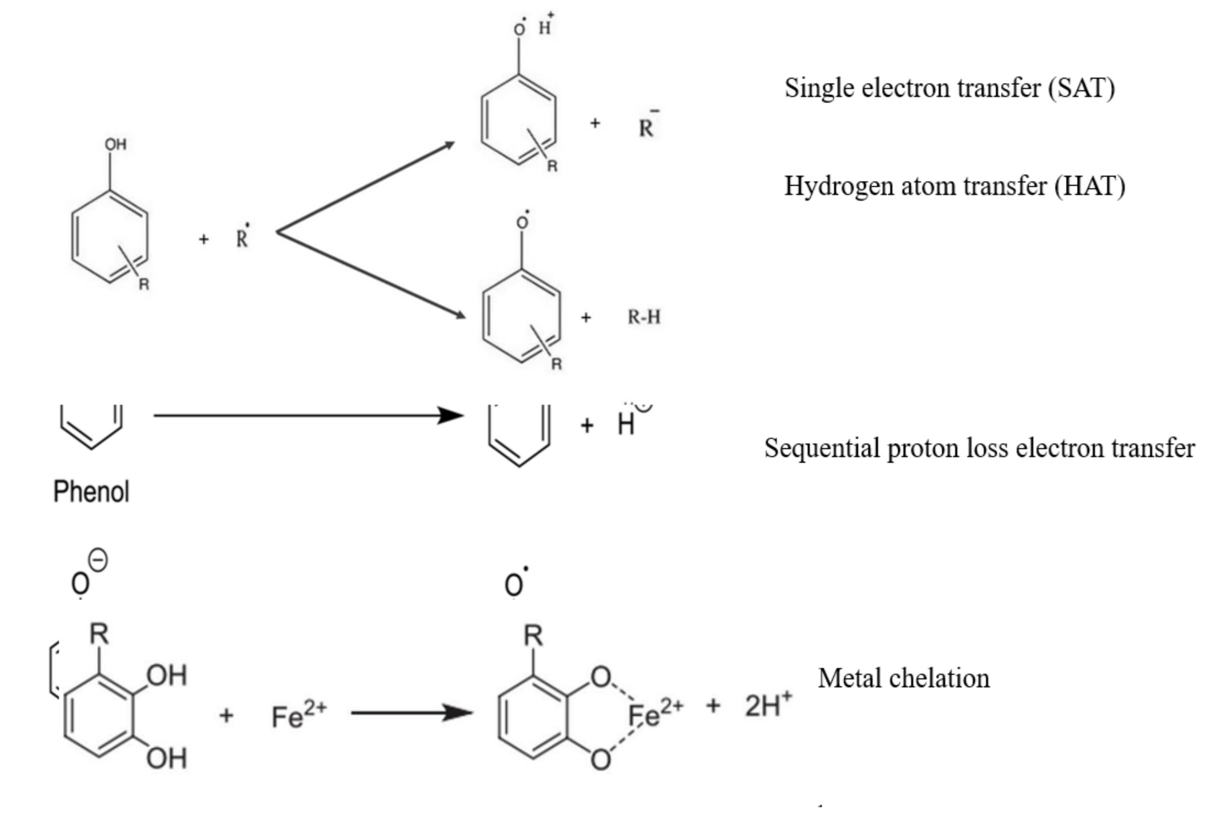
The TBARS (Thiobarbituric Acid Reactive Substances) assay is one of the most widely used methods for measuring lipid peroxidation, particularly for detecting malondialdehyde (MDA) level in meat during storage, which is an end byproduct of oxidative degradation of lipids. These aldehydes are highly reactive and can form adducts with other cellular components, while it also causes a cellular damage and a wide range of diseases. The TBARS assay is based on the reaction of MDA with thiobarbituric acid (TBA), which produce a pink chromophore. The intensity of the colour is proportional to the concentration of MDA that can be measured spectrophotometrically (Moore and Roberts, 1998) [46].

Mode of action of antioxidant activity of plant extracts and essential oils

Different parts of plant, including leaves, flowers, fruits, stems, and roots accumulate significant amounts of antioxidants. Phenols, tannins, flavonoids, isoflavonoids, anthocyanins, lignans, stilbenes, tocopherols, carotenoids, and vitamin C are primary classes of antioxidant compounds in relation to their molecular structures present in plant extracts (Manessis *et al*., 2020) [43]. Plant extracts and essential oils having an antioxidant property due to presence of bioactive compound which exhibit bioactivity due to its different phenolic compounds (Jiang and Xiong, 2016) [35]. Phenolic substances found in plant extracts include flavonoids such as quercetin, catechin, kaempferol, and hesperetin, or phenolic acids including rosmarinic acids, caffeic acids, and gallic acid as well as phenolic diterpenes like carnosol and carnosic acid (Beya *et al*., 2021) [15]. The essential oils of marjoram, peppermint, lavender, thyme, clove, cinnamon, and oregano also contain volatile oils that consist of phenolic molecules including menthol, eugenol, and thymol (Chen *et al*., 2023) [22].

Phenolic compound present in plant extracts and essential oils having at least one aromatic ring along with two hydroxy group for optimal antioxidant activity (Awad *et al*., 2022) [10]. This bioactive compound reported various mechanism of antioxidant activity (Zeb, 2021) [73].

- **Hydrogen atom transfer (HAT):** In HAT mechanism hydrogen atom consisting of proton and electron is transfers from antioxidant to free radicals and stabilize free radical by transforming itself into free radical.
- **Single electron transfer (SAT):** In SAT single electron transfer from antioxidant to free radical by formation of anion R, which is stable compound. While, cation antioxidant also stable as well as less reactive.
- **Sequential proton loss electron transfer (SPLET):** In SPLET antioxidant molecule first loses proton to free radical and form anion, then subsequent transfers electron to form stable radical molecule.
- **Metal chelation:** In metal chelation some bioactive compound reacts with metal like iron, copper, and cobalt which present in meat, preventing them participating in to pro-oxidant rection, that generate further free radical.

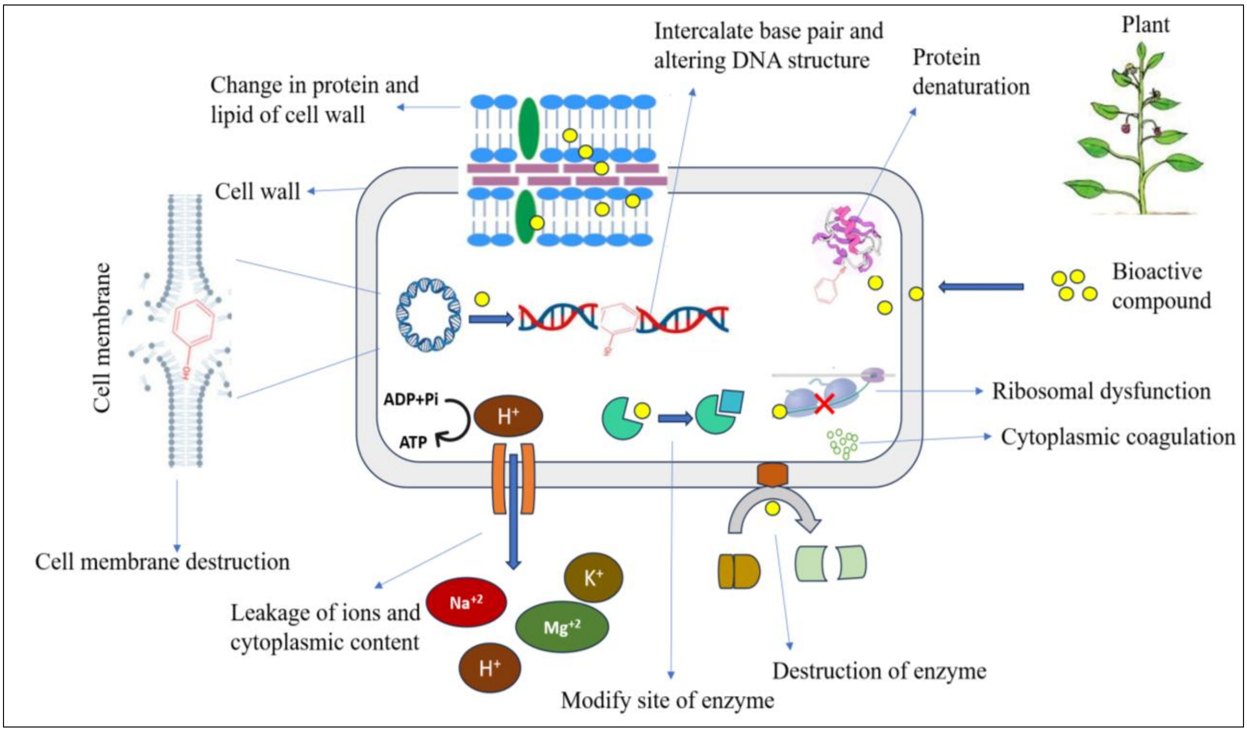


Shindia *et al*. (2024) [62] evaluated polyphenol contents of vegetable peels such as carrot, kiwi, sweet potato, eggplant and red pepper fruit by ethanolic extraction and found that the carrot peel extract exhibit highest antioxidant activity for meat preservation. Rassem *et al.* (2024) [54] examined the antioxidant properties of *Hibiscus Rosa sinensis* flower extract in order to assess its possible use in functional food in the future. They discovered that hibiscus flower methanolic and aqueous extracts had a 72.97% and 80.24% DPPH inhibition activity, respectively. While, the aqueous extract has a higher TPC value (4325.12 mg GAE/100g) than the methanolic extract (3487.05 mg GAE/100g). Bessedik (2021) [14] obtain essential oil from *Cuminum cyminum* (Cumin) by hydro-distillation and evaluated their antioxidant effect by DPPH radical scavenging, which was 318±0.1 IC50 (mg/ml). *In vitro* antioxidant activity of Cinnamon, Clove bud and Ginger essential oil or oleoresin was estimated by Sethunga *et al*. (2024) [59]. The total phenolic content of Cinnamon, Clove bud and Ginger oleoresin was 75.44±5.85 mg GAE/g, 512.69±15.18 mg GAE/g and 734.7±29.8 mg GAE/g, respectively along with essential oil of Cinnamon, Clove bud and Ginger shown a 53.68±0.62%, 88.70±0.46% and 39.48±0.49% DPPH inhibition, respectively.

Mode of action of antimicrobial activity of plant extracts and essential oils

Psychrotrophic bacteria like *Pseudomonas*, lactic acid bacteria including *Lactobacillus* spp., *Lactococcus* spp., *Leuconostoc* spp., toxin producing such as a *Staphylococcus* spp., and *E.coli* as well as anaerobic bacteria such as *Clostridium* spp., *Alcaligenes* spp., *Acinetobacter* spp., *Enterobacteriaceae*, *Aeromonas* spp., are primary meat spoilage microorganism (Marcelli *et al*., 2024) [44]. Microorganism may cause a protein breakdown during storage of meat and meat products can produce volatile organic compounds and biogenic amines. Biogenic amines including inosine and hypoxanthine, which produce unpleasant flavours and bitter taste (Pellegrini *et al*., 2023) [49]. Plant extract and essential oil are exposing antibacterial activity due to its polyphenol contents and lipophilic nature, respectively. In addition, it efficiently controls the growth of food borne microbes and extend shelf life of meat by putting off the production of biogenic amines (Šimat *et al*., 2024) [64]. Gram positive bacteria are more liable to action of plant extracts and essential oils constitutes, while gram negative bacteria having a lipopolysaccharide layer in their call wall, which restrict the diffusion of hydrophobic compound (Campolina *et al*., 2023) [17]. The antibacterial action of plant extracts as well as essential oils is entirely reliant on the OH-group of phenolic molecules.

Bioactive compound of plant extracts and essential oils accumulate on surface of bacteria and inhibiting signal induction as well as cellular transport. Then it also may enter in to cytoplasm of cell and exhibited mechanism of antibacterial activity (Abass *et al*., 2024) [1] *viz* 1) Alteration in membrane permeability, which leads to leakage of ions such as Na^{+2}, K^{+}, and H^{+} and cell contents. 2) Electron delocalization produces the depolarization that reduce proton motive force then subsequently reduces the pH gradient across the membrane. 3) Destruction of cell membrane. 4) Cytoplasmic coagulation-It refers to the solidification or aggregation of cytoplasmic components, which disrupts the structure as well as function of cell. 5) Ribosomal dysfunction which cause an alteration in protein synthesis 6) Destruction of enzymes of ATP and DNA synthesis as well as modified the active site of enzymes. 7) deformation of the lipids and proteins in the cell wall (Aguirre *et al*., 2023; Khwaza & Aderibigbe, 2025) [3, 38]. Using bioactive compound with active packaging improves the storage stability by slow down lipid peroxidation and inhibiting microbial growth (Nian *et al*., 2024) [48].



Shindia *et al*. (2024) [62] assessed the antimicrobial activity of carrot peel extract and revealed that, 20 µg/mL minimum inhibitory concentration demonstrates antimicrobial activity against two Gram-positive (Staphylococcus aureus, Bacillus cereus) and two Gram-negative (Salmonella typhi, Escherichia coli) bacteria without causing any bacterial resistance. Rassem *et al*. (2024) [54] evaluated antibacterial activity of *Hibiscus Rosa sinensis* flower extract and resulted that the aqueous extract of the flower show 15mm zone of inhibition against *S. aureus*, 14mm against *E. coli*, and 9mm against *S. typhimurium*. Additionally, the methanolic extract demonstrated 11 mm, 10 mm, 16 mm, and 12.5 mm against *B. cereus, S. aureus, E. coli*, and *K. pneumonia*, respectively. Mutlu-Ingok *et al*. (2021) evaluated antibacterial activity of thyme (*Thymus vulgaris*), oregano (*Origanum vulgare*), ginger (*Zingiber officinale*) and fennel (*Foeniculum vulgare*) essential oils by agar well diffusion and broth microdilution methods. They found 9.2±0.7 to 28.7±2.1 mm zone of inhibition against *C. jejuni* and 14.7±2.0 to 27.8±2.8 mm against *C. coli*.

Natural substances as preservatives in meat and meat products

There are an increasing demand for healthier meat products, that are less processed and utilize natural ingredients instead of synthetic substances (Sirena *et al*., 2024) [65]. The incorporation of plant extracts and essential oils to meat products is natural and effective way to preserve them, through inhibiting the growth and activity of microbes. As well as they also preserve their sensory and physicochemical properties (Campolina *et al*., 2023) [17]. In case of plant-derived natural preservatives, it is necessary to consider the form applied to food, including liquids like essential oils and powders produced via drying methods, while they are usually prepared as extracts with water and organic solvents (Yu *et al*., 2021) [71]. Although it is necessary for antioxidant compounds to come in direct contact with meat for optimal effect. Exposure to external factors such extreme light, oxygen, high pH, and temperature may result in inactivation of antioxidant potential (Cunha *et al*., 2018) [23]. Novel techniques such as active packaging, encapsulation and edible coatings/films, exploit the advantageous effects of antioxidants, while they avoiding the concurrent effects of natural compound on meat quality characteristics (colour, flavour, and taste) that come from mixing the product with natural ingredients and also avert destabilization of products. Additionally, these method reduce the amount of natural antioxidants required, which leads to increase the cost-benefit ratio in meat industry (Ahmed *et al*., 2017) [4].

Edible coatings are thin layers of biopolymer which is applied on the surface of meat products and releasing active agent directly on to surface of food. They are made from natural ingredients like proteins, polysaccharides, lipids and natural oxidants from plant extract and essential oil (Kumar *et al*., 2022) [40]. Edible coating is applied on surface of meat products by spraying, brushing, electro-spraying, and immersion. It acts as moisture barrier and oxygen as well as it having an antioxidant and antimicrobial compound that prevent lipid peroxidation and inhibit growth of microbes to preserve food products (Sen, 2024) [58].

Nanoencapsulation is the process of enclosing active substances like antioxidants or antimicrobial agents within nanoscale structures, which can be incorporated into the meat and meat products (Pisoschi *et al*., 2018) [50]. Protective coating shielding them from degradation factors like heat, light, and oxygen, thus extending the shelf life and maintain quality of the meat by preventing spoilage and oxidation reactions. In addition, encapsulation provides controlled release of the active ingredients (Smaoui *et al*., 2021) [66]. GRAS (generally regarded as safe) materials such as alginate, chitosan, starch, dextrin, xanthan, gellan, lipids, and proteins were nano encapsulated around bioactive compounds by utilizing various methods including spray-drying, extrusion, freeze drying, coacervation, electrospinning and emulsification (Zabot *et al*., 2022) [72]. Nano-encapsulation enhances the efficiency of natural antioxidants in packaging materials by improving their versatility during storage of meat product along with reduce the amount of active natural substance required (Domínguez *et al*., 2018) [25].

Active packaging is an ingenious technology, which refereed as a material or active ingredient that interact with meat products and its environment, either by releasing antioxidant molecules or absorbing unwanted components from products or by trapping pro-oxidant substances to prevent lipid oxidation which cause degradation of meat products (Domínguez *et al*., 2018) [25]. Moreover, it expands shelf life, improve microbiological safety and maintain foods original qualities. Antimicrobial or antioxidant active packaging are commonly utilized by the meat industry through various methods, including incorporating natural preservatives into sachets inside the package, composing packaging films with natural preservatives, and package coated with natural preservatives on the surface of the food (Fang *et al*., 2017) [28]. Natural antioxidant such as a plant extracts and essential oils usually utilized as integral components of the packaging container or polymer film, which exhibiting antioxidant effect by controlled release in package of food (Chang *et al*., 2023) [29].

5.1 Application of plant extracts and essential oils directly on meat and meat products

The application of plant extracts and essential oils directly on meat and meat products has become a significant area of interest in the food industry, particularly in the context of enhancing food safety, improving sensory qualities, and extending shelf life. Some of the major studies of direct application of plant extracts and essential oils to meat and meat product presented in table 1.

Rahman *et al*. (2020) [52] incorporated *M. oleifera* leaves extract into preparation of goat meat nuggets at different concentration and revealed that nuggets having 0.3% leaves extract shown higher sensory score about juiciness, appearance, colour, flavour and tenderness than control group. Free fatty acid, TBARS, total viable count and total yeast and mould count were also significantly (p<0.05) decrease in treated groups in compare to control group during 45 days of storage. On the basis of studies, researcher concluded that the synthetic preservative compound replaces with *M. oleifera* successfully. Francelin *et al*. (2022) [29] prepared chicken mortadella with hydroalcoholic extract of *M. oleifera* leaves and studied their effect on sensory parameter and storage stability of mortadella. They found 1333.84 mg GAE/ml phenolic compounds along with 12.43 mg extract/ml of EC_{50} antioxidant activity in *M. oleifera* leaves extracts. 0.25% incorporated products exhibit antimicrobial quality with comparable change in sensory attributes during refrigeration storage.

Ground pork mixed with 1.0% Arjuna fruit extracts which obtained using different solvents. Treated pork having significantly (p<0.05) lower TBARS, peroxide and carbonyl formation as well as significantly (p<0.05) superior colour with prolong storage stability in comparison to control sample (Chauhan *et al*., 2018) [20]. Birla *et al*. (2019) [16] incorporated ethanolic and aqueous extract of arjuna tree bark in pork emulsion at 1% concentration and found that the treated sample had lower peroxide and TBARS value than control sample along with superior colour stability, excellent oxidative stability, and better microbial quality than the control sample during 9 days of storage under refrigeration conditions.

Aksu *et al*. (2020) [6] evaluated storage stability of beef pastırma prepared with 1% and 1.2% red cabbage water extract and resulted in decrease TBARS and pH value, while non-significant effect on microbiological counts, protein oxidation and moisture content along with higher sensory score in red cabbage extracted treated beef pastrima during 150 days of storage.

Shange *et al*. (2019) [61] incorporated 1% v/v oregano essential oil with black wildebeest muscle and evaluated lipid peroxidation as well as appearance and colour. They found that the TBARS value of treated meat was stabilize at < 9 mg/MDA until the end of storage, while in control, sample it increases from 9 mg/MDA to 19 mg/MDA during storage period. There was improvement in colour and appearance as well as microbial quality of treated meat in comparison to control sample. Researcher concluded oregano essential oil extend the shelf life of treated meat about 3 days.

2% thyme essential oil and 2% acetic acid mix with raw beef meat and evaluated storage stability as well as sensory attributes of meat. Study resulted in significantly reduce the levels of TBARS and extended shelf life up to 15 days at 4°C. In addition, treated beef having a higher overall acceptability with improved flavour and texture. In conclusion, natural and organic preservatives may be used as an alternative to synthetic one to maintain the quality and shelf life of meat and meat products (Asuoty *et al*., 2023) [9].

Plant and EO	Forms	Dose	Products	Storage condition	Ref.
M. oleifera	Leaves extract	0.3%	Goat meat nuggets	45 days 4±1° temp.	(Rahman *et al*., 2020) [52]
	Leaves extract	0.25%	Chicken mortadella	120 days 4° temp.	(Francelin *et al*., 2022) [29]
Terminalia arjuna	Fruit extracts	1%	Ground pork	9 days 4±1° temp.	(Chauhan *et al*., 2018) [20]
	Bark extract	1%	Pork emulsion	9 days 4±1° temp.	(Birla *et al*., 2019) [16]
Red cabbage	Cabbage extract	1% and 1.2%	Beef pastırma	150 days 4° temp.	(Aksu *et al*., 2020) [6]
Oregano	Essential oil	1%	Black wildebeest meat	7 days 2.6±0.6 °C temp.	(Shange *et al*., 2019) [61]
Thyme	Essential oil	2%	Beef meat	15 days 4 °C tem.	(Asuoty *et al*., 2023) [9]

Application of plant extracts and essential oils in form of film/coating on meat and meat products

Chen *et al*. (2021) [21] investigate the effect of chitosan edible coating that comprise of 0.15% oregano essential oil (OEO) or 0.60% cinnamon essential oil (CEO) on quality and shelf life of roast duck slices under modified atmosphere packaging (MAP, 30% CO2/70% N2) during 21 days of storage at 2±2 °C. They resulted that the storage stability was improved by including OEO or CEO, which significantly lowered (p<0.05) total viable count and TBARS value together with extend shelf life about 7 days compared to control one.

Shahvandari *et al*. (2021) [60] studied the effect of cumin essential oil (CEO) in form of chitosan edible coating on the quality and shelf-life chicken meat. They concluded that the chitosan and cumin essential oil inhibiting foodborne pathogenic microorganism, reduce the rate of lipid peroxidation and increase the storage duration of meat at refrigeration storage 4ºC along with improved colour, odour and overall acceptability.

Mehdizadeh *et al*. (2020) [45] investigate physico chemical property and storage stability of beef coated with starch film comprise of a 1% pomegranate peel extract and 2% *hymus kotschyanus* essential oil (TEO) and revealed that beef had an excellent acceptable sensory characteristic together with lower TBARS value at last day of storage period and inhibited growth of *L. monocytogenes* during 21 days of storage at 4 °C. Additionally, the presence of both the oil and the extract increased the impact of films on the other microorganisms.

Xiong *et al*. (2020) [69] implemented 0.5% grape seed extract with 1% chitosan and then combined with 3% gelatine (CHI-GEL) edible coating and studied their impact on sensory attribute as well as shelf life of fresh pork for 21 days. Result shown that treated pork had lower TBARS value than control sample and exhibited antimicrobial and antioxidant capacity along with non-significant (p<0.05) changes in colour or appearance.

Plant and EO	Forms	Dose	Products	Storage condition	Ref.
Oregano Cinnamon (EO)	Coating	0.15%, 0.60%	roast duck slices	21 days 2±2 °C temp.	(Chen *et al*., 2021) [21]
Cumin (EO)	Coating	0.60%	Chicken meat	9 days 4 °C temp.	(Shahvandari *et al*., 2021) [60]
Pomegranate peel extract	Edible film	1%	Beef	21 days 4 °C temp.	(Mehdizadeh *et al*., 2020) [45]
Grape seed extract	Coating	0.5%	Fresh pork	21 days 4 °C temp.	(Xiong *et al*., 2020) [69]

Application of plant extract and essential oils in form of Nano encapsulation on meat and meat products

Rahnemoon *et al*. (2021) [53] prepared alginate Nano spheres consist of 200mg/ml pomegranate (*Punica granatum*) peel extract (PPE) using water in oil type emulsification and external gelation made with calcium chloride nanoparticles. Ratios for alginate: PPE and alginate: calcium chloride were 4:1 and 9:1, respectively. They evaluated antimicrobial activity of chicken meat coated with PPE nanospheres by agar diffusion method and found significantly (p<0.05) higher microbial inhibitory activity due to PPE slowly release during incubation period through nanospheres. So, this novel coating method are used to extend microbiological shelf life as well as it had an ability to serve as an effective antibacterial agent in food. Sarvinehbaghi *et al.* (2021) [56] utilized *Alyssum homolocarpum* (AH) and *Lepidium sativum* seed gum (LS) to encapsulate red onion extract (ROE), which is then can be used to encapsulate beef fillet. Treated products examined for antibacterial and sensory quality at 4 day interval for 20 days during refrigeration storage. Study revealed that the ROE nano-encapsulation decrease microbial load, peroxide value and pH and extend the shelf life of beef fillet with improved sensory characteristic including odour, colour, and taste.

Thyme Essential Oil (TEO) loaded chitosan nanoparticles prepared by oil/water emulsion and ionic gelation, which utilized for beef burgers coating and evaluated for storage stability along with sensory quality. Result shown that treated sausage having lower TBARS value, lesser microbial load, extended shelf life together with desired colour and sensory quality. Even at higher concentration of TEO in coating rejected by consumer due to its stronger flavour (Ghahfarokhi *et al*., 2016) [32].

Lemon essential oil (LEO) having a bioactive compound with antioxidant and antimicrobial activity which facilitate their potential use in nanoencapsulation. Chitosan: modified Starch nanophores comprise of 0.5 and 1% LEO coated on fish burgers and investigate chemical as well as sensory quality of burger, which is enhanced due to decrease in TBARS value as well as treated product had a higher overall acceptability than control. So, researcher suggested application of this novel coating in preservation and shelf life extension of food (Hasani *et al*., 2020) [33].

Plant and EO	Forms	Dose	Products	Storage condition	Ref.
Pomegranate peel extract	Nano-encapsulation	200mg/ml	Chicken meat	14 days 4 °C temp.	(Rahnemoon *et al*., 2021) [53]
Red onion extract	Nano-encapsulation	10 ml	Beef fillet	20 days 4 °C temp.	(Sarvinehbaghi *et al*., 2021) [56]
Thyme essential oil	Nano-encapsulation	0.05%	Beef sausage	8 days 4 °C temp.	(Ghahfarokhi *et al*., 2016) [32]
Lemon essential oil	Nano-encapsulation	0.5 and 1%	Fish burger	18 days 4±1° temp.	(Hasani *et al*., 2020) [33]

Application of plant extract and essential oils in form of active packaging on meat and meat products

Ahsan *et al.* (2024) [5] prepared an active film using Polyvinyl alcohol, carboxymethyl cellulose, glycerol, citric acid, flaxseed gel, and *Phyllanthus wightianus* extract and measure the thickness, opacity, degree of solubility and swelling, water vapor permeability, and antibacterial activity of film, that applied to beef patties which were store at 4 ºC for one month. They concluded that using 3% extract exhibit highest antioxidant activity and reduce the growth of foodborne pathogenic bacteria as well as slow down lipid peroxidation. Film prepared with this novel method extend the shelf life of beef patties. Kanatt and Makwana (2020) [36] developed carboxymethyl cellulose-poly vinyl alcohol packaging Film with citric acid and aloe vera extracts to increase storage life of chicken meat as well as determine physico chemical, antioxidant and antimicrobial property of active film. Citric acid of film enhanced physical characteristics, lowers the water solubility along with aloe vera reduce lipid peroxidation and inhibited microbial spoilage. They revealed that active film with natural substance and citric acid prolong shelf life of minced chicken meat. Black cumin essential oil was incorporated into active polyethylene films assembled with antimicrobial chitosan and alginate coatings using the layer-by-layer (LBL) methodology and examined the impact of the active packaging film on the shelf-life and quality of chicken breast meats kept at 4 °C for 5 days. Multilayer films with Black cumin essential oil exhibited antimicrobial activity against *Staphylococcus aureus* and *Escherichia coli*. With less deviation in pH and less significant colour changes. Study concluded that the incorporating black cumin essential oil in to active packaging may use to maintain quality characteristic and safety of fresh meat and meat products (Konuk Takma and Korel, 2019) [39]. Tabatabaee *et al*. (2020) [67] evaluated effect of *Polylophium involucratum* essential oil by integrated with polylactic acid (PLA) film that includes nano chitosan active film on sensory attributes and microbiological quality of minced lamb during the 11day refrigerated storage together with mechanical and physical properties of films. Study resulted that the 1.5% *P. involucratum* essential oil composite film shown suitable physical and water barrier property as well as retard microbial growth, slow down lipid peroxidation and prolong shelf life of minced meat. In addition to non-significant changes in sensory quality.

Plant and EO	Forms	Dose	Products	Storage condition	Ref.
Phyllanthus wightianus Extract	Active film	3%	Beef patties	1 month 4 °C temp.	(Ahsan *et al*., 2024) [5]
Aloe vera powder	Active film	90ppm	Minced chicken meat	13 days 4 °C temp.	(Kanatt and Makwana, 2020) [36]
Black cumin (EO)	Active film	1%	Chicken breast meat	5 days 4 °C temp.	(Konuk Takma & Korel, 2019) [39]
Polylophium involucratum (EO)	Active film	1.5%	Minced lamb meat	11 days 4±1° temp.	(Tabatabaee *et al*., 2020) [67]

Limitation

The knowledge of biological antioxidant and antimicrobial activity should be expanded among researcher, consumer and meat industry. There is an increase in demand of meat products prepared with natural substance due to their low toxicity and positive effect on health. As demonstrated in the previous review, using plant extracts and essential oils to meat and meat products as antioxidant and antibacterial agents had superior outcomes. However, there are still several technological obstacles in the way of using these natural substances in food (Silva *et al*., 2021) [63].

There are certain limits that must be identified when adding plant extracts and essential oils into food products. The use of natural substances directly on the meat and meat products may entirely change the sensory quality of the products. Plant extracts have characteristic aromas and flavors, while essential oils impart a strong flavour and odour due to their volatile compounds, which make them unacceptable to consumers as well as difficult to apply in meat and meat products (Lourenço *et al*., 2019) [41]. According to Danilović *et al*., (2021) [24] natural compound should be utilized at the lowest possible concentrations. Although, the concentration must be sufficient for the desired antioxidant or antibacterial activity or extended shelf life of products. Additionally, the natural substance interacting with meat components such as a lipids, proteins and moisture, consequently they are less accessible for act on microorganism (Silva *et al.*, 2021) [63]. This limitation may be resolved by application of edible or biodegradable coating or films prepared with biopolymers, encapsulation and nano emulsification (Galindo, 2020; Lovison *et al*., 2017) [31]. Encapsulation and nanoencapsulation often involves specialized materials (like biopolymers, lipids, or synthetic polymers) that can be expensive. The process also requires precision equipment, which are costly to operate and maintain. While, both are complex processes that require careful optimization to ensure consistent quality (Kaushik *et al.*, 2025) [37]. Additionally, depending on the harvesting season, extraction methods, and geographic location, the concentration of bioactive substances in herbs and spices might be different (Adiamo *et al*., 2020) [2]. Furthermore, the quality and amount of the bioactive chemicals in the plant parts (seed, leaf, root bark, and stem bark) may vary (Bernard *et al*., 2014) [13].

Conclusions

Meat and meat products are excellent source of protein, essential amino acids, lapis, vitamins and minerals. High water activity and nutrient content make meat and meat products sensitive to food-borne diseases and spoiling microbes. Consumers do not demand industrial preservatives, which frequently consist of synthetic chemicals, due to health-related concerns. Consequently, plant-derived natural preservatives have been investigated as alternatives to synthetic chemical preservatives. Plants and essential oils are rich source of antioxidant and antimicrobial (phenols, tannins, alkaloids, terpenes, saponins, and coumarins) compound and can be used in meat and meat products. Plant extracts and essential oils can adversely impact the sensory attributes of products if not utilized in appropriate doses. Edible coatings, nanoencapsulation, and active packaging can address food preservation challenges such as off-flavors and premature loss of functionality.

Future prospect

- Synergistic combinations of Essential oils or plant extract with other natural preservatives (e.g., bacteriocins, organic acids) can enhance efficacy of preservation.
- Some essential oils have strong flavors that may alter taste and aroma of meat products. Therefore, optimizing concentration levels for optimal antibacterial activity without affecting meat flavour is essential.
- The meat industry needs to conduct more studies on EO and plant extract interactions with meat matrices and consumer acceptance.
- Future initiatives will concentrate on toxicological research and regulatory approvals from food safety agencies to standardize the application of essential oils and plant extract in meat.

Conflict of Interest

Not available

Financial Support

Not available

References

1. Abass S, Parveen R, Irfan M, Malik Z, Husain SA, Ahmad S. Mechanism of antibacterial phytoconstituents: An updated review. Archives of Microbiology. 2024;206(7):325.
2. Adiamo OQ, Netzel ME, Hoffman LC, Sultanbawa Y. Acacia seed proteins: Low or high quality: A comprehensive review. Comprehensive Reviews in Food Science and Food Safety. 2020;19(1):21-43.
3. Aguirre GO, Vázquez ÁTP, García JRS, Zárate AS, Flores AAO, Campos MRS, *et al*. Using plant-based compounds as preservatives for meat products: A review. Heliyon. 2023;9(6):e17071.
4. Ahmed I, Lin H, Zou L, Brody AL, Li Z, Qazi IM, *et al*. A comprehensive review on the application of active packaging technologies to muscle foods. Food Control. 2017;82:163-78.
5. Ahsan S, Tariq A, Liaqat A, Khaliq A, Farooq MA, Hussain A, *et al*. Development of active packaging film, based on *Phyllanthus wightianus* and their application to meat product preservation. Journal of Food Measurement and Characterization. 2024;18(6):4905-19.
6. Aksu Mİ, Erdemir E, Oz F, Turan E, Gürses M. Effects of cemen paste with lyophilized red cabbage water extract on the quality characteristics of beef pastırma during processing and storage. Journal of Food Processing and Preservation. 2020;44(11):e14897.
7. Amaral AB, Silva MVD, Lannes SCDS. Lipid oxidation in meat: Mechanisms and protective factors: A review. Food Science and Technology. 2018;38(1):1-15.
8. Anonymous. 20th livestock census. All India report. Department of Animal Husbandry & Dairying, Government of India. 2019.
9. Asuoty MSME, Fayza AIET, Arab ANMM. Effect of thyme oil and acetic acid on the quality and shelf life of fresh meat. Journal of Advanced Veterinary Research. 2023;13(6):1079-83.
10. Awad AM, Kumar P, Fetry IMR, Jusoh S, Aziz AMF, Sazili AQ. Overview of plant extracts as natural preservatives in meat. Journal of Food Processing and Preservation. 2022;46(8):e16796.
11. BAHS. Basic Animal Husbandry Statistics. Ministry of Fisheries, Animal Husbandry & Dairying, Government of India; 2024.
12. Batiha GE-S, Hussein DE, Algammal AM, George TT,

Jeandet P, Al-Snafi AE, *et al*. Application of natural antimicrobials in food preservation: Recent views. Food Control. 2021;126:108066.

13. Bernard D, Kwabena AI, Osei OD, Daniel GA, Elom SA, Sandra A. The effect of different drying methods on the phytochemicals and radical scavenging activity of *Cinnamomum zeylanicum*. Journal of Medicinal Plants Research. 2014;4(11):1324-33.
14. Bessedik A. Antibacterial and antioxidant activities of the essential oil of *Cuminum cyminum* seeds. AGROFOR International Journal. 2021;6(1).
15. Beya MM, Netzel ME, Sultanbawa Y, Smyth H, Hoffman LC. Plant-based phenolic molecules as natural preservatives in comminuted meats: A review. Antioxidants. 2021;10(2):263.
16. Birla R, Malav O, Wagh R, Mehta N, Kumar P, Chatli M. Storage stability of pork emulsion incorporated with *Terminalia arjuna* tree bark extract. International Journal of Livestock Research. 2019;9(1):95-109.
17. Campolina G, Cardoso M, Caetano A, Nelson D, Ramos E. Essential oil and plant extracts as preservatives and natural antioxidants applied to meat and meat products: A review. Food Technology and Biotechnology. 2023;61(2):212-25.
18. Chaijan M, Panpipat W. Mechanism of oxidation in foods of animal origin. In: Natural Antioxidants. Apple Academic Press; 2017, p. 21-58.
19. Chang BP, Trinh BM, Tadele DT, Bandara N, Mekonnen TH. Natural antioxidant and antimicrobial agents and processing technologies for the design of active food packaging polymers. Polymer Reviews. 2023;63(4):961-1013.
20. Chauhan P, Pradhan SR, Das A, Nanda PK, Bandyopadhyay S, Das AK. Inhibition of lipid and protein oxidation in raw ground pork by *Terminalia arjuna* fruit extract during refrigerated storage. Asian-Australasian Journal of Animal Sciences. 2019;32(2):265.
21. Chen X, Chen W, Lu X, Mao Y, Luo X, Liu G, *et al*. Effect of chitosan coating incorporated with oregano or cinnamon essential oil on bacterial diversity and shelf life of roast duck in modified atmosphere packaging. Food Research International. 2021;147:110491.
22. Chen X, Shang S, Yan F, Jiang H, Zhao G, Tian S, *et al*. Antioxidant activities of essential oils and their major components. Molecules. 2023;28(11):4559.
23. Cunha LCM, Monteiro MLG, Lorenzo JM, Munekata PES, Muchenje V, Carvalho DFAL, *et al*. Natural antioxidants in processing and storage stability of sheep and goat meat products. Food Research International. 2018;111:379-90.
24. Danilović B, Djordjević N, Milićević B, Šojić B, Pavlić B, Tomović V, *et al*. Application of sage herbal dust essential oils and supercritical fluid extract for the growth control of *Escherichia coli* in minced pork. Food and Bioprocess Technology. 2021;141:110935. *(Journal name corrected)*
25. Domínguez R, Barba FJ, Gómez B, Putnik P, Kovačević BD, Pateiro M, *et al*. Active packaging films with natural antioxidants for meat industry: A review. Food Research International. 2018;113:93-101.
26. Domínguez R, Pateiro M, Gagaoua M, Barba FJ, Zhang W, Lorenzo JM. A comprehensive review on lipid oxidation in meat and meat products. Antioxidants. 2019;8(10):429.
27. Dragoev SG. Lipid peroxidation in muscle foods: Impact on quality, safety and human health. Foods. 2024;13(5):797.
28. Fang Z, Zhao Y, Warner RD, Johnson SK. Active and intelligent packaging in the meat industry. Trends in Food Science & Technology. 2017;61:60-71.
29. Francelin MF, Santos IF, Claus T, Visentainer JV, Feihrmann AC, Gomes RG, *et al*. Effects of *Moringa oleifera* leaves extract on properties of chicken mortadella. Journal of Food Processing and Preservation. 2022;46(4):e16441.
30. FSSAI. Food Safety and Standards Authority of India; 2011.
31. Galindo MV. Methods of incorporation of D-limonene microparticles in edible films. 2020;41(1):43-50.
32. Ghahfarokhi M, Barzegar M, Sahari MA, Azizi MH. Nano encapsulation approach to improve antimicrobial and antioxidant activity of thyme essential oil in beef burgers during refrigerated storage. Food and Bioprocess Technology. 2016;9(7):1187-1201.
33. Hasani SH, Ojagh SM, Ghorbani M, Hasani M. Nano-encapsulation of lemon essential oil approach to reducing the oxidation process in fish burger during refrigerated storage. Journal of Food Biosciences and Technology. 2020;10(1):35-46.
34. Hassani NA, Baraket A, Alem C. Recent advances in natural food preservatives: A sustainable solution for food safety and shelf life extension. Journal of Food Measurement and Characterization. 2025;19:293-315.
35. Jiang J, Xiong YL. Natural antioxidants as food and feed additives to promote health benefits and quality of meat products: A review. Meat Science. 2016;120:107-117.
36. Kanatt SR, Makwana SH. Development of active, water-resistant carboxymethyl cellulose-poly vinyl alcohol-Aloe vera packaging film. Carbohydrate Polymers. 2020;227:115303.
37. Kaushik D, Krishnan H, Kumar M, Oz E, Oz F. Interdisciplinary approaches to encapsulation in food science: Sustainable methods, omics techniques, and industrial applications. In: Basic Protocols in Encapsulation of Food Ingredients. Springer US; 2025. p.153-165.
38. Khwaza V, Aderibigbe BA. Antibacterial activity of selected essential oil components and their derivatives: A review. Antibiotics. 2025;14(1):68.
39. Konuk Takma D, Korel F. Active packaging films as a carrier of black cumin essential oil: Development and effect on quality and shelf-life of chicken breast meat. Food Packaging and Shelf Life. 2019;19:210-217.
40. Kumar L, Ramakanth D, Akhila K, Gaikwad KK. Edible films and coatings for food packaging applications: A review. Environmental Chemistry Letters. 2022;20(1):875-900.
41. Lourenço SC, Moldão-Martins M, Alves VD. Antioxidants of natural plant origins: From sources to food industry applications. Molecules. 2019;24(22):4132.
42. Lovison M, Marostegan LF, Peres MS, Menezes IF, Ghiraldi M, Rodrigues RA, *et al*. Nanoemulsions encapsulating oregano essential oil: Production, stability, antibacterial activity and incorporation in chicken pâté. Food Science and Technology. 2017;77:233-240.
43. Manessis G, Kalogianni AI, Lazou T, Moschovas M, Bossis I, Gelasakis AI. Plant-derived natural antioxidants in meat and meat products. Antioxidants. 2020;9(12):1215.

44. Marcelli V, Osimani A, Aquilanti L. Research progress in the use of lactic acid bacteria as natural bio preservatives against *Pseudomonas* spp. in meat and meat products: A review. Food Research International. 2024;196:115129.
45. Mehdizadeh T, Tajik H, Langroodi AM, Molaei R, Mahmoudian A. Chitosan-starch film containing pomegranate peel extract and *Thymus kotschyanus* essential oil can prolong the shelf life of beef. Meat Science. 2020;163:108073.
46. Moore K, Roberts LJ. Measurement of lipid peroxidation. Free Radical Research. 1998;28(6):659-671.
47. Ingok MA, Catalkaya G, Capanoglu E, Guler KF. Antioxidant and antimicrobial activities of fennel, ginger, oregano and thyme essential oils. Food Frontiers. 2021;2(4):508-518.
48. Nian L, Wang M, Sun X, Zeng Y, Xie Y, Cheng S, *et al*. Biodegradable active packaging: Components, preparation, and applications in the preservation of postharvest perishable fruits and vegetables. Critical Reviews in Food Science and Nutrition. 2024;64(8):2304-2339.
49. Pellegrini M, Barbieri F, Montanari C, Iacumin L, Bernardi C, Gardini F, *et al*. Microbial spoilage of traditional goose sausages produced in a northern region of Italy. Microorganisms. 2023;11(8):1942.
50. Pisoschi AM, Pop A, Cimpeanu C, Turcuş V, Predoi G, Iordache F. Nano encapsulation techniques for compounds and products with antioxidant and antimicrobial activity: A critical view. European Journal of Medicinal Chemistry. 2018;157:1326-1345.
51. Prasetyo WE, Kurniansyah V, Firdaus M, Wibowo FR, Hadda TB, Almalki FA, *et al*. Free radical scavenging behaviour of the plant-beneficial secondary metabolite 2,4-diacetylphloroglucinol derivatives under physiological conditions: A joint experimental and theoretical study. Journal of Molecular Structure. 2024;1302:137498.
52. Rahman MH, Alam MS, Monir MM, Rahman SME. Effect of *Moringa oleifera* leaf extract and synthetic antioxidant on quality and shelf-life of goat meat nuggets at frozen storage. International Journal of Food Research. 2020;7(4):34-45.
53. Rahnemoon P, Jamab SM, Bostan A, Mansouri E. Nano-encapsulation of pomegranate (*Punica granatum* L.) peel extract and evaluation of its antimicrobial properties on coated chicken meat. Food Bioscience. 2021;43:101331.
54. Rassem HH, Khamidun MHB, Ali UFM, Hadibarata T, Alrabie NA. Comprehensive analysis of antioxidant and antibacterial activities of water and methanol extracts of Hibiscus flower. Journal of King Saud University Science. 2024;36(11):103506.
55. Reitznerová A, Šuleková M, Nagy J, Marcinčák S, Semjon B, Čertík M, *et al*. Lipid peroxidation process in meat and meat products: A comparison study of malondialdehyde determination between modified 2-thiobarbituric acid spectrophotometric method and reverse-phase high-performance liquid chromatography. Molecules. 2017;22(11):1988.
56. Sarvinehbaghi MB, Ahmadi M, Shiran M, Azizkhani M. Antioxidant and antimicrobial activity of red onion (*Allium cepa* L.) extract nanoencapsulated in native seed gums coating and its effect on shelf-life extension of beef fillet. Journal of Food Measurement and Characterization. 2021;15(5):4771-4780.
57. Schirone M, Esposito L, D'Onofrio F, Visciano P, Martuscelli M, Mastrocola D, *et al*. Biogenic amines in meat and meat products: A review of the science and future perspectives. Foods. 2022;11(6):788.
58. Sen M. Food coatings and preservation technologies. John Wiley & Sons; 2024.
59. Sethunga SMMC, Ranaweera KKDS, Munaweera I, Gunathilake KDPP. *In vitro* antioxidant activity of essential oils and oleoresins of cinnamon, clove bud, ginger and their synergistic interactions. Ceylon Journal of Science. 2024;53(1):5-13.
60. Shahvandari F, Khaniki GJ, Shariatifar N, Mahmoudzadeh M, Sani MA, Alikord M, *et al*. Chitosan/cumin (*Cuminum cyminum* L.) essential oil edible biodegradable coating: Its effect on microbial, physical and sensory properties of chicken meat during refrigeration. 2021;13(1):75-89.
61. Shange N, Makasi T, Gouws P, Hoffman LC. Preservation of previously frozen black wildebeest meat (*Connochaetes gnou*) using oregano (*Origanum vulgare*) essential oil. Meat Science. 2019;148:88-95.
62. Shindia A, Shafi AS, Atef A, Osman A, Sitahy B, Sitohy M. Antibacterial activity of carrot peel HCl-ethanol extracts and its potential application in meat preservation. Food Science and Technology. 2024;207:116638.
63. Silva BD, Bernardes PC, Pinheiro PF, Fantuzzi E, Roberto CD. Chemical composition, extraction sources and action mechanisms of essential oils: Natural preservative and limitations of use in meat products. Meat Science. 2021;176:108463.
64. Šimat V, Barbieri F, Montanari C, Gardini F, Skroza D, Mekinić IG, *et al*. Bio preservation of fish. In: Novel Approaches in Bio preservation for Food and Clinical Purposes. CRC Press; 2024, p. 98-129.
65. Sirena JT, Dal Magro J, Junges A, Steffens C, Cansian RL, Paroul N. Characterization of free and encapsulated cinnamon and clove essential oils for enhancing fresh sausage quality: A natural substitute for synthetic preservatives. Food Bioscience. 2024;61:104649.
66. Smaoui S, Hlima HB, Braïek OB, Ennouri K, Mellouli L, Khaneghah AM. Recent advancements in encapsulation of bioactive compounds as a promising technique for meat preservation. Meat Science. 2021;181:108585.
67. Tabatabaee AS, Khanjari A, Teimourifard R, Yarmahmoudi F. Development of a novel active packaging film to retain quality and prolong the shelf life of fresh minced lamb meat. Journal of Food Processing and Preservation. 2020;44(11):e14880.
68. Valgimigli L. Lipid peroxidation and antioxidant protection. Biomolecules. 2023;13(9):1-15.
69. Xiong Y, Chen M, Warner RD, Fang Z. Incorporating nisin and grape seed extract in chitosan-gelatine edible coating and its effect on cold storage of fresh pork. Food Control. 2020;110:107018.
70. Ye Q, Tan J, He X, Wang C, Liu X, Li C, *et al*. Effect of lipase and lipoxygenase on lipid metabolism and the formation of main volatile flavour compounds in fermented fish products: A review. International Journal of Food Science & Technology. 2024;59(3):1248-1259.
71. Yu HH, Chin YW, Paik HD. Application of natural preservatives for meat and meat products against food-borne pathogens and spoilage bacteria: A review. Foods. 2021;10(10):2418.
72. Zabot GL, Rodrigues SF, Ody PL, Tres VM, Herrera E, Palacin H, *et al*. Encapsulation of bioactive compounds

for food and agricultural applications. Polymers. 2022;14(19):4194.
73. Zeb A. Phenolic antioxidants in foods: Chemistry, biochemistry and analysis. Springer International Publishing; 2021, p. 239-280.

How to Cite This Article
Sabalpara TA, Sindhi SH, Bariya AR, Patel AS, Kathiriya JB. Essential oil and plant extract as natural preservatives in meat and meat products. International Journal of Veterinary Sciences and Animal Husbandry. 2025;SP-10(12):23-33.