


A Systematic Review: Effectiveness of Herbs and Spices as Natural Preservatives to Enhance Meat Shelf-Life

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ABSTRACT

Background: Meat and animal products are essential sources of nutrients but are prone to microbial contamination, leading to food spoilage and food-borne illnesses. The use of synthetic preservatives has raised health concerns, prompting interest in natural alternatives.

Objective: This study systematically reviews the effectiveness of herbs and spices as natural preservatives to enhance the shelf-life of meat products.

Methods: A systematic search was conducted using PubMed, Google Scholar, and Science Direct, adhering to PRISMA guidelines. Studies published between 2002 and 2024 were reviewed, focusing on the antimicrobial activity of natural preservatives in meat. Eleven relevant studies were selected for analysis.

Results: The review found that herbs such as thyme, rosemary, and cinnamon significantly extended the shelf-life of meat, with thyme showing the most potent effect, extending shelf-life up to 60 days. Combinations of herbs were found to be more effective than individual herbs. Natural preservatives also demonstrated fewer health risks compared to synthetic preservatives.

Conclusion: Herbs and spices are effective natural preservatives that can enhance the shelf-life of meat products while minimizing health risks associated with synthetic preservatives.

INTRODUCTION

Food-borne illnesses continue to pose significant challenges in several underdeveloped nations. As awareness of chemical preservatives and their potential health risks grows globally, consumers are increasingly turning towards natural preservatives that are generally recognized as safe (GRAS) (1). The widespread prevalence of food-borne pathogens makes food a common vector for illness transmission, particularly in raw meat and meat products (2). One such pathogen, *Staphylococcus aureus*, can be transmitted by human contact during the preparation, processing, and even post-cooking stages. The heat-stable toxins produced by *S. aureus* in contaminated meat can lead to serious outbreaks of food poisoning, highlighting the critical role of proper food handling and preservation techniques (3).

The fecal contamination of meat and poultry by Enterobacteriaceae species, including *Salmonella*, *Escherichia coli*, *Proteus*, and *Klebsiella*, further underscores the need for stringent hygiene measures during meat preparation. Bacterial presence can be assessed through total coliforms, total Enterobacteriaceae, and aerobic plate counts, which are key indicators of hygiene and safety in meat processing (4). In response to growing concerns about meat quality and safety, various advancements in preservation methods have been developed. These include thermal treatment, disinfection, low-heat storage, vacuum packing, and the use of preservatives. However, no single method offers complete

protection. Currently, synthetic preservatives such as butylated hydroxyanisole (BHA), butylated hydroxytoluene (BHT), and tertiary butyl hydroquinone are commonly employed to inhibit microbial growth and extend meat shelf life (5). Despite their effectiveness, these synthetic preservatives are associated with adverse health effects, including respiratory disorders like pneumonia and bronchitis, hyperactivity in children, and potential harm to heart tissues, especially in the elderly. Notably, BHA and BHT have been identified as carcinogenic food additives (6). The increasing consumer demand for healthier products, free from conventional chemical preservatives, has led to a growing interest in natural alternatives. For centuries, dietary herbs and spices have been used globally, particularly in China and India, to enhance the sensory qualities of food and extend its shelf life (7). These natural ingredients, including garlic, basil, mint, cumin, and thyme, are derived from tropical plants known for their antibacterial properties. Essential oil extracts from these spices, such as *Thymus vulgaris*, rosemary, and oregano, have demonstrated strong antimicrobial and antioxidant activities (9). Edible films and coatings, which act as barriers against gases, water, and microorganisms, often incorporate these extracts to further enhance their preservative effects (11).

In addition to their antimicrobial properties, herbs and spices contain bioelements, including macro- and microelements, that play crucial roles in various biochemical processes. These bioelements help regulate osmotic pressure and influence enzyme activity,

contributing to the overall preservation of food products (12). However, food standards laws limit the use of multiple preservatives in a single food item, which raises concerns for consumers who may be exposed to different substances through the consumption of various products (13). Lipid oxidation, a common issue in meat products, can lead to the formation of peroxides and cholesterol, which in turn may cause pathological changes in the alimentary tract and reduce the shelf life and sensory qualities of meat (14, 16).

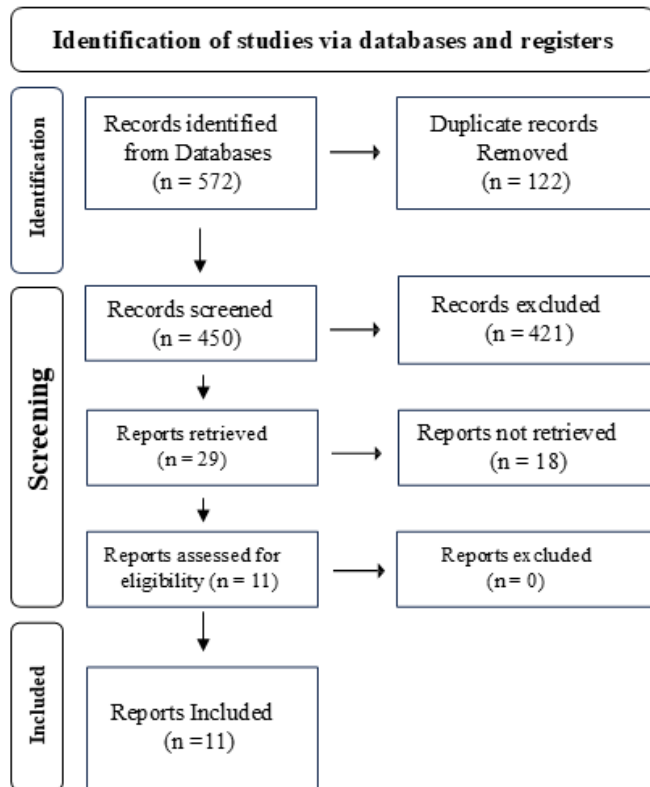


Figure 1 PRISMA Flowchart

Given these concerns, this systematic review aims to evaluate the effectiveness of natural preservatives in comparison to synthetic ones for meat preservation, utilizing the PICO criteria (Population: Natural Preservatives; Intervention: Analysis of various herbs and spices as natural preservatives; Comparison: Between synthetic and natural preservatives; Outcomes: Shelf life of meat). The goal is to provide a comprehensive analysis of the potential benefits and limitations of natural preservatives in extending the shelf life and ensuring the safety of meat products.

MATERIAL AND METHODS

The methodology of this systematic review adhered strictly to the PRISMA guidelines, which outline a comprehensive approach for reporting systematic reviews and meta-analyses. The electronic search was conducted using three major databases: PubMed, Science Direct, and Google Scholar. The search strategy employed a combination of keywords, including "antimicrobial activity," "cytotoxicity," "meat preservation," and "natural spices" or "natural plant extract." Boolean operators "AND" and "OR" were used to refine the search criteria. The search was confined to human studies published between 2002 and 2024, ensuring

that only relevant and recent literature was considered. Additionally, the search was limited to patents and citations to maintain a focus on original research findings.

The study selection process was rigorous, primarily focusing on original publications that evaluated the efficacy of various spices and herbs in preserving meat and perishable foods by assessing their antimicrobial activity and shelf-life extension properties. To meet the objectives of the systematic review, specific inclusion criteria were established. These criteria required that all research papers be published in English and be restricted to natural preservatives, such as herbs and spices. Only articles published within the specified timeframe were considered. The studies needed to include detailed datasets specifying the types of natural extracts used, the methods for detecting the preservatives, and their effects on meat preservation. Conference papers from PubMed and Science Direct were also included if they met the aforementioned criteria.

Exclusion criteria were equally stringent to avoid incorporating irrelevant information. Studies published in languages other than English were excluded, as were those focused on preservatives derived from non-meat sources, such as fruit peels. Trials involving non-perishable food items were also excluded from consideration. Research articles, systematic reviews, meta-analyses, theses, dissertations, letters, editorials, abstracts, unpublished research, and case reports were omitted to ensure the inclusion of only the most pertinent and original research findings in this systematic review.

Data extraction was performed meticulously, with each selected study undergoing a thorough evaluation of key parameters, including the principal author, publication year, study objectives, methodology, findings, and conclusions. The methodology sections of the selected articles provided detailed descriptions of the natural extracts used, the types of pathogens they targeted, and the experimental procedures employed to assess their efficacy. The limitations of each study were also noted and discussed in a summary table, along with suggestions for future research directions.

Quality appraisal of the included studies was conducted to assess the methodological rigor and potential biases within the research. This appraisal involved evaluating the study design, sample size, statistical analysis, and the clarity of reported outcomes. Studies were assessed based on criteria such as randomization, blinding, and the completeness of follow-up. The quality appraisal ensured that the studies included in the systematic review met high standards of scientific integrity and provided reliable data for analysis.

Data synthesis was carried out by summarizing the findings from the included studies, focusing on the effectiveness of various natural preservatives in extending the shelf life of meat and inhibiting the growth of foodborne pathogens. The synthesis process involved comparing the results of different studies, identifying trends, and drawing conclusions based on the collective evidence. The ethical considerations adhered to the principles outlined in the Declaration of Helsinki, ensuring that all included studies

were conducted with respect for human participants and that ethical standards were maintained throughout the research process (36).

RESULTS

The systematic review began with a comprehensive search of multiple databases, including PubMed, Science Direct, and Google Scholar. The search yielded a total of 572 publications from Google Scholar alone. Articles from PubMed and Science Direct were also considered, although many were excluded during the review process to eliminate duplicates. Ultimately, 450 articles were shortlisted after this initial phase of exclusion. The final stage of article selection involved a thorough review of the titles, abstracts, and full-text PDFs, which led to the identification of 11 relevant studies that met the inclusion criteria. These studies were selected based on their focus on the use of natural preservatives, including herbs and spices, and their effectiveness in extending the shelf life of meat and combating foodborne pathogens.

Among the studies reviewed, several herbs and spices were highlighted for their significant impact on meat preservation. For instance, thyme was found to be particularly effective, extending the shelf life of meat up to 60 days due to its potent antibacterial properties. However, not all herbs demonstrated the same level of effectiveness. Herbs such as sumac, basil, and tarragon were noted to have shorter shelf lives, around 6 days, indicating that not all natural preservatives are equally effective in preserving meat. The review also identified that certain combinations of herbs and spices, such as *Thymus daenensis* with cinnamon and rosemary or thyme with rosemary, were more effective in extending the shelf life of meat than when used individually. These combinations should be considered for optimal meat preservation.

In addition to natural preservatives, the review also examined the efficacy of synthetic preservatives. It was found that some synthetic preservatives were more effective in increasing the shelf life of meat for longer periods. However, these preservatives also came with

several side effects, which raises concerns about their use. For example, butylated hydroxytoluene (BHT) was found to extend the shelf life of meat up to 60 days, whereas residual nitrite and potassium sorbate extended it to 27 and 24 days, respectively. While BHT was the most effective among the synthetic preservatives reviewed, its potential health risks underscore the preference for natural alternatives.

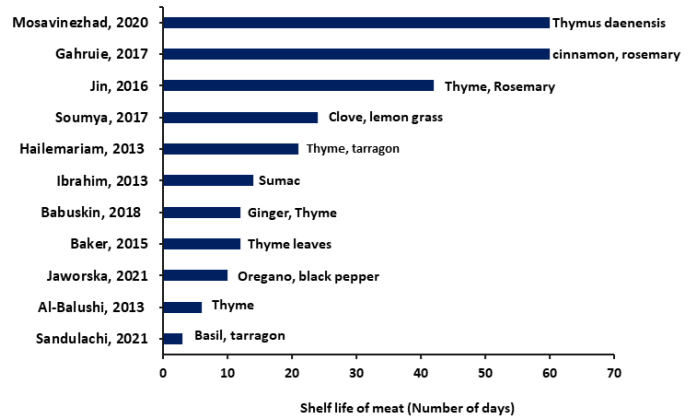


Figure 2 Different studies showing the effectiveness of natural preservatives used to enhance the shelf life of meat.

The review also provided a comparison of various natural preservatives in their effectiveness against foodborne pathogens and in extending the shelf life of meat products. For instance, Shirazi thyme extract was noted to have the longest shelf life of up to 60 days, demonstrating its strong preservative qualities, making it ideal for meat preservation. Thyme, with its notable antibacterial properties, provided a substantial shelf life of 42 days. Rosemary extracts, though not as potent as thyme, still significantly extended the freshness of meat up to 28 days. The mixture of clove and cinnamon extracts resulted in a 24-day shelf life when combined, though this was less effective than thyme and rosemary. The combination of ginger, thyme, and marjoram, while beneficial, offered the shortest shelf life extension of 21 days, indicating that these extracts may be less effective when combined compared to some individual herbs

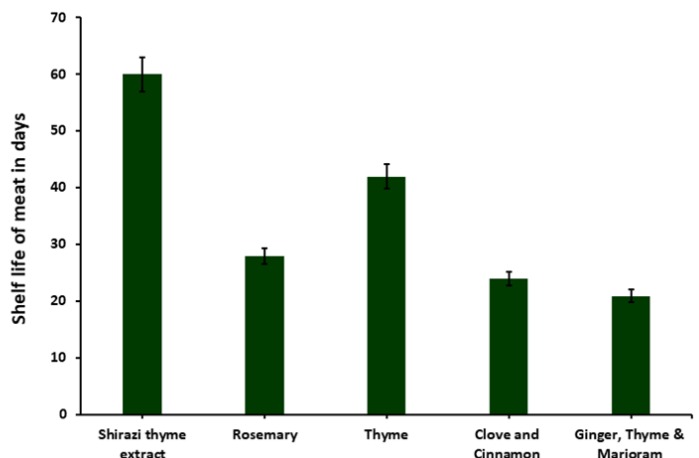
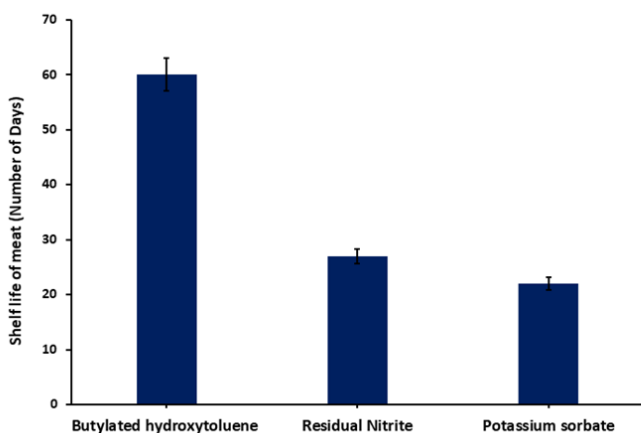


Figure 3 Comparison of Synthetic and Natural Preservatives Based on Their Shelf-Life Extension of Meat

This systematic review underscores the potential of natural preservatives, particularly herbs and spices, in enhancing

the shelf life of meat while also presenting a safer alternative to synthetic preservatives.

Table 1 Study Characteristics

Author & Year	Objective	Methodology	Type of Extract	Shelf Life	Natural Preservative	Result	Conclusion
Al-Balushi, 2013 (17)	Decide antibacterial activity and cytotoxicity	Disc diffusion method, cytotoxicity by brine shrimp	Petroleum ether, chloroform, hydro alcoholic	6 days at 4°C	Thyme (Thymus vulgaris L.)	Inhibitory zones of 7-20 mm	Effective in pinpointing substances causing cytotoxic activity
Baker, 2015 (18)	Evaluate antibacterial and antioxidant properties of minced lamb and chicken	HPLC, microbial count (TPC), MDA	Aqueous, ethanolic extract	12 days at 4°C	Thyme leaves	Delayed oxidative rancidity and microbiological growth	Thyme addition (500 ppm) is beneficial against oxidation and microbial growth
Babuskin, 2018 (19)	Assess phenolic, flavonoid, antioxidant, and antibacterial potentials	Antioxidant, antimicrobial activity	Aqueous thyme leaves powder	12 days at 4°C	Ginger, Thyme, Marjoram	Mixed extract delayed lipid and protein oxidation, suppressed microbial development	Mixed extract (ME) is effective in prolonging shelf life during cold storage
Ibrahim, 2013 (20)	Assess antibacterial, antioxidant, preservation qualities of thyme and sumac	HPLC, agar wall diffusion, MIC method, DPPH assay	Hot water extract	2 weeks at 4°C	Thyme, Sumac	Resistant bacteria (<i>B. subtilis</i>) showed reduction	Potential source of natural antioxidants and antimicrobial agents for meat preservation
Hashemi, 2017 (21)	Evaluate rosemary, cinnamon, and Shirazi thyme's effect on BHT oxidation	DPPH, burger preparation, lipid oxidation, pH	Aqueous extract	60 days at -18°C	Shirazi thyme, Cinnamon, Rosemary	Natural extracts could substitute BHT	Effective natural preservatives compared to BHT
Jin, 2016 (22)	Examine thyme and rosemary combination's impact on sausage quality	TBARS, pH, residual nitrates, TPC, sensory evaluation	Powder of rosemary, thyme	6 weeks at 10°C	Thyme, Rosemary	Reduced TPC, lactic acid bacteria; enhanced antioxidant activity	Strong dietary bioactive components improving shelf life and antimicrobial activity
Jaworska, 2021 (23)	Evaluate effect of pepper, thyme, oregano on minced poultry meat stability	Antimicrobial activity by TVC, sensory evaluation	Dry herbs, herbal extract	10 days at 4°C	Oregano, Thyme, Black Pepper	Antibacterial, antioxidant properties preserved meat quality	Dried herbs serve as effective antioxidants, antimicrobials, and preservatives for poultry meat products
Sandulachi, 2021 (24)	Investigate microbiological and antioxidant characteristics of tarragon, thyme, and basil	Antimicrobial, antioxidant activity	Lyophilized hydroalcoholic extracts	72 hours at 37°C	Basil, Thyme, Tarragon	Reduced Salmonella abony infestation by 62%-84%	Effective in controlling pathogenic microorganisms in meat products
Hailemariam, 2013 (25)	Evaluate thyme's preservative effect on soybean oil, butter, meat	Antioxidant, antimicrobial activity by ATVC	Ethanol extract	3 weeks at 4°C	Thyme (Thymus schimperi R.)	Reduced microbial, fungal, and yeast counts	Demonstrated preservation and antioxidant activity in meat, butter, and soybean oil
Mosavinezhad, 2020 (26)	Assess antibacterial and antioxidant properties of <i>T. daenensis</i> and <i>C. sinensis</i>	pH, TVN, TBARS, microbial counts, sensory characteristics	Ethanolic extract	60 days at -18°C	Thymus daenensis, Camellia sinensis	Suitable as natural preservatives with strong properties	First report demonstrating effectiveness in preserving chicken meat using these extracts
Soumya, 2017 (27)	Compare natural vs synthetic preservatives in muffins	Microbial load analysis, sensory evaluation	Aqueous extract	24 days at room temperature	Clove, Cinnamon (CC), Lemongrass	Controlled microbial growth in muffins without harmful microorganisms	Natural ingredients like CC and LG help regulate microbial growth and extend shelf life

DISCUSSION

Meat and meat products are rich sources of protein, vital amino acids, vitamins, and minerals, making them important nutrient providers. However, due to their high water activity and nutrient content, they are particularly susceptible to contamination by various spoilage microbes and food-borne pathogens. Food-borne illnesses remain a major concern for consumers and food safety authorities because of the excessive food spoilage associated with these products. Natural preservatives have emerged as an alternative to chemical preservatives for enhancing food safety and extending the shelf life of food products. This systematic review aimed to evaluate the literature on the effectiveness of natural preservatives in extending the shelf life of meat and other food products. Natural preservatives not only help to extend the shelf life of food by preventing microbial development, but they also retain the original texture and flavor of the products without allowing them to spoil.

Previous studies have highlighted thyme as an aromatic plant used both as a spice and for health-related purposes. Thyme has preservative, antioxidant, antifungal, and antibacterial properties (28). Another study reported that cinnamon contains cinnamaldehyde, a compound with a high electronegativity (50.5%), found abundantly in cinnamon bark. These electronegative substances disrupt biological processes that involve electron transfer and react with nitrogen-containing components such as proteins and DNA, thereby inhibiting the growth of microorganisms in meat (29). Both natural and synthetic preservatives are effective in inhibiting the growth of food-borne pathogens. Synthetic preservatives like butylated hydroxyanisole (BHA) and butylated hydroxytoluene (BHT) have been widely used to stabilize poultry meat against lipid oxidation, with a shelf life extension of up to 2 weeks (30, 31). However, other studies have reported that the consumption of preservatives like potassium sorbate may lead to anxiety, and there has been an ongoing discussion about the potential of these preservatives to promote hyperactivity, particularly in children (32, 33). Furthermore, safety concerns regarding their potential to cause chronic diseases such as cancer have limited their use in food products. Previous research has shown that a number of artificial preservatives, including formaldehyde, nitrates, sorbates, sulfites, parabens, BHT, BHA, and others, can pose significant health risks, including cancer, neurological damage, hyperactivity, and hypersensitivity (34). Additionally, BHT, BHA, and sodium nitrite have been linked to further health issues, such as endocrine disruption, lung and skin toxicity, and organ distribution. Sodium nitrite, while essential for controlling the germs that cause botulism, can react with proteins or with heat during cooking to create cancer-causing N-nitrosamines (35). Several natural herbs and spices have been studied for their preservative properties, all of which have been found to significantly inhibit the growth of pathogenic microorganisms, though the antimicrobial potential of these natural substances can vary. The comparison of different

natural herbs, plants, and spices revealed that while natural preservatives are effective in inhibiting pathogens, their antimicrobial action can differ significantly from one to another. Commonly found spices and herbs with potent antibacterial and antioxidant properties include clove, cinnamon, and oregano (39, 40). These natural substances contain phytochemicals such as eugenol, carvacrol, and cinnamaldehyde, which contribute to their antimicrobial action. Phytochemicals also offer various health benefits, including reduced risks of cancer, heart disease, stroke, and protection against Alzheimer's disease, cataracts, and some age-related functional impairments (41, 42). Therefore, this systematic review concludes that natural herbs and spices such as clove, ginger, thyme, marjoram, and rosemary provide notable preservation and significantly extend the shelf life of meat. In contrast, although synthetic preservatives like BHT can extend the shelf life of meat, they carry several health risks. As a result, it is recommended to use natural herbs and spices rather than synthetic chemicals in food preservation to avoid the risk of various complications and diseases.

CONCLUSION

In conclusion, this systematic review demonstrates that spices and herbs used as natural preservatives can effectively preserve meat and enhance its shelf life. While synthetic preservatives can also reduce food spoilage and kill pathogenic microorganisms, they pose adverse side effects on human health and reduce the quality of meat products. Synthetic food preservatives can disrupt dietary balance when they interact with the body's biological components. Therefore, natural food preservatives that are generally recognized as safe (GRAS) should be prioritized if the addition of food additives is necessary. This systematic review identifies numerous natural preservatives that can prevent the growth of bacteria responsible for spoilage and food-borne diseases. These naturally derived active compounds offer a promising opportunity for effective bio-preservation of meat products that are chemical-free, environmentally friendly, and cause minimal or no side effects to human health. However, further studies are necessary to establish these practices as the new standard for future generations.

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