**Dendeng as a Functional Food: Opportunities and Challenges in Innovating Local Meat-Based Products**

## ABSTRACT

Dendeng, a traditional Indonesian meat product, holds strong potential to be developed as a functional food. In addition to its distinctive flavor and long shelf life, dendeng contains bioactive compounds such as antihypertensive peptides, antioxidants, and CLA that offer health benefits. The use of natural spices during marination further enhances its functional properties. Technological innovations including probiotic fermentation, low-temperature drying, and vacuum or modified-atmosphere packaging improve the stability and bioactivity of these functional components. Challenges include raw material sustainability, functional claim standardization, and industrial scalability. Nonetheless, growing consumer awareness of healthy foods creates a promising opportunity for dendeng to be positioned as a functional food that supports the prevention of degenerative diseases. Cross-sector collaboration is crucial to strengthen dendeng’s position as an innovative product capable of competing in both local and global markets.

*Keywords: Dendeng, functional food, bioactive compounds, technological innovation, meat processing.*

**1. INTRODUCTION**

This paper aims to provide a scientific and practical review of the development of dendeng (Indonesian-style dried meat) as a functional food. The primary target audience includes academic researchers interested in food and nutrition studies, meat processing industry stakeholders seeking value-added product innovations, and policymakers involved in developing healthy and functional food regulations in Indonesia. Accordingly, this manuscript is intended to serve as a strategic cross-sector reference supporting food diversification based on local wisdom.

Dendeng is a traditional processed meat product native to Indonesia, that has long been an integral part of the archipelago's culinary heritage. With its rich flavors and distinctive processing techniques, dendeng not only embodies deep cultural significance but also holds substantial potential as a functional food source. According to Mediani et al. (2022), dendeng contains a variety of bioactive compounds that provide additional health benefits, including antioxidant, anti-inflammatory, and immune-modulating properties. The global trend toward healthy eating and natural food consumption has gained momentum, driven by increasing public awareness of the importance of a healthy lifestyle (Selani et al., 2022). This creates a significant opportunity to develop dendeng as a functional food, particularly since its primary ingredient meat can be enriched with essential nutrients derived from local spices traditionally used in dendeng preparation. The production process, involving marination, drying, and heating, also contributes to a longer shelf life, making it suitable for both urban and remote community consumption (Nam et al., 2016).

Through innovations in spice formulation, processing techniques, and the diversification of meat raw materials, dendeng has the potential to become a culturally grounded food product that contributes to public health improvement (Saputra et al., 2024). A major opportunity lies in utilizing abundant natural spices in Indonesia, such as turmeric, ginger, galangal, and garlic, which are widely recognized for their health-promoting properties (Shaukat et al., 2023). However, realizing this potential presents several challenges in terms of product development, processing, and marketing. One major issue is maintaining dendeng’s traditional taste while complying with increasingly stringent food quality and health standards (Kim et al., 2021). Ensuring sustainable to high-quality raw materials particularly antibiotic-residue-free meat from environmentally responsible farming is also essential to preserving key bioactive compounds such as CLA and functional peptides (Ji et al., 2021). Additionally, eco-friendly processing innovations, such as low energy drying and natural nitrite replacements, require significant technological adaptation and investment (Fekete et al., 2025). Efficient supply chain development remains another challenge, particularly with regard to ensuring nutritional stability over an extended shelf life.

The advancement of dendeng as a functional food must be supported by multi-stakeholder collaboration involving small-scale producers, food scientists, and both local and national government policymakers. Cross-sector partnerships have been shown to be crucial for developing locally based functional food products in various countries (Mazukabzova & Zaitseva, 2022). With the right approach, dendeng has the potential not only to preserve Indonesia’s rich culinary heritage but also to serve as a strategic product for enhancing public health and national food security in a sustainable manner.

**2. Functional Composition of Dendeng**

As a traditional Indonesian meat product, dendeng is more than just a flavorful and nutritious source of animal protein. Through innovations in processing methods and the utilization of raw materials rich in bioactive components, dendeng possesses the potential to function as a functional food that goes beyond fulfilling basic nutritional needs. Functional foods are defined as foods that provide health benefits beyond their basic nutritional functions as sources of energy or essential nutrients (Lopez Pedrousu et al., 2023). As part of a rich culinary tradition, dendeng exemplifies the integration of food technology with public health objectives by incorporating bioactive compounds that support various physiological functions (Guo et al., 2024). In the production of dendeng, the use of natural spices, minimal processing techniques, and high-quality meat ingredients plays a crucial role in generating healthier and value-added products. Research on the bioactive content of dendeng from proteins and bioactive peptides to antioxidants and functional fatty acids indicates that this meat product holds promise for further development as a health-oriented food that considers both flavor and consumer wellness (Mediani et al., 2022). The following sections highlight key functional components in dendeng that offer benefits beyond basic nutrition:

1. Proteins and Bioactive Peptides

Peptides derived from the enzymatic hydrolysis of meat proteins, particularly beef, have shown antihypertensive activity through the inhibition of angiotensin-converting enzyme (ACE). In vitro studies by Aluko (2015) demonstrated that such peptides can effectively lower blood pressure via inhibition of the renin-angiotensin aldosterone system (RAAS). Specifically, beef derived peptides exhibited ACE-inhibitory activity ranging from 70% to 90% in controlled laboratory assays, reinforcing dendeng’s functional potential in managing hypertension. Although this bioactivity is promising, current data predominantly stem from in vitro and animal model studies; therefore, further clinical trials are required to validate their efficacy in humans.

1. Antioxidant Compounds from Traditional Spices

Traditional spices used during the marination of dendeng such as garlic, ginger, coriander, black pepper, and turmeric not only impart unique flavors but also enhance its functional properties. These spices contain potent bioactive compounds, including allicin (garlic), curcumin (turmeric), gingerol (ginger), and piperine (black pepper), which exhibit well-documented antioxidant and anti-inflammatory activities (Edo et al., 2025). A study by Kurniawan et al. (2023) reported that incorporating these spices into dendeng significantly increased its ORAC (Oxygen Radical Absorbance Capacity) score, indicating improved antioxidant capacity. This antioxidant activity plays a critical role in protecting cells from oxidative damage caused by free radicals, which are associated with premature aging and the development of degenerative diseases such as cancer and cardiovascular disorders. Additionally, the anti-inflammatory properties of these compounds may help mitigate chronic inflammation, a major contributor to metabolic disorders (Dable-Tupos et al., 2020).

1. Functional Fatty Acids and CLA

Conjugated linoleic acid (CLA), a bioactive fatty acid found in ruminant-derived meats, has been reported to exhibit anti-cancer and anti-obesity effects in numerous in vivo studies, particularly those involving rodent models (Mediani et al., 2022). These effects include improved lipid metabolism and reduced atherosclerotic plaque formation. However, human clinical trials have yielded inconsistent results, suggesting that the functional benefits of CLA in dendeng remain speculative and may be influenced by its stability during processing.

**Table 1.** Key Bioactive Compounds in Dendeng and Their Health Benefits

|  |  |  |  |
| --- | --- | --- | --- |
| **Bioactive Compound** | **Source** | **Health Benefits** | **Reference** |
| Bioactive Peptides | Hydrolyzed meat proteins | Antihypertensive, antioxidant, antimicrobial | Aluko (2015); Lopez-Pedrouso et al. (2023) |
| CLA (Conjugated Linoleic Acid) | Ruminant animal fat | Anti cancer, anti-obesity | Mediani et al. (2022); Kim et al. (2020) |
| Allicin | Garlic | Antioxidant, antimicrobial | Edo et al. (2025) |
| Curcumin | Turmeric | Anti-inflammatory, antioxidant | Dable-Tupas et al. (2020); Shaukat et al. (2023) |
| Gingerol | Ginger | Antioxidant, anti-inflammatory | Shaukat et al. (2023); Edo et al. (2025) |
| Piperine | Black pepper | Enhances nutrient absorption, antioxidant | Kurniawan et al. (2023) |

*Note: The health benefit claims of the bioactive compounds listed in this table are primarily based on previous studies, the majority of which are derived from in vitro and some in vivo experiments. However, not all effects have been confirmed through human clinical trials.*

**3. Processing Technologies Supporting the Functional Properties of Dendeng**

With advances in technology, artificial intelligence (AI) based approaches have been increasingly adopted in the development of functional foods, including the formulation and optimization of meat processing. Machine learning models such as artificial neural networks (ANN) and support vector machines (SVM) have been applied to predict the stability of bioactive compounds, lipid oxidation levels, and the effectiveness of drying and fermentation processes in meat-based products. A study by Khan et al. (2023) demonstrated that AI approaches can improve the efficiency of shelf-life prediction and microbiological quality of dendeng based on physicochemical parameters, with accuracy rates reaching up to 92%. Similarly, Zhang et al. (2024) highlighted the integration of the Internet of Things (IoT) and AI for temperature and humidity control during dendeng drying, resulting in a 18% improvement in sensory quality compared to conventional methods.

Accurate dendeng processing plays a critical role in preserving and enhancing its functional components. The chosen processing technologies influence not only the taste and shelf-life but also the nutritional quality and bioactivity of the final product (Gomez et al., 2020). Technological innovations are essential to optimize the nutritional profile and health benefits of dendeng as a functional food (Hernandez-Jaime et al., 2025). The following are several key processing techniques that support the functional potential of dendeng:

****

Figure 1. A schematic overview of modern meat-processing techniques such as sun‑drying, oven‑drying, freeze‑drying, and vacuum‑drying illustrating how different drying methods can preserve bioactive peptides, antioxidants, fatty acids, and other functional components.

1. **Drying and Smoking**

Drying and smoking are core processes in dendeng production, primarily intended to extend shelf life while potentially enhancing the formation of bioactive peptides. Low-temperature drying is particularly effective in preserving bioactive compounds such as antihypertensive and antimicrobial peptides derived from meat protein hydrolysis (Pushparaj et al., 2025). Smoking adds phenolic and aldehyde compounds, which exhibit antioxidant and anti-inflammatory properties (Kim et al., 2021). However, careful control of temperature and duration is crucial to prevent nutrient degradation. Innovative drying techniques such as hot air drying or ultraviolet (UV) irradiation have shown potential to improve functional quality without compromising taste and texture (Mediani et al., 2022).

1. **Fermentation and Probiotics**

Fermentation technologies offer an alternative method for producing dendeng with probiotic properties. Beneficial microorganisms such as lactic acid bacteria can be incorporated to enhance gut health and immunity (Guo et al., 2024). Fermentation also boosts the bioactive content of dendeng by enabling microbial breakdown of meat and spice components into health-promoting peptides (Dable-Tupos et al., 2020). For instance, proteolytic bacteria may generate bioactive compounds with antihypertensive or anti-inflammatory effects (Aluko, 2015). Fermentation adds a distinctive taste and texture, differentiating it from traditionally dried or smoked dendeng.

1. **Marination and Herbal Spice Innovation**

Marination plays a critical role in flavor development and the functional enhancement of dendeng (Ehsanur et al., 2023). Advanced marination technologies improve the absorption of bioactive compounds from spices. Techniques such as ultrasonication and microwave-assisted heating enhance the penetration of compounds like curcumin, gingerol, and allicin into the meat matrix, thereby increasing the health-promoting potential of the product (Saputra et al., 2024). Controlled marination conditions optimal temperature, duration, and natural ingredients can significantly boost antioxidant and anti-inflammatory capacities. Kurniawan et al. (2023) showed that combining spice blends with modern marination techniques led to dendeng with higher ORAC values, reflecting greater antioxidant potential.

1. **Packaging Technologies for Shelf-Life and Functional Integrity**

Innovative packaging technologies also play an essential role in preserving the functional quality of dendeng. Vacuum packaging and modified atmosphere packaging (MAP) extend shelf life while maintaining nutrional and sensory quality (Stahlke et al., 2018). Vacuum sealing reduces lipid oxidation and preserves bioactive compounds during storage (Luzardo et al., 2024). Furthermore, packaging that maintains consistent humidity and temperature helps retain essential nutrients such as conjugated linoleic acid (CLA) and bioactive peptides (Kandeepan & Tahseen, 2022). The use of sustainable or biodegradable materials in packaging may also enhance consumer appeal, especially among environmentally conscious markets.

These technological innovations enable the development of dendeng that aligns with modern consumer preferences for nutritious and health-promoting foods, while retaining its cultural and traditional identity**.**

**4. Functional Dendeng as an Opportunity in the Meat Industry**

With the increasing trend toward healthy and natural food consumption, the meat industry has a growing opportunity to innovate through functional meat products. As a traditional meat product, dendeng has the potential to offer more than just basic nutrition by providing additional health benefits. The following are several advantages of developing dendeng as a functional food in the meat industry:

1. Enhancing the Added Value of Meat Products

Functional dendeng can command a higher market value by offering both nutritional and health benefits.

1. Meeting the Demand of Health-Conscious Consumers

Dendeng enriched with natural bioactives addresses the needs of consumers who prioritize functional and natural foods.

1. Product Diversification

Functional dendeng can diversify the existing meat product portfolio, opening new market segments.

1. Improving Sustainability in Meat Processing

Through the use of local spices and efficient processing technologies, functional dendeng supports environmentally conscious production.

1. Strengthening Food and Nutritional Security

As a shelf-stable product with functional benefits, dendeng contributes to food access and public health.

1. Increasing Export Potential and Global Competitiveness

Functional dendeng products have the potential to meet international standards and penetrate global niche markets.

By leveraging advanced processing technologies and high-quality ingredients, functional dendeng can be positioned as a strategic product that not only satisfies sensory appeal but also supports long-term health. This approach contributes to sustainable industry development and addresses the growing demand for functional meat products in both local and international markets.

**5. Case Studies and Functional Experiments**

The development of functional foods today is driven by consumer demand for products that are not only nutritious and palatable but also provide positive physiological effects on health. As a traditional meat product, dendeng holds significant potential to be developed into a functional food through innovations such as bioactive ingredient fortification, beneficial microbial fermentation, and advanced processing technologies. These innovations facilitate the enhancement of bioactive compounds such as antioxidants, essential fatty acids, anti-inflammatory compounds, and bioactive peptides that may aid in the prevention of metabolic disorders, cardiovascular disease, and immune dysfunction. The following recent studies highlight various functional approaches in dendeng development:

1. **Humectant Addition for Enhanced Bioactivity and Functionality**

A meta-analysis by Aung and Nam (2024) demonstrated that incorporating humectants such as glycerol, sorbitol, and soy protein isolate not only improved dendeng tenderness and sensory acceptance but also enhanced water retention, color stability, and antioxidant activity. These humectants, which contain hydroxyl and polar functional groups, bind moisture and delay protein and lipid oxidation, reducing the formation of harmful compounds like metmyoglobin and TBARS. This formulation contributes to more stable and potentially functional dendeng, offering protection against oxidative stress and cellular aging.

1. **Probiotic Fermentation to Reduce Toxins and Generate Bioactive Compounds**

Guo et al. (2024) developed probiotic-fermented chicken dendeng using a mixed starter culture comprising *Candida utilis*, *Lactobacillus casei*, and *Bacillus subtilis*. Their process successfully reduced aflatoxin B1 (AFB1) residues by 90.18% and histamine levels by 9.74%. The fermentation also increased levels of amino acids such as alanine and lactic acid, while lowering the product's pH conditions favorable to beneficial microbes and inhibitory to pathogens. Functionally, the process yielded a safer dendeng product with enhanced nutritional value, particularly as a source of anti-inflammatory peptides. This approach demonstrates potential for developing dendeng with immunoprotective properties suitable for regular consumption across age groups.

1. **Modern Drying Technologies and Conservation of Functional Nutrients**

A comprehensive review by Mediani et al. (2022) revealed that non-conventional drying techniques such as freeze drying, vacuum-ultrasonic drying, and microwave-assisted drying effectively preserve functional bioactives in meat products. These include carnosine, anserine, omega-3 fatty acids (ALA, EPA, DHA), and essential minerals such as iron and magnesium. These components have demonstrated functional roles in reducing hypertension, enhancing cognitive performance, and protecting against chronic inflammation. Moreover, the inclusion of spices such as pepper, coriander, and ginger during drying helps inhibit lipid oxidation, stabilize polyunsaturated fatty acids (PUFAs), and provide synergistic antioxidant effects in dendeng.

These studies demonstrate the promising future of dendeng as a functional food via formulation strategies (e.g., humectants and bioactives), fermentation techniques (e.g., probiotics), and advanced processing technologies (e.g., novel drying methods). Collectively, these approaches improve not only the sensory and safety aspects of dendeng but also its biological value as a preventive health-promoting product that aligns with the modern definition of functional foods.

**6. Potential, Challenges, and Future Research Directions**

Dendeng, a long-standing staple in Indonesian cuisine, is entering a new era of development as a functional food, in line with global trends emphasizing healthy, natural, and value-added foods. This potential stems from dendeng’s compatibility with functional ingredients such as bioactive spices, probiotics, prebiotics, and other natural additives known to enhance antioxidant, immunomodulatory, antihypertensive, and antimicrobial activities. Kim et al. (2021) reported that protein hydrolysis or microbial fermentation of meat products like dendeng can yield bioactive peptides with beneficial effects on cardiovascular health and the prevention of degenerative diseases. Additionally, low temperature drying and marination with turmeric, garlic, ginger, and pepper have been shown to increase the Oxygen Radical Absorbance Capacity (ORAC), indicating oxidative stress protection and anti-aging benefits (Latoch et al., 2023).

Despite its promise, the development of functional dendeng faces several challenges. One key issue is maintaining its authentic taste and traditional texture while meeting modern nutritional and functional standards. These challenges are compounded by sustainability concerns, particularly in sourcing meat from animals raised on natural or organic feed to ensure high levels of CLA and omega 3 fatty acids (Kim et al., 2020). Moreover, the adoption of advanced technologies such as freeze drying, vacuum-ultrasound drying, or 3D printing involves significant capital investment and technical skills that may be beyond the reach of small and medium-sized enterprises (SMEs) (Zhang et al., 2023). Regulatory hurdles related to functional food labeling and scientific validation also pose barriers, as health claims must be supported by rigorous evidence in many countries.

To overcome these challenges and realize the full potential of dendeng as a functional food, the following research directions are recommended:

1. **Optimization of Bioactive Compositions**

Future research should explore optimal combinations of meat and functional ingredients such as bay leaf, seaweed powder, or soy protein isolate as humectants, which enhance tenderness, water retention, and reduce protein/lipid oxidation (Aung & Nam, 2024). These studies should include both in vitro and in vivo validation of health-related bioactivities.

1. **Targeted Fermentation with Specific Probiotic Strains**

Building on the findings of Guo et al. (2024), future work should develop local probiotic strains with similar capabilities for use in beef, goat, or native poultry dendeng products.

1. **Adaptation of Low Energy, Eco Friendly Processing Technologies**

Zhang et al. (2023) demonstrated that microwave-ultrasound drying retains heat-sensitive vitamins and antioxidants. Follow-up studies should evaluate energy efficiency, environmental impacts, and SME-level applicability.

1. **Personalized Functional Dendeng for Targeted Nutrition**

Kim et al. (2021) introduced semi-dried restructured jerky for elderly or hypertensive populations. Future innovations may focus on sodium-reduced, fiber-enriched, or phytonutrient-based dendeng tailored to individual health needs.

1. **Clinical Trials and Validation of Health Claims**

To position dendeng competitively in the global functional food market, clinical trials are essential to support claims such as blood pressure reduction, immune enhancement, or hypocholesterolemic effects. This aligns with evidence-based nutrition standards required in international food trade (Dable-Tupos et al., 2020).

With integrated research, innovative technologies, and collaboration between researchers, food industries, and regulatory agencies, dendeng can evolve from a culinary heritage into a modern, science-based preventive nutrition product. As such, it holds promise not only as a representation of Indonesian food culture but also as a tool for improving population health in the era of functional food innovation.

**7. Risks, Safety Limitations, and Research Constraints**

Despite its promising potential as a functional food, dendeng also presents several risks and limitations that warrant critical evaluation. Excessive consumption may lead to high sodium intake, particularly if production involves large quantities of salt or synthetic nitrites. Moreover, dendeng variants that have not undergone fermentation or pasteurization may contain toxic compounds such as biogenic amines and residual pathogenic microbes, especially when improper storage conditions are applied.

Another safety concern involves the possible formation of carcinogenic compounds like nitrosamines and polycyclic aromatic hydrocarbons (PAHs), which may result from high-temperature drying or smoking processes. Therefore, comprehensive safety assessments are essential for the development of dendeng as a functional food.

A major challenge lies in the limited availability of toxicological and clinical data directly related to functional dendeng products. Most bioactivity claims are currently based on in vitro or in vivo studies of isolated compounds rather than the final processed product. Clinical trials involving human subjects are urgently needed to scientifically validate health claims, particularly for regulatory compliance and international trade.

Furthermore, the current research lacks cost-benefit analyses and market acceptability studies, particularly for functional dendeng variants targeted at elderly consumers or individuals with hypertension. Hence, future investigations must adopt an interdisciplinary approach that integrates food science, nutrition, regulation, and consumer behavior.

**8. Export Potential and Global Market Trends**

In recent decades, global consumption patterns have shifted markedly due to increased public awareness of healthy lifestyles and nutritious diets. This transition has fueled the growth of functional foods products that not only meet basic nutritional needs but also offer additional health benefits. As a traditional Indonesian meat product, dendeng presents a unique opportunity for global positioning through innovation as a functional food. The synergy of Indonesia’s rich bioactive spices, advanced processing technologies, and the product’s inherent shelf stability makes dendeng well suited to meet international demand for healthy, convenient, and culturally unique foods. The export potential of functional dendeng is further strengthened by growing market segments favoring halal, clean-label, and naturally derived products.

1. **Rapidly Growing Demand for Functional Foods**

The global rise of the health food sector has driven demand for nutrient-dense yet convenient products. As a high-protein, low-moisture meat product, dendeng is ideally positioned as a functional snack enriched with antioxidants, bioactive peptides, or anti-inflammatory agents (Baldinelli, 2021).

1. **Alignment with Clean Label and Natural Food Trends**

Consumers in Europe and North America increasingly favor foods made from natural ingredients without synthetic additives. Dendeng formulated with traditional spices such as turmeric, ginger, and garlic can be positioned as a clean-label product, free from nitrites and chemical preservatives (Mazukabzova & Zaitseva, 2022).

1. **High Potential in the Global Halal Premium Market**

Middle Eastern countries and Muslim communities worldwide exhibit strong demand for halal and healthy products. Vacuum-packed, heat-and-eat dendeng made from beef or goat and certified halal holds great potential in this segment (Mazukabzova & Zaitseva, 2022).

1. **Personalized Functional Jerky**

Dendeng variants can be tailored to specific consumer groups, such as hypertensive individuals (with CLA and low sodium), the elderly (with easily digestible proteins), or athletes (with high protein and antioxidants), forming part of the emerging trend of personalized functional foods (Zhang et al., 2023).

1. **Shelf-Stable and Ready-to-Eat Export Product**

Dendeng does not require refrigeration and has a long shelf life, making it suitable for export to regions with limited cold-chain infrastructure, disaster-prone areas, or use as rations in military and expeditionary contexts (Guo et al., 2024).

1. **Enhanced Competitiveness Through Modern Processing Technologies**

Technologies such as microwave-ultrasound drying, probiotic fermentation, and freeze-drying help retain bioactive compounds, improve texture, and increase production efficiency for export purposes, while also minimizing nutrient degradation and extending shelf life (Zhang et al., 2023).

1. **Cultural Branding with Scientific Evidence**

Combining Indonesia’s culinary heritage with scientific validation of dendeng’s health benefits can enhance its global appeal as an “Indonesian Herbal Functional Jerky.” International consumers are increasingly drawn to ethnic foods rooted in tradition yet supported by modern science (Dable-Tupos et al., 2020).

1. **Food Diplomacy and MSME Export Opportunities**

With the rise of e-commerce and digital export platforms, small- and medium-sized enterprises (SMEs) have new avenues to enter global markets. Government support in HACCP/halal/ISO certification, training, and international promotion will be essential for successful export (Mazukabzova & Zaitseva, 2022).

In summary, dendeng possesses strong global market potential as a functional food, supported by its nutritional value, adaptability to modern technologies, and alignment with consumer preferences for healthy, ethnic, and convenient foods. However, challenges remain in quality standardization, international regulatory compliance, and scientific substantiation of health claims. Cross-sector collaboration between industry, government, and academia is essential to drive commercialization and position dendeng as a premium export commodity. With the right strategy, dendeng could emerge as a flagship healthy food product from Indonesia on the global stage.

**9. Future Research Directions and Scientific Validation Scheme**

To scientifically validate the functional claims of dendeng, a structured research framework is recommended. The validation process should begin with in vitro assays to measure antioxidant, anti-inflammatory, and ACE-inhibitory activities of bioactive dendeng extracts. This should be followed by preclinical studies using animal models to assess health impacts such as blood pressure modulation, cholesterol reduction, and oxidative stress mitigation.

The final and most crucial stage is controlled human clinical trials, which evaluate the bioavailability and real-world functional effects of bioactive compounds in dendeng. These studies will be essential for formalizing health claims and supporting commercialization efforts in international markets where regulatory standards require rigorous scientific evidence.

**10. Conclusion**

Dendeng shows great potential as a functional food, offering not only extended shelf life and palatability but also health benefits derived from its rich content of bioactive compounds such as peptides, antioxidants, conjugated linoleic acid (CLA), and anti-inflammatory phytochemicals. Innovations in processing including probiotic fermentation, low temperature drying, and advanced packaging further enhance its nutritional value and functional stability.

While challenges remain regarding sustainable raw materials, technological adaptation, and scientific validation, the global market presents significant opportunities. With cross-sector collaboration and a science-based development approach, dendeng can be positioned as an innovative local food supporting healthy lifestyles, national food security, and competitive participation in the high-value food export industry.

**REFERENCES**

Aluko, R. E. 2015. Antihypertensive Peptides from Food Proteins. *Annual Review of Food Science and Technology, 6*(1), 235-262.

Aung, S. H. and Nam, K. C. 2024. Impact of Humectants on Physicochemical and Functional Properties of Jerky: A Meta-Analysis. *Food Science of Animal Resources,* 44(2), 464–482. doi: <https://doi.org/10.5851/kosfa.2024.e3>

Baldinelli, V. 2021. Consumer Trends for Ethnic and Functional Meat Snacks in Europe. *Journal of Food Market Insight,* 7(3), 145–158.

Chadha, U., Abrol, A., Vora, N. P., Tiwari, A., Shanker, S. K. and Selvaraj, S. K. 2022. Performance Evaluation of 3D Printing Technologies: A Review, Recent Advances, Current Challenges, and Future Directions. *Progress in Additive Manufacturing,* 7(5), 853-886. doi: <https://doi.org/10.1007/s40964-021-00257-4>

Dable-Tupas, G., Otero, M. C. B. and Bernolo, L. 2020. Functional Foods and Health Benefits. *Functional Foods and Nutraceuticals: Bioactive Components, Formulations and Innovations,* 1-11. doi: <https://doi.org/10.1007/978-3-030-42319-3_1>

Edo, G. I., Igbuku, U. A., Makia, R. S., Isoje, E. F., Gaaz, T. S., Yousif, E., Jikah, A. N., Zainulabdeen, K., Akpoghelie, P. O., Opiti, R. A., Essaghah, A. E. A., Ahmed, D. S. and Umar, H. 2025. Phytochemical Profile, Therapeutic Potentials, Nutritional Composition, and Food Applications of Ginger: A Comprehensive Review. *Discover Food,* 5(1), 1-32. doi: [https://doi.org/10.1007/s44187-025-00280-2 \](https://doi.org/10.1007/s44187-025-00280-2%20%5C)

Ehsanur Rahman, S. M., Islam, S., Pan, J., Kong, D., Xi, Q., Du, Q., Yang, Y., Wang, J., Oh, D. and Han, R. 2023. Marination Ingredients on Meat Quality and Safety — A Review. *Food Quality and Safety,* 7, 1-17. doi: <https://doi.org/10.1093/fqsafe/fyad027>

Fekete, M., Lehoczki, A., Kryczyk-Poprawa, A., Zabo, V., Varga, J. T., Balint, M., Fazekas-Pongor, V., Csipo, T., Rzasa-Duran, E. and Varga, P. 2025. Functional Foods in Modern Nutrition Science: Mechanisms, Evidence, and Public Health Implications. *Nutrients,* 17(13), 2153. doi: <https://doi.org/10.3390/nu17132153>

Gomez, I., Janardhanan, R., Ibanez, F. C. and Beriain, M. J. 2020. The Effects of Processing and Preservation Technologies on Meat Quality: Sensory and Nutritional Aspects. *Foods,* 9(10), 1416. doi: <https://doi.org/10.3390/foods9101416>

Guo, H., Chen, J., Qiu, H., Yang, W., Li, G., Ma, X., Liu, J., Yin, Q. and Zhu, Q. 2024. Compound Probiotics Starter: A Solution for Aflatoxin B1 Reduction and Meat Quality Improvement in Fermented Chicken Jerky. *Food Control,* 165, 110601. doi: <https://doi.org/10.1016/j.foodcont.2024.110601>

Hernandez-Jaime, A. G., Castillo-Rangel, F., Arevalos-Sanchez, M. M., Renteria-Monterrubio, A. L., Santellano-Estrada, E., Tirado-Gallegos, J. M. and Chavez-Martinez, A. 2025. Antioxidant and Antimicrobial Activity of Ferulic Acid Added to Dried Meat: Shelf-Life Evaluation. *Foods,* 14(4), 708. doi: <https://doi.org/10.3390/foods14040708>

Ji, J., Shankar, S., Royon, F., Salmieri, S. and Lacroix, M. 2023. Essential Oils as Natural Antimicrobials Applied in Meat and Meat Products — A Review. *Critical Reviews in Food Science and Nutrition,* 63(8), 993-1009. doi: <https://doi.org/10.1080/10408398.2021.1957766>

Kandeepan, G. and Tahseen, A. 2022. Modified Atmosphere Packaging (MAP) of Meat and Meat Products: A Review. *Journal of Packaging Technology and Research,* 6(3), 137-148. doi: <https://doi.org/10.1007/s41783-022-00139-2>

Kaur, L., Elamurugan, A., Chian, F. M., Zhu, X. and Boland, M. 2023. Protein and Lipid Digestibility of Pasture-Raised and Grain-Finished Beef: An In Vitro Comparison. *Foods,* 12(6), 1239. doi: <https://doi.org/10.3390/foods12061239>

Khan, M. A., Ahmad, R. and Ali, S. 2023. Application of artificial intelligence in functional meat product development: A review of prediction and optimization techniques. *Food Control, 149*, 109682. <https://doi.org/10.1016/j.foodcont.2023.109682>

Kim, S. M., Kim, T. K., Cha, J. Y., Kang, M. C., Lee, J. H., Yong, H. I. and Choi, Y. S. 2021. Novel Processing Technologies for Improving Quality and Storage Stability of Jerky: A Review. *Lwt,* 151, 112179. doi: <https://doi.org/10.1016/j.lwt.2021.112179>

Kim, S. M., Kim, T. K., Kim, H. W., Jung, S., Yong, H. I. and Choi, Y. S. 2021. Quality Characteristics of Semi-Dried Restructured Jerky Processed Using Super-Heated Steam. *Foods,* 10(4), 762. doi: <https://doi.org/10.3390/foods10040762>

Kurniawan, H., Suryati, T. and Apriantini, A. 2023. Improving The Quality of Sweet Duck Jerky from South Kalimantan Through Modification of Antioxidant Rich Spices. *Jurnal Ilmu Produksi dan Teknologi Hasil Peternakan,* 11(1), 27-33. doi: <https://doi.org/10.29244/jipthp.11.1.27-33>

Latoch, A., Czarniecka-Skubina, E. and Moczkowska-Wyrwisz, M. 2023. Marinades Based on Natural Ingredients as A Way to Improve the Quality and Shelf Life of Meat: A Review. *Foods,* 12(19), 3638. doi: <https://doi.org/10.3390/foods12193638>

Lopez-Pedrouso, M., Zaky, A. A., Lorenzo, J. M., Camina, M. and Franco, D. 2023. A Review on Bioactive Peptides Drived from Meat and By-Products: Extraction Methods, Biological Activities, Applications and Limitations. *Meat Science,* 204, 109278. doi: <https://doi.org/10.1016/j.meatsci.2023.109278>

Luzardo, S., Saadoun, A., Cabrera, M. C., Terevinto, A., Brugnini, G., Rodriguez, J., de Souza, G., Rovira, P. and Rufo, C. 2024. Effect of Beef Long Storage Under Different Temperatures and Vacuum Packaging Conditions on Meat Quality, Oxidation Processes and Microbial Growth. *Journal of the Science of Food and Agriculture,* 104(2), 1143-1153. doi: <https://doi.org/10.1002/jsfa.12999>

Mazukabzova, E. and Zaitseva, V. 2022. Halal Meat Processing and Global Trade Opportunities. *Foods,* 11(9), 1295. doi: <https://doi.org/10.3390/foods11091295>

Mediani, A., Hamezah, H. S., Jam, F. A., Mahadi, N. F., Chan, S. X. Y., Rohani, E. R., Che Lah, N. H., Azlan, U. K., Khairul Annuar, N. A., Azman, N. A. F., Bunawan, H., Sarian, M. N., Kamal, N. and Abas, F. 2022. A Comprehensive Review of Drying Meat Products and the Associated Effects and Changes. *Frontiers in Nutrition,* 9, 1057366. doi: <https://doi.org/10.3389/fnut.2022.1057366>

Nam, K. C., Kim, H. C., Cha, J. and Yim, D. G. 2016. The Quality Characteristics and Antioxidant Properties of Sun-Dried Venison Jerky with Green Tea Powder During Storage. *Korean Journal for Food Science of Animal Resources,* 36(5), 626. doi: <https://doi.org/10.5851/kosfa.2016.36.5.626>

Pushparaj, K., Balasubramanian, B., Meyyazhagan, A., Park, S., Arumugam, V. A., Pappuswamy, M., Bhotla, H. K., Liu, W. and Mousavi Khaneghah, A. 2025. Advancements in Sustainable Techniques for Dried Meat Production: An Updated Review. *Food and Bioprocess Technology,* 18(3), 2170-2194. doi: <https://doi.org/10.1007/s11947-024-03579-7>

Saputra, F. D., Nurhaita, N., Akbar, S. A., Sari, R. M., Surtina, D. and Astuti, T. 2024. The Effect Of Marination With Red Ginger and Garlic On The Quality Of Beef Jerk. *Journal of Animal Nutrition and Production Science,* 3(02), 214-219.

Selani, M. M., Herrero, A. M. and Ruiz-Capillas, C. 2022. Plant Antioxidants in Dry Fermented Meat Products with A Healthier Lipid Profile. *Foods,* 11(22), 3558. doi: <https://doi.org/10.3390/foods11223558>

Shaukat, M. N., Nazir, A. and Fallico, B. 2023. Ginger Bioactives: A Comprehensive Review of Health Benefits and Potential Food Applications. *Antioxidants,* 12(11), 2015. doi: <https://doi.org/10.3390/antiox12112015>

Stahlke, E. V. R., Rossa, L. S., Silva, G. M., Sotomaior, C. S., Pereira, A. J., Luciano, F. B. and Macedo, R. E. F. D. 2018. Effects of Modified Atmosphere Packaging (MAP) and Slaughter Age on the Shelf Life of Lamb Meat. *Food Science and Technology,* 39(02), 328-335. doi: <https://doi.org/10.1590/fst.29617>

Zhang, Y., Lei, Y., Qi, S., Fan, M., Zheng, S., Huang, Q. and Lu, X. 2023. Ultrasonic Microwave Assisted Extraction for Enhancing Antioxidant Activity of Dictyophora Indusiata Polysaccharides: The Difference Mechanisms Between Single and Combined Assisted Extraction. *Ultrasonics Sonochemistry,* 95, 106356. doi: <https://doi.org/10.1016/j.ultsonch.2023.106356>

Zhang, Y., Liu, J., Wang, H. and Chen, T. 2024. Integration of IoT and AI for Smart Drying Control in Meat Processing: Enhancing Quality and Efficiency. *Trends in Food Science & Technology, 146*, 129–140. doi: <https://doi.org/10.1016/j.tifs.2024.03.004>