ISSN 1998 – 409X

REVIEW ARTICLE

Moringa oleifera in Meat Products: Evidence for Oxidative Stability, Microbial Safety, Shelf-Life Extension and Functional Food Development

Deepali T. Sakunde[1], Ashali V. Karande[2], Vikas V. Karande[3], Chandrakant D. Bhong[4], Uma M. Tumlam[5], Vikas S. Waskar[4]

[1]Department Livestock Products Technology, Government of Maharashtra, Satara, Maharashtra, India, [2]Department of Animal Husbandry, Government of Maharashtra, Satara, Maharashtra, India, [3]Department of Veterinary Pharmacology and Toxicology, KNP College of Veterinary Science, Shirwal, Maharashtra Animal and Fishery Sciences University, Nagpur, Maharashtra, India, [4]Department of Veterinary Public Health, KNP College of Veterinary Science, Shirwal, Maharashtra Animal and Fishery Sciences University, Nagpur, Maharashtra, India, [5]Department of Veterinary Microbiology, KNP College of Veterinary Science, Shirwal, Maharashtra Animal and Fishery Sciences University, Nagpur, Maharashtra, India

Abstract

Moringa oleifera Lam., commonly known as drumstick tree, is an edible plant originating from the Indian subcontinent and is increasingly investigated as a source of nutrients and biologically active phytochemicals. Leaves and leaf-derived preparations contain phenolic compounds, flavonoids, carotenoids, glucosinolates, isothiocyanates, vitamins, minerals and other bioactive constituents with reported antioxidant and antimicrobial properties. These characteristics have generated interest in the incorporation of *M. oleifera* into meat and meat products as a natural functional ingredient and potential alternative or complement to conventional preservatives. This review evaluates the available scientific evidence concerning the nutritional and bioactive composition of *M. oleifera*, mechanisms underlying its antioxidant and antimicrobial activities, and its application in fresh and processed meat products. Available studies indicate that *Moringa* leaf powder and extracts can reduce lipid oxidation in meat matrices while potentially improving nutritional and functional characteristics. Studies in ground beef and chicken sausages provide direct evidence for reductions in oxidative deterioration, and aqueous leaf extract in ground beef and leaves in chicken sausages also reduced microbial counts; however, increasing concentrations of leaf powder in ground beef were associated with higher microbial counts, and effects vary with plant part, preparation method, concentration, storage conditions and meat matrix. Sensory effects also require careful optimization because increasing *Moringa* concentrations may influence color, flavor and acceptability. Future research should focus on standardized extracts, bioavailability, dose-response relationships, encapsulation, edible coatings, mechanistic studies, safety assessment and commercial-scale validation. Overall, *M. oleifera* represents a promising plant-derived functional ingredient for the development of meat products with enhanced nutritional, oxidative and microbiological stability.

Key words: Antimicrobial activity, antioxidants, food safety, functional food, lipid oxidation, meat products, *Moringa oleifera*, phytochemicals, shelf life

INTRODUCTION

Meat and meat products are important sources of high-quality protein, essential amino acids, minerals, vitamins and other nutrients. However, their high water activity, nutrient availability and relatively favorable physicochemical characteristics also make them susceptible to microbial growth and chemical deterioration.

Address for correspondence:
Vikas Karande, Department of Veterinary Pharmacology and Toxicology, KNP College of Veterinary Science, Shirwal, Nagpur, Maharashtra, India.
E-mail: vikaskarande@mafsu.ac.in

Received: 19-08-2026
Revised: 20-09-2026
Accepted: 26-09-2026

© 2026 Author(s). This is an open-access article distributed under the terms of the Creative Commons Attribution 4.0 International License (CC BY 4.0)

Lipid oxidation, protein oxidation, pigment oxidation and microbial multiplication can progressively impair nutritional quality, color, flavor, texture, safety and shelf life.

Synthetic antioxidants and antimicrobial preservatives have traditionally been used to control deterioration in processed foods. Increasing interest in clean-label foods and naturally derived ingredients has stimulated research into plant materials containing phenolic compounds, flavonoids, essential oils, peptides and other bioactive substances. In this context, *Moringa oleifera* has attracted considerable attention because different parts of the plant provide nutrients and phytochemicals with reported antioxidant, antimicrobial and other biological activities.[1-4]

The leaves are particularly relevant to food applications because they contain proteins, essential amino acids, minerals, vitamins, carotenoids, phenolic acids, flavonoids and glucosinolates. The phytochemical profile is influenced by plant part, cultivar, maturity, geographical origin, harvesting conditions and processing.[1,2] Glucosinolates can undergo enzymatic conversion to isothiocyanates, compounds that have received considerable attention due to their biological activities.[5,6]

Previous reviews have described the nutritional, pharmacological and functional properties of *M. oleifera*, including its use in animal nutrition and food products.[2,7] More recently, comprehensive reviews have addressed the incorporation of *Moringa* into several food categories, including meat products.[8] Therefore, a focused synthesis of the evidence specifically relating to meat and meat products is warranted.

The objective of this review is to critically examine the role of *M. oleifera* in meat and meat products, with particular emphasis on its bioactive constituents, antioxidant and antimicrobial mechanisms, effects on physicochemical and microbiological quality, oxidative stability, sensory characteristics, functional-food potential, safety and emerging technological applications.

M. OLEIFERA: NUTRITIONAL AND PHYTOCHEMICAL PROFILE

M. oleifera belongs to the family Moringaceae and is widely cultivated in tropical and subtropical regions. Leaves, flowers, pods and seeds are used as food or food-related materials. The leaves are especially attractive for food fortification because they provide protein, minerals, vitamins, carotenoids and diverse phytochemicals.[1-3]

The major phytochemical groups reported in *Moringa* include phenolic acids, flavonoids, glucosinolates, isothiocyanates, carotenoids, tocopherols, alkaloids and other secondary metabolites.[1,5] Saini *et al*. identified glucosinolates, flavonoids, phenolic acids, carotenoids, tocopherols and minerals among important constituents of the plant.[1]

The chemical composition is not constant. Leaf age, growing conditions, genotype, processing and extraction procedure may substantially alter the concentration and activity of individual compounds. Consequently, comparison of studies based only on the percentage of *Moringa* added to meat may be misleading unless the chemical characteristics of the preparation are also considered.

BIOACTIVE COMPOUNDS RELEVANT TO MEAT APPLICATIONS

The major bioactive groups of *M. oleifera* relevant to meat applications are summarized in Table 1.

Phenolic compounds

Phenolic acids and polyphenols can donate hydrogen atoms or electrons to reactive species and thereby contribute to antioxidant activity. Their ability to interact with reactive oxygen species makes them relevant to lipid oxidation in meat.

Flavonoids

Flavonoids constitute an important class of *Moringa* phytochemicals. Quercetin and related compounds have been reported among the flavonoid constituents of *Moringa*.[1,3] Their antioxidant potential may contribute to suppression of oxidative deterioration in meat matrices.[9]

Glucosinolates and isothiocyanates

Glucosinolates are sulfur-containing secondary metabolites. One of the characteristic glucosinolates in *Moringa* is glucomoringin. Plant tissue disruption can facilitate myrosinase-mediated conversion of glucosinolates into isothiocyanates and related products.[5,6] *Moringa* isothiocyanates have received increasing attention due to reported antibacterial and other biological activities.[5]

Carotenoids and tocopherols

Carotenoids and tocopherols may contribute to antioxidant protection. Their presence is particularly relevant in foods undergoing oxidative deterioration during refrigerated storage.

Proteins, amino acids and minerals

Moringa leaves also provide proteins, essential amino acids and minerals. Incorporation into meat products may therefore

provide nutritional enrichment in addition to preservation-related functionality.[2,7]

ANTIOXIDANT PROPERTIES AND MECHANISMS

Oxidative deterioration is one of the major quality problems in meat products. Polyunsaturated fatty acids can undergo free-radical-mediated oxidation, generating hydroperoxides and secondary compounds that adversely affect flavor and nutritional quality.

Moringa phytochemicals may interfere with oxidative processes through several mechanisms [Table 2]:

- Scavenging reactive oxygen species;
- Donating hydrogen atoms or electrons;
- Chelating pro-oxidant metal ions;
- Inhibiting propagation reactions;
- Reducing formation of secondary lipid-oxidation products; and
- Potentially protecting proteins and pigments from oxidative damage.

Experimental studies support the relevance of these mechanisms in meat systems. Mashau *et al.* reported that incorporation of 0.2–0.8% *Moringa* leaf powder into ground beef affected nutritional and technological characteristics and reduced thiobarbituric acid reactive substances (TBARS) values during cold storage.[10] The authors also observed that microbial growth, pH and color values increased with increasing concentration of the powder, an observation that underlines the importance of the microbiological quality of the leaf powder itself (Section 13).

Similarly, Jayawardana *et al.* reported lower TBARS values in chicken sausages containing 0.5–1.0% *Moringa* leaves compared with controls, indicating an antioxidant effect during storage.[11]

These findings suggest that the antioxidant activity observed in chemical assays can translate into measurable protection within a complex meat matrix. However, the magnitude of protection depends on concentration, extraction method, meat composition, storage temperature and duration.

ANTIMICROBIAL PROPERTIES AND MECHANISMS

Microbial contamination is a major determinant of the safety and shelf life of fresh and processed meat. *Moringa* contains phenolic compounds, flavonoids, isothiocyanates and other substances that may interfere with microbial growth.[12]

Potential antimicrobial mechanisms [Table 2] include:

- Disruption of bacterial cell membranes;
- Alteration of membrane permeability;
- Interference with cellular enzymes;
- Oxidative or redox-related cellular damage;

Table 1: Major bioactive components of *Moringa oleifera* relevant to meat applications

Bioactive group	Representative components	Potential relevance to meat
Phenolic compounds	Phenolic acids, polyphenols	Antioxidant activity
Flavonoids	Quercetin and related compounds	Radical scavenging and oxidative stability
Glucosinolates	Glucomoringin and related compounds	Precursors of biologically active compounds
Isothiocyanates	*Moringa*-derived isothiocyanates	Potential antimicrobial and bioactive effects
Carotenoids	β-carotene and related pigments	Antioxidant/nutritional activity
Tocopherols	Vitamin E-related compounds	Lipid antioxidant activity
Proteins	Soluble and structural proteins	Nutritional enrichment
Minerals	Calcium, iron, potassium and others	Nutritional enhancement

Table 2: Potential mechanisms of *Moringa* action in meat

Target	Possible mechanism	Expected outcome
Reactive oxygen species	Radical scavenging	Reduced oxidative damage
Lipid oxidation	Chain-breaking antioxidant activity	Lower TBARS*/secondary oxidation products
Pro-oxidant metals	Metal chelation	Reduced oxidation
Bacterial membranes	Membrane disruption	Reduced bacterial growth
Microbial enzymes	Interaction/inhibition	Reduced microbial metabolism
Meat matrix	Fiber/protein interactions	Changes in water retention and texture
Functional nutrition	Addition of phytochemicals and micronutrients	Nutritional enrichment

*TBARS: Thiobarbituric acid reactive substances

- Interaction with microbial proteins; and
- Interference with metabolic processes.

The direct meat-based evidence is particularly important. Abdallah *et al*. evaluated aqueous *Moringa* leaf extract in ground beef stored at 4°C for 18 days. The study reported reductions in aerobic plate counts and Enterobacteriaceae and significant reductions in experimentally inoculated *Escherichia coli* O157:H7, *Salmonella enterica* serovar Typhimurium and *Staphylococcus aureus* with the 2% extract treatment.[13]

This study provides evidence that *Moringa* extract can exert antimicrobial effects within a meat matrix rather than only under *in vitro* conditions. Nevertheless, antimicrobial efficacy should not be generalized across all *Moringa* preparations because extraction solvent, concentration, plant material, storage conditions and target microorganisms vary considerably.

APPLICATION OF *M. OLEIFERA* IN MEAT AND MEAT PRODUCTS

Representative studies of the application of *Moringa* in meat products are summarized in Table 3.

Ground meat

Ground meat provides a particularly relevant matrix for natural preservatives because grinding increases surface area and facilitates exposure to oxygen and microorganisms.

Mashau *et al.* investigated 0.2, 0.4, 0.6 and 0.8% *Moringa* leaf powder in ground beef during cold storage. The study reported effects on nutritional composition, phenolic content, physicochemical characteristics, lipid oxidation and microbial growth. Moderate concentrations (0.2 and 0.4%) also maintained sensory acceptability.[10]

Chicken sausages

Jayawardana *et al.* investigated *Moringa* leaves at 0.25–1% in chicken sausages. Treatments containing 0.5–1% *Moringa* showed significantly lower TBARS values and lower total plate counts during storage than the 0.25% treatment and the control sausages. Sensory differences were not detected at 0.25 and 0.5% inclusion compared with controls.[11]

Ground beef treated with aqueous extract

Abdallah *et al.* evaluated aqueous *Moringa* leaf extract at 0.5, 1 and 2% in ground beef stored at 4°C for 18 days. The 2% treatment showed pronounced reductions in experimentally inoculated foodborne pathogens by the end of refrigerated storage.[13] The study also reported no adverse effect on overall sensory acceptability.

Chicken nuggets

Gomkale *et al.* optimized the incorporation of an aqueous *Moringa* leaf extract at 0, 2.5, 5 and 7.5% in ground chicken nuggets and evaluated proximate composition, physicochemical characteristics and sensory quality. Protein and ash increased significantly up to 5% extract, whereas moisture and fat did not differ significantly.[14]

These studies collectively indicate that both powdered leaves and aqueous extracts have potential, but they should not be considered interchangeable. Powder introduces the whole plant matrix and insoluble components, whereas extracts provide a more concentrated and selective fraction of phytochemicals.

Table 3: Representative evidence for *Moringa* application in meat products

Meat matrix	*Moringa* preparation (%)	Major parameters investigated	Principal observations
Ground beef	Leaf powder, 0.2–0.8	Nutritional composition, TBARS*, microbial growth, pH, color, sensory quality	Improved nutritional characteristics and reduced lipid oxidation; concentration-dependent effects on quality parameters, including increased microbial counts, pH and color values at higher concentrations
Chicken sausage	Leaf powder, 0.25–1	TBARS*, pH, microbial count, color, sensory characteristics	0.5–1% treatments showed lower TBARS* and total plate counts
Ground beef	Aqueous leaf extract, 0.5–2	Foodborne pathogens, spoilage bacteria, sensory quality	2% treatment showed substantial reductions in experimentally inoculated foodborne pathogens
Chicken nuggets	Aqueous leaf extract, 2.5–7.5	Proximate composition, physicochemical characteristics, sensory quality	Protein and ash increased significantly up to 5% extract; moisture and fat did not differ significantly

*TBARS: Thiobarbituric acid reactive substances

EFFECT ON PHYSICOCHEMICAL AND TECHNOLOGICAL PROPERTIES

The incorporation of plant powders or extracts can influence pH, color, water-holding capacity, cooking loss, texture and emulsion characteristics.

Moringa leaf powder may alter color due to its chlorophyll and other pigments. This can be advantageous when a characteristic appearance is desired but may become a sensory limitation at higher concentrations.[10,11]

Changes in pH can influence microbial growth, water-holding capacity and color stability. Mashau *et al.* observed concentration-dependent changes in pH and color parameters in *Moringa*-treated ground beef.[10]

The effect on cooking loss and water-holding capacity is likely influenced by the fiber and protein content of the leaf material. These effects should therefore be considered when developing functional meat products rather than evaluating *Moringa* solely as an antioxidant.

EFFECT ON OXIDATIVE STABILITY AND SHELF LIFE

The preservation potential of *Moringa* is particularly relevant because meat deterioration involves simultaneous chemical and microbiological processes.

The available evidence suggests three potentially complementary actions:

Moringa bioactives → reduced oxidative reactions → improved color/flavor stability

Moringa bioactives → reduced microbial multiplication → improved microbiological shelf life

Moringa nutrients/fiber → altered product composition → functional/nutritional enhancement.

However, the available studies are heterogeneous. Different investigators have used different concentrations, plant preparations, storage periods, and analytical endpoints. Therefore, a universal "shelf-life extension" value cannot currently be assigned to *Moringa*-treated meat.

MICROBIOLOGICAL QUALITY AND FOOD SAFETY

Potential target organisms in meat systems include *Salmonella*, pathogenic *Escherichia coli*, *Staphylococcus aureus*, Enterobacteriaceae, and general spoilage flora.

The ground-beef study by Abdallah *et al.* provides direct evidence of antimicrobial activity against three major foodborne pathogens.[13] Such findings are relevant from a veterinary public health perspective because reduction of pathogen loads in meat could potentially contribute to improved food safety.

However, antimicrobial activity observed experimentally should not be equated automatically with complete pathogen control. *Moringa* should be considered a potential intervention within a broader food-safety system incorporating hygienic slaughter, temperature control, good manufacturing practices, hazard analysis and critical control point systems, and validated preservation procedures.

SENSORY QUALITY AND CONSUMER ACCEPTABILITY

Sensory acceptance is one of the most important limitations when introducing plant materials into meat products.

Moringa leaves can influence:

- Color;
- Herbal aroma;
- Flavor;
- Bitterness;
- Aftertaste;
- Texture; and
- Overall acceptability.

Jayawardana *et al.* found no detectable sensory differences in chicken sausages containing 0.25 and 0.5% *Moringa* leaves compared with controls.[11] Mashau *et al.* similarly reported acceptable sensory characteristics at moderate concentrations (0.2 and 0.4%) in ground beef.[10] Abdallah *et al.* reported no adverse overall sensory effect of aqueous *Moringa* extract in ground beef.[13]

These findings indicate that functionality and sensory acceptance need to be optimized together. The highest concentration is not necessarily the most appropriate formulation.

MORINGA AS A FUNCTIONAL INGREDIENT IN MEAT PRODUCTS

Functional meat products are increasingly being investigated as a means of combining the nutritional contribution of animal-source foods with bioactive plant ingredients.

Moringa may provide several simultaneous functions:

- Nutritional: Protein, minerals, vitamins and phytochemicals
- Antioxidant: Reduction of lipid oxidation and potentially oxidative damage

- Antimicrobial: Inhibition of selected spoilage and foodborne microorganisms
- Technological: Possible effects on water retention, texture and product composition
- Functional/nutraceutical: Provision of plant-derived bioactive compounds.

The concept is therefore different from simply adding a preservative. *Moringa* can potentially be considered a multifunctional ingredient that combines nutritional enrichment with technological and preservation-related properties.

Nevertheless, claims concerning specific health benefits of consuming *Moringa*-fortified meat should be made cautiously. Evidence for pharmacological effects of isolated *Moringa* constituents does not automatically establish equivalent benefits from consumption of a *Moringa*-containing meat product.

EMERGING TECHNOLOGIES

Extract standardization

One major research requirement is standardization of *Moringa* preparations according to total phenolics, flavonoids, glucosinolates/isothiocyanates, and antioxidant activity. Standardized extracts would allow meaningful comparison among studies.

Encapsulation

Microencapsulation and nanoencapsulation may protect sensitive phytochemicals from degradation and permit controlled delivery within meat matrices.

Edible films and coatings

Moringa extracts could potentially be incorporated into edible coatings or films applied to fresh meat. This approach may permit localized antimicrobial activity at the food surface while reducing the quantity of extract required within the product.

Combination preservation

Moringa could be evaluated in combination with other natural preservatives, modified-atmosphere packaging, refrigeration, organic acids, or other validated hurdles.

Omics and computational approaches

Metabolomics, proteomics and microbiome sequencing could help clarify how *Moringa* changes meat chemistry and microbial communities during storage. Machine-learning models could potentially be used for formulation optimization and shelf-life prediction, although such applications require sufficiently large, standardized datasets.

SAFETY AND REGULATORY CONSIDERATIONS

The widespread dietary use of *Moringa* leaves does not eliminate the need for systematic safety assessment. *Moringa* contains numerous bioactive compounds, and safety may vary according to plant part, dose, and preparation.

Published reviews have emphasized that although many studies suggest favorable safety profiles for leaf preparations, evidence remains incomplete for some preparations and dose ranges.[4,15] Certain reviews have also highlighted the need for additional toxicological and clinical research.

For meat applications, safety assessment should consider:

- Identity and purity of plant material;
- Pesticide and heavy-metal contamination;
- Microbial contamination of leaf powder;
- Antinutritional factors;
- Extraction solvents;
- Concentration of bioactive compounds;
- Stability during processing;
- Interaction with meat components; and
- Consumer exposure.

Regulatory requirements for botanical ingredients differ between jurisdictions. Therefore, future product development should establish the regulatory status and permitted use conditions applicable to the target market before commercialization.

CURRENT RESEARCH GAPS

Despite promising findings, several important gaps remain. The advantages and current limitations of *Moringa* in meat products are summarized in Table 4.

Table 4: Advantages and limitations of *Moringa* in meat products

Potential advantages	Current limitations
Natural plant-derived ingredient	Variation in phytochemical composition
Antioxidant activity	Limited standardized preparations
Antimicrobial potential	Limited number of meat-specific studies
Nutritional enrichment	Possible color changes
Potential shelf-life improvement	Possible herbal/bitter flavor at higher levels
Multifunctional activity	Limited commercial-scale validation
Compatibility with functional-food development	Need for detailed safety and regulatory evaluation

First, relatively few studies have evaluated *Moringa* directly in meat matrices compared with the large body of literature describing its general nutritional and pharmacological properties.

Second, there is substantial variability in the plant material and preparation methods. Studies may use fresh leaves, dried powder, aqueous extracts, or hydroalcoholic extracts, making direct comparison difficult.

Third, standardized dose-response studies are required. The concentration that maximizes antioxidant or antimicrobial activity may not be the concentration that provides optimal sensory acceptance.

Fourth, many studies evaluate TBARS, total plate count, or individual pathogens, whereas simultaneous evaluation of lipid oxidation, protein oxidation, volatile compounds, microbial ecology, sensory quality, and nutritional changes would provide a more comprehensive understanding.

Fifth, bioavailability and stability of *Moringa* phytochemicals after incorporation into meat and subsequent cooking require greater attention.

Sixth, commercial-scale studies are limited. Laboratory-scale success does not necessarily predict industrial processing performance.

FUTURE PERSPECTIVES

Future research should move from proof-of-concept experiments toward standardized product-development studies.

A useful research framework would include:

Moringa cultivar and plant part selection
↓
Standardized extraction or powder preparation
↓
Phytochemical characterization
↓
Antioxidant and antimicrobial screening
↓
Incorporation into specific meat matrices
↓
Optimization of concentration
↓
Storage challenge studies
↓
Microbiological + physicochemical + oxidative + sensory assessment
↓
Bioavailability and safety evaluation
↓
Pilot-scale validation

Particular attention should be given to *Moringa* extracts rich in phenolics and isothiocyanates, controlled-release systems, edible coatings, and combination preservation strategies.

Future studies should also distinguish between antioxidant capacity measured in chemical assays and actual preservation efficacy in meat. The latter should be demonstrated using validated meat-storage experiments.

CONCLUSION

M. oleifera represents a promising plant-derived multifunctional ingredient for meat and meat products. Its nutritional constituents and diverse bioactive compounds, particularly phenolics, flavonoids, carotenoids, glucosinolates and isothiocyanates, provide a scientific basis for antioxidant and antimicrobial functionality.

Available meat-specific studies demonstrate that *Moringa* leaf powder and extracts can influence lipid oxidation, microbial growth, physicochemical characteristics, and, under appropriate conditions, sensory properties. Evidence from chicken sausages and ground beef provides direct support for its potential as a natural functional ingredient and preservation aid.[10,11,13]

However, the current evidence does not justify treating *Moringa* as a universal replacement for established meat-preservation systems. Differences in plant material, extraction method, concentration, meat matrix, and storage conditions substantially affect outcomes. Future research should prioritize standardized preparations, mechanistic studies, bioavailability, safety, sensory optimization, encapsulation, and commercial-scale validation.

The greatest potential of *M. oleifera* may therefore lie in its multifunctionality: Simultaneous nutritional enrichment, antioxidant protection, antimicrobial activity, and development of value-added functional meat products. Integration of *Moringa* with modern food-processing technologies and One Health-oriented food-safety approaches may provide an important direction for future research.

ETHICAL APPROVAL

Not applicable because this article is a review of previously published literature.

DATA AVAILABILITY

Not applicable.

REFERENCES

1. Saini RK, Sivanesan I, Keum YS. Phytochemicals of *Moringa oleifera*: A review of their nutritional, therapeutic and industrial significance. 3 Biotech 2016;6:203.
2. Falowo AB, Mukumbo FE, Idamokoro EM, Lorenzo JM, Afolayan AJ, Muchenje V. Multi-functional application of *Moringa oleifera* Lam. In nutrition and animal food products: A review. Food Res Int 2018;106:317-34.
3. Fahey JW. *Moringa oleifera*: A review of the medical evidence for its nutritional, therapeutic, and prophylactic properties. Part 1. Trees Life J 2005;1:5.
4. Stohs SJ, Hartman MJ. Review of the safety and efficacy of *Moringa oleifera*. Phytother Res 2015;29:796-804.
5. López-Rodríguez NA, Gaytán-Martínez M, De La Luz Reyes-Vega M, Loarca-Piña G. Glucosinolates and isothiocyanates from *Moringa oleifera*: Chemical and biological approaches. Plant Foods Hum Nutr 2020;75:447-57.
6. Wu Q, Zhou HJ, Sheng J, Su LY, Tian Y. Extraction, structural properties, and bioactivities of *Moringa* (*Moringa oleifera* Lam.) isothiocyanates: A review. Food Biosci 2024;57:103447.
7. Gopalakrishnan L, Doriya K, Kumar DS. *Moringa oleifera*: A review on nutritive importance and its medicinal application. Food Sci Hum Wellness 2016;5:49-56.
8. Ramesh B, Chauhan R, Don PM, Joshi R, Pansare S, Modi Z, *et al*. *Moringa oleifera*: A comprehensive review of its nutritional benefits, functional applications, and future potential in food science. J Sci Food Agric 2026;106:5125-41.
9. Wang Y, Gao Y, Ding H, Liu S, Han X, Gui J, *et al*. Subcritical ethanol extraction of flavonoids from *Moringa oleifera* leaf and evaluation of antioxidant activity. Food Chem 2017;218:152-8.
10. Mashau ME, Ramatsetse KE, Ramashia SE. Effects of adding *Moringa oleifera* leaves powder on the nutritional properties, lipid oxidation and microbial growth in ground beef during cold storage. Appl Sci 2021;11:2944.
11. Jayawardana BC, Liyanage R, Lalantha N, Iddamalgoda S, Weththasinghe P. Antioxidant and antimicrobial activity of drumstick (*Moringa oleifera*) leaves in herbal chicken sausages. LWT-Food Sci Technol 2015;64:1204-8.
12. Tshabalala T, Ndhlala AR, Ncube B, Abdelgadir HA, Van Staden J. Potential substitution of the root with the leaf in the use of *Moringa oleifera* for antimicrobial, antidiabetic and antioxidant properties. S Afr J Bot 2020;129:106-12.
13. Abdallah R, Mostafa NY, Kirrella GA, Gaballah I, Imre K, Morar A, *et al*. Antimicrobial effect of *Moringa oleifera* leaves extract on foodborne pathogens in ground beef. Foods 2023;12:766.
14. Gomkale AP, Sakunde DT, Kadam BR, Mane DV, Durala D. Effect of incorporation of drumstick (*Moringa oleifera*) leaves extract on the quality of ground chicken nuggets. J Meat Sci 2023;18:9-13.
15. Panghal A, Kaur A, Mann S, Garg MK, Sofi SA, Panghal A. Bioactive compounds, associated health benefits and safety considerations of *Moringa oleifera* L.: An updated review. Nutr Food Sci 2021;51:255-77.

Source of Support: Nil. **Conflicts of Interest:** None declared.