ENHANCING FOOD SAFETY IN MEAT AND MEAT PRODUCTS: THE COMBINED ANTIMICROBIAL AND ANTIOXIDANT EFFECTS OF MORINGA, GINGER, AND OLIVE AGAINST ESKAPE PATHOGENS

Mejora de la seguridad alimentaria en la carne y los productos cárnicos: los efectos antimicrobianos y antioxidantes combinados de la moringa, el jengibre y la oliva contra los patógenos de escape

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RESUMEN

La contaminación alimentaria continúa siendo un problema crítico de salud pública a nivel mundial, impactando significativamente tanto a la industria alimentaria como a los consumidores. Aunque se han utilizado aditivos sintéticos para enfrentar este desafío, sus efectos perjudiciales potenciales sobre la salud humana y la creciente preferencia de los consumidores por eliminar o sustituir estos compuestos por alternativas naturales, han llevado a un interés creciente entre los investigadores en identificar alternativas naturales y seguras que mejoren la seguridad alimentaria y la salud pública.

En este contexto, la moringa, el jengibre y el olivo han emergido como opciones prominentes debido a sus perfiles de seguridad naturales y su potencial como suplementos alimenticios. Estas plantas se destacan particularmente por sus propiedades antimicrobianas, antioxidantes y antiinflamatorias, especialmente contra los patógenos ESKAPE, grupo de seis especies bacterianas (*Enterococcus faecium, Staphylococcus aureus, Klebsiella pneumoniae, Acinetobacter baumannii, Pseudomonas aeruginosa* y *Enterobacter* spp.) reconocidas como bacterias críticas por su alta resistencia a los antibióticos y su virulencia, representando una amenaza significativa en entornos hospitalarios, siendo los principales causantes de infecciones nosocomiales.

Además, estudios independientes han resaltado las propiedades anticancerígenas de estas plantas. Sin embargo, a pesar de las amplias actividades biológicas atribuidas a la moringa, el jengibre y el olivo, existe una brecha significativa en la literatura con respecto a sus efectos combinados en la seguridad alimentaria, especialmente en lo que respecta a los productos cárnicos. Este estudio tiene como objetivo subrayar la importancia de estas tres plantas en la mejora de la seguridad alimentaria, con un enfoque particular en su aplicación potencial en la industria cárnica.

Palabras clave: *Moringa Oleifera*; Gengibre; Olivo; bacterias ESKAPE;

ABSTRACT

Food-borne pathogens remain a critical global public health issue, significantly impacting both the food industry and consumers. While synthetic additives have been employed to address this challenge, their potential side effects on human health, along with a growing consumer preference for their elimination or replacement with natural alternatives, have spurred increased interest among researchers in identifying safe, natural options that enhance food safety and public health.

In this context, moringa, ginger, and olive have emerged as prominent options due to their natural safety profiles and potential as food supplements. These plants are particularly notable for their antimicrobial, antioxidant, and anti-inflammatory properties, especially against ESKAPE pathogens, a group of six species (*Enterococcus faecium, Staphylococcus aureus, Klebsiella pneumoniae, Acinetobacter baumannii, Pseudomonas aeruginosa,* and *Enterobacter* spp.). These pathogens are recognised for their multidrug resistance and virulence ability, posing a significant threat in hospital settings as the primary causative agents of Healthcare Associated Infections (HAIs).

Furthermore, independent studies have highlighted the anticancer properties of these plants. However, despite the extensive biological activities attributed to moringa, ginger, and olive, a significant gap exists in the literature regarding their combined effects on food safety, particularly concerning meat products. This review aims to underscore the importance of these three plants and extracts in enhancing food safety, with a specific focus on their potential application in the meat industry.

Keywords: *Moringa Oleifera*; Ginger; Olive; ESKAPE bacteria

1. INTRODUCTION

The discovery of antibiotics constituted a revolutionary advance in the treatment of infectious diseases, thereby establishing the foundations of modern medicine. However, the excessive and misuse of antibiotics has resulted in the development of resistance to these drugs over time. The slowdown in the development of new antibiotics and the increasing resistance represent significant challenges in the treatment of diseases in the present era. The emergence of antimicrobial resistance can restrict the range of available treatment options, potentially leading to even relatively straightforward infections becoming fatal (Vasconcelos et al., 2018; Miller & Arias, 2024). The World Health Organization (WHO) has highlighted the prevalence of antibiotic-resistant bacteria globally and underscored the necessity for a One Health approach to address the antibiotic resistance crisis (WHO, 2015; Denissen et al., 2022).

The term 'ESKAPE pathogens' is an acronym that refers to a specific group of pathogens that includes *Enterococcus faecium, Staphylococcus aureus, Klebsiella pneumoniae, Acine-*

tobacter baumannii, Pseudomonas aeruginosa and *Enterobacter* spp. (Santajit & Indrawattana, 2016; Miller & Arias, 2024). ESKAPE bacteria are a major cause of nosocomial infections due to their multidrug resistance and virulence. This poses a serious burden to healthcare systems worldwide and increases mortality rates (Mulani et al., 2019). The ESKAPE pathogens also represent a significant threat in terms of multidrug resistance in food products. The microbiota of meat and meat products can serve as a reservoir for food-borne pathogens, contributing to the transmission of multidrug resistant bacteria from agricultural environments to human consumers (Denissen et al., 2022; Conceição et al., 2023).

The high protein content of meat and meat products contributes them susceptible to microbial spoilage. Consumer preference and shelf life of these products are significantly influenced by their composition, susceptibility to oxidation, and microbial diversity. The incorporation of bioactive compounds derived from plant extracts has been demonstrated to detain these oxidative processes, thereby enabling meat to retain its freshness and extend its shelf life (Zhang et al., 2016). Processing conditions can alter the lipid composition of meat, thereby increasing its susceptibility to oxidation (Munekata et al., 2020; Velázquez et al., 2021). The increase and spread of pathogenic bacteria with multidrug resistance on food products such as meat represents a significant public health concern, prompting a heightened interest in the development of novel antimicrobial agents (Vasconcelos et al., 2018; Li et al., 2020). It is crucial to comprehend the resistance mechanisms of these bacteria to facilitate the development of novel antimicrobial agents or alternative strategies for combating these significant public health concerns (Santajit & Indrawattana, 2016). The use of traditional herbal compounds obtained from plant extracts such as Moringa (*Moringa oleifera* LAM), Ginger (*Zingiber officinale* Roscoe) and Olive (*Olea europaea* L.) offers more effective, more economical and generally less side-effect antimicrobial additive options than existing medications (Mao et al., 2019; Seleshe & Kang, 2019; Romero-Márquez et al., 2023). It is not only the plant extracts of these plants that have been demonstrated to be effective against a wide range of microorganisms; their oils and derivative compounds have also been shown to have antimicrobial properties. These have been used for hundreds of years to combat pathogens such as bacteria, fungi and viruses (Vasconcelos et al., 2018).

Moringa oleifera is a tropical crop that is relatively unknown in developed countries, yet has been widely cultivated in Africa, Central and South America, Sri Lanka, India, Mexico, Malaysia, Indonesia, and the Philippines since ancient times (Trigo et al., 2023). The leaves, seeds, and seed oil of *Moringa oleifera* have been demonstrated to possess a range of pharmacological and nutritional properties, as well as antioxidant and antimicrobial (Table 1) abilities of their components (Sharma et al., 2020).

The ginger (*Zingiber officinale* Roscoe) has a long history of consumption as a spice and herbal medicine. Recently, studies have demonstrated that ginger possesses a range of biological activities, including antioxidant, anti-inflammatory, antimicrobial (Table 1), and anticancer properties (Mao et al., 2019; Ballester et al., 2022).

The olive, its oil and the leaves of the olive tree are notable for their high nutritional value. Olive is an important product in the Mediterranean Basin, with a production capacity of 98% worldwide. Olive has a long history of use in traditional medicine in the European Mediterranean islands and in countries such as Spain, Italy, France, Greece, Israel, Morocco, Tunisia and Turkey (El & Karakaya, 2009). Furthermore, compounds derived from olive leaf extract have been demonstrated to possess antimicrobial (Table 1), antioxidant, antiviral, anti-atherogenic, cardioprotective and antihypertensive properties (Borjan et al., 2020).

In this review, we explore the latest advancements in therapeutic strategies utilising moringa, ginger, and olive herbal extracts to

Table 1. Overview of recent studies on the antimicrobial effects of Moringa, Ginger, and Olive extracts.

Plant	**Solvent**	**Microorganism**	**Minimum inhibitory concentration (MIC)** mg/mL	**Minimum bactericidal concentration (MBC)** mg/mL	**References**
Moringa oleifera	Methanol	*Salmonella* Typhimurium	1.23		El-Fakharany et al., (2024)
Moringa oleifera	Methanol	*Escherichia coli*	22.50		El-Fakharany et al., (2024)
Moringa oleifera	Methanol	*Staphylococcus aureus*	1.25		El-Fakharany et al., (2024)
Moringa oleifera	Methanol	*Streptococcus pneumoniae*	0.06		Seleshe & Kang, (2019)
Moringa oleifera	Chloroform	*Escherichia coli*	0.12		Seleshe & Kang, (2019)
Moringa oleifera	Chloroform	*Salmonella* Typhimurium	0.12		Seleshe & Kang, (2019)
Moringa oleifera	Chloroform	*Staphylococcus aureus*	0.12		Seleshe & Kang, (2019)
Moringa oleifera	Chloroform	*Listeria monocytogenes*	0.12		Seleshe & Kang, (2019)
Moringa oleifera	Chloroform	*Bacillus Cereus*	0.12		Seleshe & Kang, (2019)
Ginger essential oil		*Escherichia coli*	2.00	4.00	Wang et al., (2020)
Ginger essential oil		*Staphylococcus aureus*	1.00	2.00	Wang et al., (2020)
Ginger	Acetone	*Staphylococcus aureus*	2.50		Akullo et al., (2020)
Ginger	Acetone	*Escherichia coli*	2.50		Akullo et al., (2020)
Ginger	Acetone	*Candida albicans*	2.50		Akullo et al., (2020)
Olive	Ethanol	*Staphylococcus aureus*	20.00	30.00	Sánchez-Gutiérrez et al., (2021)
Olive	Ethanol	*Yersinia enterocolitica*	20.00	30.00	Sánchez-Gutiérrez et al., (2021)
Olive	Ethanol	*Listeria monocytogenes*	40.00	50.00	Sánchez-Gutiérrez et al., (2021)
Olive	Ethanol	*Escherichia coli*	30.00	40.00	Sánchez-Gutiérrez et al., (2021)
Olive	Ethanol	*Salmonella* Typhimurium	40.00	50.00	Sánchez-Gutiérrez et al., (2021)
Olive	Water	*Staphylococcus aureus*	2.50	5.00	Sánchez-Gutiérrez et al., (2021)
Olive	Water	*Yersinia enterocolitica*	5.00	10.00	Sánchez-Gutiérrez et al., (2021)
Olive	Water	*Listeria monocytogenes*	30.00	40.00	Sánchez-Gutiérrez et al., (2021)
Olive	Water	*Escherichia coli*	40.00	50.00	Sánchez-Gutiérrez et al., (2021)
Olive	Water	*Salmonella* Typhimurium	40.00	60.00	Sánchez-Gutiérrez et al., (2021)

combat ESKAPE pathogens, a critical public health issue, particularly concerning the hygiene and safety of meat products.

2. ESKAPE PATHOGENS ON MEAT

2.1. Meat Characteristics Favouring Bacterial Growth

Meat and meat products are highly susceptible to microbial contamination due to their nutrient-rich composition and favourable physicochemical properties. The abundance of proteins, essential amino acids, vitamins (particularly B-group), and minerals (such as iron and zinc) provide an optimal growth medium for bacteria (Zhou et al., 2010). Additionally, the high-water activity ($a_w > 0.95$) and near-neutral pH (5.5-6.5) in fresh meat further support the proliferation of both spoilage microorganisms and foodborne pathogens (Toldrá et al., 2016).

Processing methods such as mincing and vacuum packaging can disrupt the meat's natural structure, facilitating bacterial colonisation by altering oxygen availability and redox potential (Xu et al., 2021). Of particular concern are multidrug-resistant bacteria, including *Staphylococcus aureus* and *Enterobacter* spp., which have been detected in meat products, posing significant food safety challenges (Ramatla et al., 2017; EFSA, 2022).

Given these risks, there is increasing interest in natural preservation strategies, such as plant-derived antioxidants and antimicrobials, to enhance meat safety and shelf life (Selani et al., 2021). These approaches not only inhibit microbial growth but also reduce oxidative deterioration, addressing two major factors in meat spoilage.

2.2. The Presence and Impact of ESKAPE Pathogens in Meat and Meat Products

The presence of antimicrobial-resistant bacteria in meat and meat products represents a significant challenge (Conceição et al., 2023). The probability of occurrence of cross-contamination and recontamination at almost every step of food production chains serves to increase the presence of antimicrobial-resistant bacteria in foods. In particular, bacteria exhibit alterations in their bacterial genetic structures and can acquire resistance mechanisms by horizontal gene transfer, which accelerate the development of antibiotic resistance (Hernández-Cortez et al., 2017; Collineau et al., 2019; Conceição et al., 2023). This situation also presents significant challenges to the treatment of foodborne infections, threatening the safety of the food supply and posing a serious public health concern. Furthermore, scientific studies indicate that antimicrobial resistance genes carried by foodborne bacteria can reach the human intestine through nutrition and be transferred to the resident microbiota there (Bouchami et al., 2020; Conceição et al., 2023). This has a significant impact on the development and dissemination of antibiotic resistance in pathogenic bacteria.

In accordance with data obtained from hospital-based surveillance studies, a specific group of nosocomial pathogens has been classified as 'ESKAPE pathogens' (Rice, 2008). However, ESKAPE pathogens comprise complex ecosystems of the same diverse bacteria found in the same niches, beyond the clinical context, in food production, agricultural, soil or aquatic environments. These bacteria include not only strains that infect patients but also common commensal and environmental bacteria that potentially serve as conduits for the spread of Complex antibiotic Resistance gene Locus (CRL) (Djordjevic et al., 2013). Other important sites for antibiotic resistance genes include microorganisms in hospital wastewater, aquaculture and other aquatic environments, food animal manure ponds and the gastrointestinal tract of mammals. These host a large number of bacteria and are important environments where genetic information is exchanged on mobile elements through Late Gene Transfer (LGT) (Forsberg et al., 2012; Djordjevic et al., 2013).

Antimicrobial-resistant bacteria, especially methicillin-resistant *S. aureus*, ESBL-producing *Enterobacteriaceae*, and vancomycin-resistant *Enterococcus* spp., along with other ESKAPE bacteria, are transmitted from animals to humans through the consumption of meat and meat products (Conceição et al., 2023). *S.aureus*, especially methicillin-resistant (MRSA) and vancomycin-resistant (VRSA) strains, are increasingly gaining importance as foodborne zoonotic agents (Cong et al., 2020). Studies have revealed that these resistant strains have been detected in chicken carcasses, ready-to-eat chicken sandwiches, and raw buffalo milk (Elshebrawy et al., 2025). The *mecA* and *vanA*/*vanB* genes carried by these bacteria are generally carried via mobile genetic elements. This poses the risk of transferring resistance genes to other bacterial species in the environment through horizontal gene transfer (Cong et al., 2020; Elshebrawy et al., 2025). In this context, three resistance genes of critical public health importance were identified in *Acinetobacter* species isolated from beef, pork and duck meat: $bla_{OXA\text{-}58}$ (carbapenem resistance), *mcr-4.3* (colistin resistance) and *tet(X3)* (tigecycline resistance) (Puente et al., 2025).

Recent studies suggest that meat and meat products may contribute to the spread of ESKAPE pathogens (Conceição et al., 2023).

3. ANTİMİCROBİAL AND ANTİOXİDANT EFFİCACY OF PLANT EXTRACTS TO COMBAT ESKAPE PATHOGENS

3.1. Moringa (*Moringa oleifera*) and Meat Matrices: Pathogen Inhibition and Quality Preservation

Moringa (*M. oleifera*) is a widely cultivated plant species belonging to the *Moringaceae* family, native to the Indian subcontinent. It is the best-known of the 13 species within this family (Milla et al., 2021; Rode et al., 2022). It is a rapidly growing tropical crop with a global distribution, due to its high nutritional value and minimal water and agricultural input requirements (Trigo et al., 2023). The leaves of moringa are a rich source of vitamins A and C, while the seeds and seed oil possess a range of pharmacological and nutritional properties (Seleshe & Kang, 2019; Sharma et al., 2020; Rode et al., 2022). Additionally, moringa is referred to as the "miracle tree," "long-living tree," or "horseradish tree" due to its roots' resemblance to horseradish in taste (Klimek-Szczykutowicz et al., 2024).

Moringa is a key ingredient in herbal medicines and cosmetics, due to its valuable properties (Karim et al., 2015; Klimek-Szczykutowicz et al., 2024; Peñalver et al., 2024) and also has a significant importance in the food industry, where it is used in the production of a wide range of products, including cakes, cereals, oatmeal, bread, biscuits, dairy products, soups, salads and tea.

Moringa's bioactive compounds, including flavonoids (such as myricetin, quercetin, and kaempferol) and phenolic acids (primarily chlorogenic acid), have demonstrated protective effects against various chronic diseases, such as cardiovascular disease, diabetes, and cancer (Sharma et al., 2020; Abd El-Hack et al., 2022). These compounds exert beneficial effects through their antioxidant, anti-inflammatory, antidiabetic, antimutagenic, and anticancer properties (Sharma et al., 2020; Trigo et al., 2023). The antimicrobial properties of moringa leaves, flower essence, and seeds and their impact on the shelf life and organoleptic properties of meat and poultry products (Madane et al., 2019; Abdallah et al., 2023).

Moringa extracts exhibit diverse biological activities, including antimicrobial, antifungal, and antioxidant effects against foodborne pathogens (Seleshe & Kang, 2019; Klimek-Szczykutowicz et al., 2024). Notably, they demonstrate antimicrobial activity against key pathogens such as *Salmonella typhimurium*, *Staphylococcus aureus*, *Enterococcus faecalis*, *Escherichia coli*, *Klebsiella pneumoniae*, *Listeria monocy-*

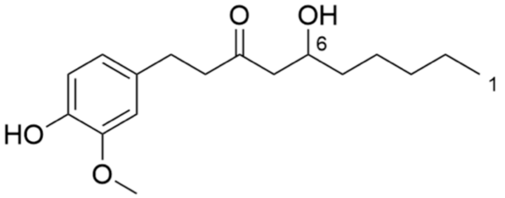
togenes, and *Bacillus cereus*, all of which have significant risks to human health through food contamination (Ndhlala et al., 2014; Seleshe & Kang, 2019; Sharma et al., 2020; Jahan et al., 2022; El-Fakharany et al., 2024). Notably, Moringa's bioactive compounds exhibit enhanced bioavailability compared to those of other plants, primarily due to their glycosylated form, which facilitates faster absorption in epithelial cells than alkylated compounds (Gheorghita et al., 2023). Research by Muthukumar et al. (2023) confirmed Moringa's potent antioxidant properties, effectively inhibiting lipid oxidation in pork meatballs. Similarly, Abdallah et al. (2023) reported strong antimicrobial activity of Moringa extract in refrigerated ground meat, significantly reducing counts of *Enterobacteriaceae*, *E. Coli* O157:H7, *S. typhimurium*, and *S. aureus*. Importantly, the treatment preserved the meat's organoleptic properties while slightly improving tenderness and juiciness compared to controls.

The threat posed by ESKAPE pathogens to meat safety and hygiene remains a significant and persistent challenge in the food industry. This growing concern has driven increased research into natural alternatives, particularly focusing on plant-derived antioxidants and antimicrobial compounds (Trigo et al., 2023). Among these, *Moringa oleifera* has emerged as a particularly promising natural antimicrobial agent, with demonstrated benefits for both meat quality and animal productivity (Safwat et al., 2014; Mahfuz & Piao, 2019). A key advantage of Moringa's bioactive compounds lies in their superior bioavailability compared to other plant sources. This enhanced absorption is primarily due to their glycosylated molecular structure, which facilitates more efficient uptake by epithelial cells compared to alkylated forms (Gheorghita et al., 2023). Additionally, Moringa extracts show cytotoxic effects against human cancer cell lines, including colon epidermal adenocarcinoma (Caco-2), hepatocellular carcinoma (HepG2), and breast cancer (MCF-7). These effects are mediated through cell cycle arrest and apoptosis induction, particularly in HepG2 cells, highlighting their potential anticancer properties (Mansour et al., 2019; El-Fakharany et al., 2024). Further research has explored the biosynthesis of silver nanoparticles using Moringa extracts, which also exhibit antimicrobial, antifungal, and anticarcinogenic activities (Mohammed et al., 2022; Ahmed et al., 2023). Collectively, these findings underscore the therapeutic and food safety potential of Moringa-derived compounds.

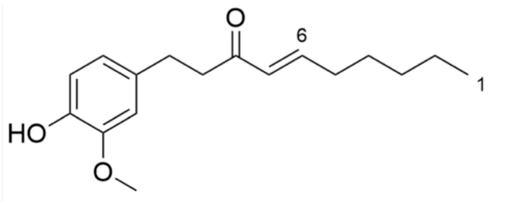
3.2. Bioactive Compounds of Ginger (Zingiber officinale) and Their Role in Meat Quality and Safety

Ginger (*Zingiber officinale* Roscoe) is a member of the *Zingiberaceae* family and is one of the most widely used spices globally (Wen et al., 2020). In addition to its use as a spice for over 3,000 years, due to the strong aroma of the rhizomes, ginger is also employed as a traditional herbal medicine due to its anti-inflammatory, anti-cancer and antibacterial properties (Semwal et al., 2015; Kiyama, 2020; Ivane et al., 2022). Ginger contains a plethora of active ingredients, including phenolic and terpene compounds. The phenolic compounds present in ginger primarily include gingerols, shogaols, and paradols (Figure 1). Furthermore, kaempferol, rutin and other phenolic compounds have also been identified (Mao et al., 2019; Ivane et al., 2022).

It is a well-established finding from scientific research that ginger and its active compounds demonstrate anti-biofilm, antibacterial, antifungal and antiviral properties (Moon et al., 2018; Çobur & Bülbül, 2021; Utama-Ang et al., 2021). Furthermore, it exhibits potent antioxidant and anticancer properties due to the presence of its bioactive compounds (De Lima et al., 2018; Çobur et al., 2021). The lipophilic essential oil content of ginger gives it mechanical properties that inhibit the growth of microorganisms by disrupting the integrity of the cell wall and cytoplasmic membrane (Mao et al., 2019). Furthermore, the components present, including shogaol and zingerone, exert a significant influence on biological activities such as apoptosis, DNA damage, epigenetic regulation and inflammation (Kiyama, 2020). The anti-inflammatory effects of ginger are associated with the inhibition of protein kinase B (Akt) and nuclear factor-ϰB (NF-ϰB) signalling pathways, upregulation of anti-inflammatory cytokines and downregulation of pro-inflammatory cytokines. Ginger nanoparticles have been identified as a potential therapeutic agent for inflammatory bowel diseases (Ueno et al., 2014; Mao et al., 2019). A study on the anti-inflammatory effects of ginger nanoparticles revealed that these nanoparticles are not toxic to intestinal epithelial cells and enhance intestinal repair in various mouse colitis models. Furthermore, they have been shown to prevent colitis-related cancer (Zhang et al., 2016). Evidence indicates a reduction in pro-inflammatory cytokine levels, including tumour necrosis factor α (TNF-α), interleukin 6 (IL-6) and IL-1β, accompanied by an increase in anti-inflammatory cytokines, such as IL-10 and IL-22 (Zhang et al., 2016).



6-gingerol



6-shogaol

Figure 1. Chemical structure of 6-gingerol and 6-shogaol (Zimmermann-Klemd et al., 2022).

The pH environment of meat products is conducive to the growth of bacteria, yeast, and mould. Furthermore, meat spoilage occurs as a result of biochemical reactions involving microbial degradation and oxidation of lipids. Besides, such unfavourable alterations occur in the organoleptic characteristics of meat (Naqvi et al., 2022).

A substantial body of research has been conducted to clarify the impact of ginger and its derivatives on a range of meat products. The antioxidant capacity of ginger was demonstrated to be high, and lipid peroxidation was reduced in a study on pork burgers. Moreover, it has been demonstrated that the substance can extend the product's shelf life by suppressing the growth of potential meat contaminants, including *Enterobacteriaceae, Enterococcus* spp., *E. coli and Pseudomonas* spp. (Mancini et al., 2017).

In their study, Karpińska-Tymoszczyk et al. (2022) examined the changes in the physicochemical and organoleptic properties of pork meatballs during the storage process with the addition of ginger. From a physicochemical perspective, the addition of ginger resulted in a reduction in lipid oxidation in the meat. From an organoleptic standpoint, there was a notable decrease in texture and an improvement in the ease of chewing. Furthermore, it enhanced the brightness of the meat (Karpińska-Tymoszczyk et al., 2022).

In their study, Abdel-Naeem et al. (2022) found that camel meat has become a less preferred meat product due to its texture. To address this issue, ginger and papain were employed to reduce the hardness of the meat. Consequently, a notable decline in shear-force values was observed, accompanied by a considerable reduction in the population of pathogenic bacteria, including *E. coli, S.* Typhi, *Enterobacter spp., Klebsiella spp.,* and *P. aeruginosa*, on the meat (Abdel-Naeem et al., 2022).

In another study, the impact of fermented ginger on the shelf life of chicken meat was investigated. The findings revealed that it significantly enhanced the antibacterial activity against *S*. Typhimurium (97%), *L. monocytogenes* (97%), and *S. aureus* (100%), while also decreasing the microbial load ($p < 0.05$), this resulted in a notable reduction in the shelf life of the meat (Muhialdin et al., 2020).

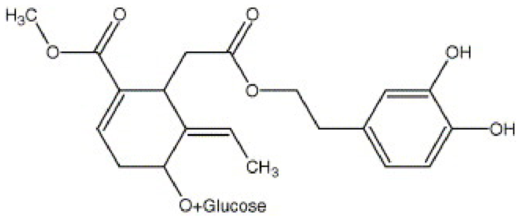
Furthermore, in studies combining various ingredients, such as thyme and ginger nanoparticles or ginger and rosemary, it was observed that chickens and rabbits exhibited enhanced growth performance, a reduction in the total bacterial load in the intestinal tract, and an improvement in meat quality (Elazab et al., 2022; Hassan et al., 2024).

The evidence suggests that ginger enhances the nutritional value of meat products while also functioning as a potent antioxidant that mitigates oxidative degradation (Felfoul et al., 2017). Furthermore, it enhances food safety by reducing the microbial load of meat and improves the sensory properties of meat. The incorporation of ginger into animal nutrition has been demonstrated to enhance the quality of meat products by influencing the fatty acid profile of the animals. These findings suggest that ginger can be employed as a natural additive in the meat industry, with the potential to enhance product quality and promote consumer health (Shaukat et al., 2023; Zhang et al., 2023).

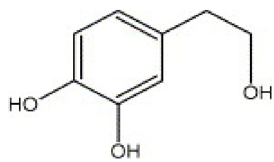
3.3. Polyphenolic Compounds from the Olive (Olea europaea): Antimicrobial, Antioxidant and Functional Applications in Meat Products

Olive tree (*Olea europaea* L.) and its derivatives are the basic element of the Mediterranean diet with their valuable polyphenol content (Grubić Kezele & Ćurko-Cofek et al., 2022). Spain, Greece and Italy are among the leading countries in olive and olive oil production (Skodra et al., 2021). Olives and their derivatives have anti-inflammatory, antimicrobial and antioxidant activity in terms of health-promoting properties (Melguizo-Rodríguez et al., 2022). Its various biological activities are generally bioactive compounds it contains; mainly oleuropein, tyrosol and hydroxytyrosol (Marcelino et al., 2019; Melguizo-Rodríguez et al., 2022; Grubić Kezele & Ćurko-Cofek, 2022).

Oleuropein, the main phenolic component found in olive tree leaves and olive fruit, has a strong antioxidant property as well as an anti-inflammatory and apoptosis-inducing role (Nediani et al., 2019) (Figure 2). The main phenolic components of extra virgin olive oil are tyrosol and hydroxytyrosol, and they have high bioactive properties (Gervasi et al., 2024) (Figure 2).



Oleuropein



Hydroxytyrosol

Figure 2. Chemical structure of Oleuropein and Hydroxytyrosol (Soni et al., 2006).

3.4. Biological properties of the olive tree on meat products

Olives contain phenolic substances that have been demonstrated to enhance a range of biological processes, including fat oxidation and the organoleptic properties of food (Soni et al., 2006). It is a well-established finding from scientific studies that olives and their derivatives possess antimicrobial properties (Elnahas et al., 2021; Melguizo-Rodríguez et al., 2022). Furthermore, the oleuropein, hydroxytyrosol and tyrosol present in olives have been demonstrated to possess anticancer properties and exhibit antimicrobial, antiviral and antioxidant activity (Fabiani, 2016; Owen et al., 2000; Bisignano et al., 1999).

In the study conducted by Sánchez-Gutiérrez et al. (2021), olive leaves were used with different solvents against foodborne pathogens. The results demonstrated that the extract exhibited antimicrobial properties against several strains of bacteria, including *S. aureus* (CECT 5193), *Salmonella t*yphimurium (CECT 704), *E. coli* (CECT 8295), *L. monocytogenes* (CECT 4032), and *Yersinia enterocolitica* (CECT 754). In this context, it has been proposed that olive leaf extract could be employed in the food industry (Sánchez-Gutiérrez et al., 2021).

The study by Ibrahim et al. (2022) evaluated the effectiveness of Moringa extract and olive leaf extract in improving the quality and shelf life of chicken burgers. The findings demonstrated that Moringa extract had notably stronger antioxidant and natural antimicrobial activities compared to olive leaf extract. While olive leaf extract was more effective in reducing protein hydrolysis, Moringa extract better preserved the organoleptic properties of the burgers, including taste and texture. Both extracts contributed to extending the shelf life by inhibiting microbial spoilage, but Moringa extract stood out for its superior overall impact, underscoring its potential as a more effective natural preservative in meat products.

To enhance animal performance and refine the fatty acid profile of meat, olive cake was incorporated into the diet of pigs, and the resulting outcomes were assessed. Consequently, olives enhanced the fatty acid profile of meat and its nutritional value (Caparra et al., 2023).

Saleh et al. (2020) evaluated the impact of varying concentrations of olive leaf extract on the shelf life of raw poultry meat, organoleptic properties of meat and microbiological quality of meat. The findings indicated that olive leaf extracts reduced microbial growth and consequently extended the shelf life of meat. Furthermore, the researchers demonstrated that the meat maintains its organoleptic properties.

The evidence from scientific studies indicates that olives and olive oil induce early apoptosis and, over time, lead to the death of cancer cells (Mijatovic et al., 2011; Lopez de las Hazas et al., 2017). Consequently, olives and its derivates could potentially serve as a natural anticarcinogen, helping to neutralise carcinogenic substances commonly found in food (Gorzynik-Debicka et al., 2018). Thanks to the polyphenol compounds it contains, it reduces the promotion of colon cancer by reducing oxidative stress in cellular DNA and prevents the formation of inflammatory responses by inhibiting lipoxygenase expression (Escrich et al., 2007). The most significant polyphenols present in the composition of the substance in question are oleuropein and hydroxytyrosol. These polyphenols typically exert their effects on cancer cell lines through caspase (casp) activation, which encompasses pro-apoptotic Bcl-2 family members. Additionally, in the context of breast cancer, they act through p53 activation and the inhibition of pro-proliferation protein NFϰB and cyclin D1. These findings are supported by the results of Rigacci & Stefani (2016).

4. CONCLUSİONS

Bacterial contamination in foods, particularly in meat, is a significant public health concern due to its impact on the shelf life, quality, and organoleptic properties of meat products. Lipid oxidation is the primary cause of spoilage in meat, which not only diminishes the product's nutritional value but also degrades its sensory characteristics. ESKAPE pathogens, a group of highly antibiotic-resistant bacteria, represent a major threat during this process.

Studies in the literature suggest that natural antimicrobial and antioxidant compounds found in moringa, ginger, and olive are effective against ESKAPE pathogens in meat and meat products. However, there is a notable lack of research on the combined use of these three plant extracts and their collective impact on pathogens responsible for food spoilage. Additionally, the anti-inflammatory effects of these plants are not fully understood.

In this review, we highlight the potential of combining moringa, ginger, and olive extracts in future studies, which could address existing gaps in the literature and advance our understanding of their synergistic effects on food safety.

5. REFERENCES

Abd El-Hack, M. E., Alqhtani, A. H., Swelum, A., El-Saadony, M. T., Salem, H. M., Babalghith, A. O., El-Tarabily, K. A., & El-Tarabily, K. A. (2022). Pharmacological, nutritional and antimicrobial uses of Moringa oleifera Lam. leaves in poultry nutrition: An updated knowledge. Poultry Science, 101(9), 102031.

Abdallah, H. M., Mohamed, M. E., El-Halawany, A. M., & El-Bassossy, H. M. (2023). Moringa oleifera extracts as natural preservatives in meat products: Impact on shelf-life extension and sensory quality. *Food Chemistry, 405*(Part A), 134823.

Abdel-Naeem, H. H., Talaat, M. M., Imre, K., Morar, A., Herman, V., & El-Nawawi, F. A. (2022). Structural changes, electrophoretic pattern, and quality attributes of camel meat treated with fresh ginger extract and papain powder. Foods, 11(13), 1876.

Ahmed, M., Marrez, D. A., Abdelmoeen, N. M., Mahmoud, E. A., Abdel-Shakur Ali, M., Decsi, K., & Tóth, Z. (2023). Proximate analysis of Moringa oleifera leaves and the antimicrobial activities of successive leaf ethanolic and aqueous extracts compared with green chemically synthesized Ag-NPs and crude aqueous extract against some pathogens. International Journal of Molecular Sciences, 24(4), 3529.

Akullo JO, Kiage B, Nakimbugwe D, Kinyuru J. Effect of aqueous and organic solvent extraction on in-vitro antimicrobial activity of two varieties of fresh ginger (Zingiber officinale) and garlic (Allium sativum). Heliyon. 2022 Aug 28;8(9):e10457.

Ballester, P., Cerdá, B., Arcusa, R., Marhuenda, J., Yamedjeu, K., & Zafrilla, P. (2022). Effect of ginger on inflammatory diseases. Molecules, 27(21), 7223.

Bisignano, G., Tomaino, A., Cascio, R. L., Crisafi, G., Uccella, N., & Saija, A. (1999). On the in-vitro antimicrobial activity of oleuropein and hydroxytyrosol. Journal of Pharmacy and Pharmacology, 51(8), 971–974.

Borjan, D., Leitgeb, M., Knez, Ž., & Hrnčič, M. K. (2020). Microbiological and antioxidant activity of phenolic compounds in olive leaf extract. Molecules, 25(24), 5946.

Bouchami, O., Fraqueza, M. J., Faria, N. A., Alves, V., Lawal, O. U., de Lencastre, H., & Miragaia, M. (2020). Evidence for the dissemination to humans of methicillin-resistant Staphylococcus aureus ST398 through the pork production chain: A study in a Portuguese slaughterhouse. Microorganisms, 8(12), 1892.

Caparra, P., Chies, L., Scerra, M., Foti, F., Bognanno, M., Cilione, C., & Cifuni, G. F. (2023). Effect of dietary ensiled olive cake supplementation on performance and meat quality of Apulo-Calabrese pigs. Animals, 13(12), 2022.

Çobur, H., Bülbül, A. S., & Cömertpay, S. (2021). Investigation of anti-cancer and antioxidant properties of zingerone. Biyoloji Bilimleri Araştırma Dergisi, 14(1), 70–75.

Collineau, L., Boerlin, P., Carson, C. A., Chapman, B., Fazil, A., Hetman, B., & Smith, B. A. (2019). Integrating whole-genome sequencing data into quantitative risk assessment of foodborne antimicrobial resistance: A review of opportunities and challenges. Frontiers in Microbiology, 10, 1107.

Conceição, S., Queiroga, M. C., & Laranjo, M. (2023). Antimicrobial resistance in bacteria from meat and meat products: A one health perspective. Microorganisms, 11(10), 2581.

Cong, W., Wang, X., Zheng, F., Huang, S., & Liu, Y. (2020). Methicillin-resistant *Staphylococcus aureus* (MRSA) and vancomycin-resistant *Enterococcus* spp. (VRE) in food-producing animals and meat: A review of the zoonotic potential. *Foodborne Pathogens and Disease, 17*(5), 287-298.

De Lima, R. M. T., Dos Reis, A. C., de Menezes, A. A. P. M., Santos, J. V. D. O., Filho, J. W. G. D. O., Ferreira, J. R. D. O., & Melo-Cavalcante, A. A. D. C. (2018). Protective and therapeutic potential of ginger (Zingiber officinale) extract and [6]-gingerol in cancer: A comprehensive review. Phytotherapy Research, 32(10), 1885–1907.

Djordjevic, S. P., Stokes, H. W., & Roy Chowdhury, P. (2013). Mobile elements, zoonotic pathogens and commensal bacteria: conduits for the delivery of resistance genes into humans, production animals and soil microbiota. Frontiers in Microbiology, 4, 86.

Denissen, J., Reyneke, B., Waso-Reyneke, M., Havenga, B., Barnard, T., Khan, S., & Khan, W. (2022). Prevalence of ESKAPE pathogens in the environment: Antibiotic resistance status, community-acquired infection and risk to human health. International Journal of Hygiene and Environmental Health, 244, 114006.

EFSA (European Food Safety Authority). (2022). The European Union One Health 2022 zoonoses report. EFSA Journal, 21(12), e08491.

El-Fakharany, E. M., Elsharkawy, W. B., El-Maradny, Y. A., & El-Gendi, H. (2024). Moringa oleifera seed methanol extract with consolidated antimicrobial, antioxidant, anti-inflammatory, and anticancer activities. Journal of Food Science, 89(3), 1234–1245.

El, S. N., & Karakaya, S. (2009). Olive tree (*Olea europaea*) leaves: Potential beneficial effects on human health. Nutrition Reviews, 67(11), 632–638.

Elazab, M. A., Khalifah, A. M., Elokil, A. A., Elkomy, A. E., Rabie, M. M., Mansour, A. T., & Morshedy, S. A. (2022). Effect of dietary rosemary and ginger essential oils on the growth performance, feed utilization, meat nutritive value, blood biochemicals, and redox status of growing NZW rabbits. Animals, 12(3), 375.

Elnahas, R. A., Elwakil, B. H., Elshewemi, S. S., & Olama, Z. A. (2021). Egyptian Olea europapaea leaves bioactive extract: Antibacterial and wound healing activity in normal and diabetic rats. Journal of Traditional and Complementary Medicine, 11(5), 427–434.

Escrich, E., Moral, R., Grau, L., Costa, I., & Solanas, M. (2007). Molecular mechanisms of the effects of olive oil and other dietary lipids on cancer. Molecular Nutrition & Food Research, 51(10), 1279–1292.

Elshebrawy, H. A., Mahros, M. A., Khalifa, E., & Samir, A. (2025). Prevalence of methicillin-resistant Staphylococcus aureus (MRSA) in retail chicken meat and buffalo milk: Implications for food safety. International Journal of Food Microbiology, 378, 109815.

Fabiani, R. (2016). Anti-cancer properties of olive oil secoiridoid phenols: A systematic review of in vivo studies. Food & Function, 7(10), 4145–4159.

Felfoul, I., Borchani, M., Samet-Bali, O., Attia, H., & Ayadi, M. A. (2017). Effect of ginger (Zingiber officinalis) addition on fermented bovine milk: Rheological properties, sensory attributes and antioxidant potential. Journal of New Sciences, 44, 2400–2409.

Forsberg, K. J., Reyes, A., Wang, B., Selleck, E. M., Sommer, M. O. A., & Dantas, G. (2012). The shared antibiotic resistome of soil bacteria and human pathogens. Science, 337(6098), 1107-1111.

Gervasi, F., & Pojero, F. (2024). Use of oleuropein and hydroxytyrosol for cancer prevention and treatment: Considerations about how bioavailability and metabolism impact their adoption in clinical routine. Biomedicines, 12(3), 502.

Gheorghita, R., Filip, R., Lupaescu, A. V., Iavorschi, M., Anchidin-Norocel, L., & Gutt, G. (2023). Innovative materials with possible applications in the wound dressings field: Alginate-based films with Moringa oleifera extract. Gels, 9(7), 560.

Gorzynik-Debicka, M., Przychodzen, P., Cappello, F., Kuban-Jankowska, A., Marino Gammazza, A., Knap, N., & Gorska-Ponikowska, M. (2018). Potential health benefits of olive oil and plant polyphenols. International Journal of Molecular Sciences, 19(3), 686.

Grubić Kezele, T., & Ćurko-Cofek, B. (2022). Neuroprotective panel of olive polyphenols: Mechanisms of action, anti-demyelination, and anti-stroke properties. Nutrients, 14(21), 4533.

Hassan, A. H., Youssef, I. M., Abdel-Atty, N. S., & Abdel-Daim, A. S. (2024). Effect of thyme, ginger, and their nano-particles on growth performance, carcass characteristics, meat quality and intestinal bacteriology of broiler chickens. BMC Veterinary Research, 20(1), 1–13.

Hernández-Cortez, C., Palma-Martínez, I., Gonzalez-Avila, L. U., Guerrero-Mandujano, A., Solís, R. C., & Castro-Escarpulli, G. (2017). Food poisoning caused by bacteria (food toxins). In Poisoning: From specific toxic agents to novel rapid and simplified techniques for analysis (p. 33).

Ibrahim, M. E. E. D., Alqurashi, R. M., & Alfaraj, F. Y. (2022). Antioxidant activity of *Moringa oleifera* and olive *Olea europea* L. leaf powders and extracts on quality and oxidation stability of chicken burgers. Antioxidants, 11(3), 496.

Ivane, N. M. A., Elysé, F. K. R., Haruna, S. A., Pride, N., Richard, E., Foncha, A. C., & Dandago, M. A. (2022). The anti-oxidative potential of ginger extract and its constituent on meat protein isolate under induced Fenton oxidation. Journal of Proteomics, 269, 104723.

Jahan, S., Shahjahan, M., Rasna, S. S., Aktar, M., Sultana, S., Ahmed, S. M., & Nahar, S. (2022). Antibacterial effect of Moringa (*Moringa oleifera*) leaf ethanolic extract against *Staphylococcus aureus* and *Escherichia coli*. Mymensingh Medical Journal: MMJ, 31(4), 976–982.

Karim, O., Kayode, R., Oyeyinka, S., & Oyeyinka, A. (2015). Muz (*Musa paradisca*) unu ve Moringa (*Moringa oleifera*) yaprak tozundan hazırlanan sert hamur "amala"nın fizikokimyasal özellikleri. Hrana u zdravlju i bolesti: Znanstveno-stručni časopis za nutricionizam i dijeteteku, 4(1), 48–58.

Karpińska-Tymoszczyk, M., Draszanowska, A., & Danowska-Oziewicz, M. (2022). The effect of ginger rhizome addition and storage time on the quality of pork meatloaf. Foods, 11(22), 3563.

Kiyama, R. (2020). Nutritional implications of ginger: Chemistry, biological activities and signaling pathways. The Journal of Nutritional Biochemistry, 86, 108486.

Klimek-Szczykutowicz, M., Gaweł-Bęben, K., Rutka, A., Blicharska, E., Tatarczak-Michalewska, M., Kulik-Siarek, K., & Szopa, A. (2024). *Moringa oleifera* (drumstick tree) nutraceutical, cosmetological and medicinal importance: A review. Frontiers in Pharmacology, 15, 1288382.

Li, H., Sun, X., Liao, X., & Gänzle, M. (2020). Control of pathogenic and spoilage bacteria in meat and meat products by high pressure: Challenges and future perspectives. Comprehensive Reviews in Food Science and Food Safety, 19(6), 3476–3500.

Lopez de las Hazas, M. C., Piñol, C., Macià, A., & Motilva, M. J. (2017). Hydroxytyrosol and the colonic metabolites derived from virgin olive oil intake induce cell cycle arrest and apoptosis in colon cancer cells. Journal of Agricultural and Food Chemistry, 65(31), 6467–6476.

Madane, P., Das, A. K., Pateiro, M., Nanda, P. K., Bandyopadhyay, S., Jagtap, P., & Lorenzo, J. M. (2019). Drumstick (*Moringa oleifera*) flower as an antioxidant dietary fibre in chicken meat nuggets. Foods, 8(8), 307.

Mahfuz, S., & Piao, X. S. (2019). Application of Moringa (Moringa oleifera) as natural feed supplement in poultry diets. Animals, 9(7), 431.

Mancini, S., Paci, G., Fratini, F., Torracca, B., Nuvoloni, R., Dal Bosco, A., & Preziuso, G. (2017). Improving pork burgers quality using *Zingiber officinale* Roscoe powder (ginger). Meat Science, 129, 161–168.

Mansour, M., Mohamed, M. F., Elhalwagi, A., El-Itriby, H. A., Shawki, H. H., & Abdelhamid, I. A. (2019). Moringa peregrina leaves extracts induce apoptosis and cell cycle arrest of hepatocellular carcinoma. BioMed Research International, 2019(1), 2698570.

Mao, Q. Q., Xu, X. Y., Cao, S. Y., Gan, R. Y., Corke, H., Beta, T., & Li, H. B. (2019). Bioactive compounds and bioactivities of ginger (*Zingiber officinale* Roscoe). Foods, 8(6), 185.

Marcelino, G., Hiane, P. A., Freitas, K. D. C., Santana, L. F., Pott, A., Donadon, J. R., & Guimarães, R. D. C. A. (2019). Effects of olive oil and its minor components on cardiovascular diseases, inflammation, and gut microbiota. Nutrients, 11(8), 1826.

Melguizo-Rodríguez, L., González-Acedo, A., Illescas-Montes, R., García-Recio, E., Ramos-Torrecillas, J., Costela-Ruiz, V. J., & García-Martínez, O. (2022). Biological effects of the olive tree and its derivatives on the skin. Food & Function, 13(22), 11410–11424.

Mijatovic, S. A., Timotijevic, G. S., Miljkovic, D. M., Radovic, J. M., Maksimovic-Ivanic, D. D., Dekanski, D. P., & Stosic-Grujicic, S. D. (2011). Multiple antimelanoma potential of dry olive leaf extract. International Journal of Cancer, 128(8), 1955–1965.

Milla, P. G., Peñalver, R., & Nieto, G. (2021). Health benefits of uses and applications of Moringa oleifera in bakery products. Plants, 10(2), 318.

Miller, W. R., & Arias, C. A. (2024). ESKAPE pathogens: Antimicrobial resistance, epidemiology, clinical impact and therapeutics. Nature Reviews Microbiology, 1–19.

Mohammed, G. M., & Hawar, S. N. (2022). Green biosynthesis of silver nanoparticles from Moringa oleifera leaves and its antimicrobial and cytotoxicity activities. International Journal of Biomaterials, 2022(1), 4136641.

Moon, Y. S., Lee, H. S., & Lee, S. E. (2018). Inhibitory effects of three monoterpenes from ginger essential oil on growth and aflatoxin production of Aspergillus flavus and their gene regulation in aflatoxin biosynthesis. Applied Biological Chemistry, 61, 243–250.

Muhialdin, B. J., Kadum, H., Fathallah, S., & Hussin, A. S. M. (2020). Metabolomics profiling and antibacterial activity of fermented ginger paste extends the shelf life of chicken meat. LWT, Food Science and Technology, 132, 109897.

Mulani, M. S., Kamble, E. E., Kumkar, S. N., Tawre, M. S., & Pardesi, K. R. (2019). Emerging strategies to combat ESKAPE pathogens in the era of antimicrobial resistance: A review. Frontiers in Microbiology, 10, 539.

Munekata, P. E. S., Rocchetti, G., Pateiro, M., Lucini, L., Domínguez, R., & Lorenzo, J. M. (2020). Addition of plant extracts to meat and meat products to extend shelf-life and health-promoting attributes: An overview. Current Opinion in Food Science, 31, 81–87.

Muthukumar, M., Naveena, B. M., Vaithiyanathan, S., Sen, A. R., & Sureshkumar, K. (2023). Moringa oleifera leaf powder as a natural antioxidant in pork meatballs: Impact on lipid oxidation and quality during storage. Meat Science, *195*, 109023.

Naqvi, Z. B., Campbell, M. A., Latif, S., Thomson, P. C., Astruc, T., Friend, M. A., & Warner, R. D. (2022). The effect of extended refrigerated storage on the physicochemical, structural, and microbial quality of sous vide cooked biceps femoris treated with ginger powder (zingibain). Meat Science, 186, 108729.

Ndhlala, A. R., Mulaudzi, R., Ncube, B., Abdelgadir, H. A., Du Plooy, C. P., & Van Staden, J. (2014). Antioxidant, antimicrobial and phytochemical variations in thirteen *Moringa oleifera* Lam. cultivars. Molecules, 19(7), 10480–10494.

Nediani, C., Ruzzolini, J., Romani, A., & Calorini, L. (2019). Oleuropein, a bioactive compound from *Olea europaea* L., as a potential preventive and therapeutic agent in non-communicable diseases. Antioxidants, 8(12), 578.

Owen, R. W., Giacosa, A., Hull, W. E., Haubner, R., Spiegelhalder, B., & Bartsch, H. (2000). The antioxidant/anticancer potential of phenolic compounds isolated from olive oil. European Journal of Cancer, 36(10), 1235–1247.

Peñalver, R., Martínez-Zamora, L., Lorenzo, J. M., Ros, G., & Nieto Martínez, G. (2024). Effect of hydroxytyrosol, Moringa, and spirulina on the physicochemical properties and nutritional characteristics of gluten-free brownies. Food Science & Nutrition, 12(1), 385–398.

Puente, H., García-Meniño, I., Fernández, J., & Mora, A. (2025). Detection of high-priority resistance genes (*blaOXA-58*, *mcr-4.3*, tet(X3)) in Acinetobacter spp. from retail meat. Antimicrobial Agents and Chemotherapy, 69(3), e01542-24.

Ramatla, T., Ngoma, L., Adetunji, M., & Mwanza, M. (2017). Evaluation of antibiotic residues in raw meat using different analytical methods. Antibiotics, 6(4), 34.

Rice, L. B. (2008). Federal funding for the study of antimicrobial resistance in nosocomial pathogens: No ESKAPE. The Journal of Infectious Diseases, 197(8), 1079–1081.

Rigacci, S., & Stefani, M. (2016). Nutraceutical properties of olive oil polyphenols. An itinerary from cultured cells through animal models to humans. International Journal of Molecular Sciences, 17(6), 843.

Rode, S. B., Dadmal, A., & Salankar, H. V. (2022). Nature's gold (Moringa oleifera): Miracle properties. Cureus, 14, e26640.

Romero-Márquez, J. M., Forbes-Hernández, T. Y., Navarro-Hortal, M. D., Quirantes-Piné, R., Grosso, G., Giampieri, F., & Quiles, J. L. (2023). Molecular mechanisms of the protective effects of olive leaf polyphenols against Alzheimer's disease. International Journal of Molecular Sciences, 24(5), 4353.

Safwat, A. M., Sarmiento-Franco, L., Santos-Ricalde, R., & Nieves, D. (2014). Effect of dietary inclusion of Leucaena leucocephala or Moringa oleifera leaf meal on performance of growing rabbits. Tropical Animal Health and Production, 46, 1193–1198.

Saleh, E., Morshdy, A. E., El-Manakhly, E., Al-Rashed, S., F. Hetta, H., Jeandet, P., & Ali, E. (2020). Effects of olive leaf extracts as natural preservative on retailed poultry meat quality. Foods, 9(8), 1017.

Sánchez-Gutiérrez, M., Bascón-Villegas, I., Rodríguez, A., Pérez-Rodríguez, F., Fernández-Prior, Á., Rosal, A., & Carrasco, E. (2021). Valorisation of *Olea europaea* L. olive leaves through the evaluation of their extracts: Antioxidant and antimicrobial activity. Foods, 10(5), 966.

Santajit, S., & Indrawattana, N. (2016). Mechanisms of antimicrobial resistance in ESKAPE pathogens. BioMed Research International, 2016(1), 2475067.

Selani, M. M., Herrero, A. M., & Ruiz-Capillas, C. (2022). Plant antioxidants in dry fermented meat products with a healthier lipid profile. Foods, 11, 3558.

Seleshe, S., & Kang, S. N. (2019). In vitro an-timicrobial activity of different solvent extracts from Moringa stenopetala leaves. Preventive Nutrition and Food Science, 24(1), 70.

Semwal, R. B., Semwal, D. K., Combrinck, S., & Viljoen, A. M. (2015). Gingerols and shogaols: Important nutraceutical principles from ginger. Phytochemistry, 117, 554–568.

Sharma, P., Wichaphon, J., & Klangpetch, W. (2020). Antimicrobial and antioxidant activities of defatted Moringa oleifera seed meal extract obtained by ultrasound-assisted extraction and application as a natural antimicrobial coating for raw chicken sausages. International Journal of Food Microbiology, 332, 108770.

Shaukat, M. N., Nazir, A., & Fallico, B. (2023). Ginger bioactives: A comprehensive review of health benefits and potential food applications. Antioxidants, 12(11), 2015.

Skodra, C., Titeli, V. S., Michailidis, M., Bazakos, C., Ganopoulos, I., Molassiotis, A., & Tanou, G. (2021). Olive fruit development and ripening: Break on through to the "-omics" side. International Journal of Molecular Sciences, 22(11), 5806.

Soni, M. G., Burdock, G. A., Christian, M. S., Bitler, C. M., & Crea, R. (2006). Safety assessment of aqueous olive pulp extract as an antioxidant or antimicrobial agent in foods. Food and Chemical Toxicology, 44(7), 903-915.

Toldrá, F., Mora, L., & Reig, M. (2016). New insights into meat by-product valorization. Meat Science, 120, 54–59.

Trigo, C., Castelló, M. L., & Ortolá, M. D. (2023). Potentiality of *Moringa oleifera* as a nutritive ingredient in different food matrices. Plant Foods for Human Nutrition, 78(1), 25–37.

Ueno, N., Hasebe, T., Kaneko, A., Yamamoto, M., Fujiya, M., Kohgo, Y., & Musch, M. W. (2014). TU-100 (daikenchuto) and ginger ameliorate anti-CD3 antibody induced T cell-mediated murine enteritis: Microbe-independent effects involving Akt and NF-κB suppression. PloS One, 9(5), e97456.

Utama-Ang, N., Sida, S., Wanachantararak, P., & Kawee-Ai, A. (2021). Development of edible Thai rice film fortified with ginger extract using microwave-assisted extraction for oral antimicrobial properties. Scientific Reports, 11(1), 14870.

Vasconcelos, N. G., Croda, J., & Simionatto, S. (2018). Antibacterial mechanisms of cinnamon and its constituents: A review. Microbial Pathogenesis, 120, 198–203.

Velázquez, L., Quiñones, J., Díaz, R., Pateiro, M., Lorenzo, J. M., & Sepúlveda, N. (2021). Natural antioxidants from endemic leaves in the elaboration of processed meat products: Current status. Antioxidants, 10(9), 1396.

Wang, S., Payne, G. F., & Bentley, W. E. (2020). Quorum sensing communication: molecularly connecting cells, their neighbors, and even devices. Annual review of chemical and biomolecular engineering, 11(1), 447-468.

Wen, C., Liu, Y., Ye, Y., Tao, Z., Cheng, Z., Wang, T., & Zhou, Y. (2020). Effects of gingerols-rich extract of ginger on growth performance, serum metabolites, meat quality and antioxidant activity of heat-stressed broilers. Journal of Thermal Biology, 89, 102544.

World Health Organization. (2015). WHO estimates of the global burden of foodborne diseases: Foodborne disease burden epidemiology reference group 2007-2015. World Health Organization.

Xu, Z., Deng, Y., Zhao, X., Sun, X., Yu, J., Wang, R., Wang, Q., & Shi, X. (2021). Editorial: Emerging frontiers in the formation of viable but non-culturable microorganisms and biofilms during food processing. Frontiers in Microbiology, 12, 726348.

Zhang, J., Wang, Y., Pan, D. D., Cao, J. X., Shao, X. F., Chen, Y. J., & Ou, C. R. (2016a). Effect of black pepper essential oil on the quality of fresh pork during storage. Meat Science, 117, 130–136.

Zhang, M., Viennois, E., Prasad, M., Zhang, Y., Wang, L., Zhang, Z., & Merlin, D. (2016b). Edible ginger-derived nanoparticles: A novel therapeutic approach for the prevention and treatment of inflammatory bowel disease and colitis-associated cancer. Biomaterials, 101, 321–340.

Zhang, B., Liu, Y., Peng, H., Lin, Y., & Cai, K. (2023). Effects of ginger essential oil on physicochemical and structural properties of agar-sodium alginate bilayer film and its application to beef refrigeration. Meat Science, 198, 109051.

Zhou, G. H., Xu, X. L., & Liu, Y. (2010). Preservation technologies for fresh meat -A review. Meat Science, 86(1), 119–128.

Zimmermann-Klemd, A. M., Reinhardt, J. K., Winker, M., & Gründemann, C. (2022). Phytotherapy in integrative oncology -An update of promising treatment options. Molecules, 27(10), 3209.