

A Review On Role Of Papaya seeds incorporation in spices for meat tenderization

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Abstract : The review paper is dedicated to the addition of papaya seeds and chosen spices as natural tenderizers of meat. An important quality parameter that determines consumer acceptance is meat tenderness, and conventional tenderizing chemicals have caused concerns on safety and health. Thus, the use of plant-based alternatives has become a topic of great interest in the recent years. Papaya seeds (*Carica papaya*) are rich in proteolytic enzymes including papain that is effective in breaking down the muscle proteins giving meat a good texture. Moreover, the most prevalent spices like coriander (dhaniya), cumin (zeera), and cardamom (elaichi) are used to add flavor, antimicrobial properties, and sensory in general. The current paper summarizes the existing literature on the importance of papaya seeds and natural spices in meat processing, with a special focus on their combination in terms of tenderness, taste, aroma, and shelf life. The results indicate that natural tenderizers do not only enhance meat quality, but also, promote clean-label and sustainable food production. The paper concludes that papaya seed and spice grading is a safe, cost-effective, and environmentally friendly substitute to synthetic tenderizers, and has a high potential to be used in households and industries

Keywords: Papaya seeds, Meat tenderization, Papain enzyme, Natural tenderizers, Spices, Marination

INTRODUCTION

Papaya seeds (*Carica papaya*) have a pungent and peppery taste and have been traditionally used in some cultures as a black pepper substitute. Some studies focus on identifying papaya seed powder as an adulterant in black pepper its resemblance to pepper and potential use as a spice itself. Meat is a common food item and a source of protein, essential amino acids, vitamins and minerals. But its quality and acceptability primarily rest with tenderness, texture and sensory features. The reason why tough meat is less preferred is because it has fibrous structure, low juiciness, and low chewability. Thus, meat tenderization is significant to enhance palatability in domestic cooking and the food industry. Historically, tenderizing meat has been carried out by way of mechanical tenderizing, aging, and chemical tenderizing. Despite its efficacy, chemical tenderizers have attracted health-related issues and a need to seek healthier and safer options. This has promoted the use of plant-based tenderizers (Muhammad Saeed, et.al 2017). Plant tenderizers, particularly fruit and spice

tenderizers are getting popular because of their enzymatic nature. The papaya (*Carica papaya*) seeds are also popular due to the presence of papain enzyme that degrades muscle proteins and enhances the softness of meat. Studies indicate that the use of papaya-based preparations, such as seed and peel extracts, is effective, particularly in combination with other ingredients, such as ginger and garlic. Other spices used in meat processing are coriander (dhaniya), cumin (zeera) and cardamom (elaichi). They increase flavor, aroma and offer functional advantages such as antimicrobial effects and digestive effects. The mixture of papaya seeds and spices enhances tenderness and sensory attributes of meat. (Chavan, 2018). Recent research on plant-based proteases and natural extracts indicates their safety as alternatives to chemical tenderizers. These enhance the quality of meat and address the need to produce clean-label food products. Improved meat tenderness and physicochemical properties of meat, including buffalo meat, are also reported in studies done on tropical fruit extracts (Kadioğlu, et.al 2019).

Natural Meat Tenderization and Plant-Based Alternatives

Enzymes of vegetable origin have become a viable and promising alternative to chemical tenderizers. These enzymes act by degrading protein structures of meat that makes them softer and less tough. The interest in plant-derived proteases continues to grow due to its safety, natural source and its adaptability to the current trends in food processing. Research has demonstrated that plant proteases can enhance the texture of meat, in addition to helping to increase demand among consumers toward healthier and less processed food products (Pathak, et.al 2019).

Role of Papaya Seeds and Spices in Meat Quality Improvement

Bioactive compounds and proteolytic enzymes abundant in papaya seeds play a key role in tenderizing meat. During marination, these enzymes help in breaking down muscle fibers, resulting in softer and more palatable meat. In combination with the conventional spices, dhaniya (coriander), zeera (cumin), and elaichi (cardamom), the total quality of meat is further promoted in respect of flavor, aroma and acceptability. It has been shown that the application of tropical fruit extracts and natural plant-based formulations results in apparent changes in the tenderness, as well as sensory properties, of meat (Issa-Zacharia, et.al 2023)

LITERATURE REVIEW

papain enzyme found in *Carica papaya* is an important tenderizer in meat because it is a good proteolytic enzyme. The research report has indicated that papain assists in the breakdown of complex proteins in meat to simpler compounds, which makes meat soft and tender. Natural enzymes like papain and bromelain were also found to have potential in enhancing microbial safety in meat products and hence they could be utilized in the processing of natural foods. This paper is a solid argument in favor of papaya-based constituents as effective natural tenderizers. (Elgendy, et.al 2025), analyzed the impact of *Carica pubescens* marinade on buffalo meat and they observed considerable changes in physicochemical characteristics of the meat including tenderness, moisture retention, and the overall meat quality. It was confirmed that marinades made out of fruits can modify the structure of muscle fibers, resulting in enhanced softness and sensory acceptability. Those results suggest that the natural agents, which are based on fruits, like papaya, are applicable to the meat tenderization process. (Patriani, et.al 2024) conducted a review on the use of food additives in meat and meat products and highlighted that the use of natural additives is being more adopted compared to synthetic additives. The authors concluded that plant-based ingredients enhance meat quality by increasing tenderness, flavor, and stability of shelf life. The research also pointed to increased consumer interest in clean-label, and chemical-free meat products, which justifies the inclusion of natural tenderizers like papaya seeds and spices into meat processing systems. (Elgadir, and Mariod, 2025) concentrated on papaya wastes and by-products and indicated that papaya seeds and other parts of the plants have bioactive compounds, enzymes, and antioxidants with high functional properties. The authors of the study have pointed out the possible application of these by-products in the food industry especially in value addition and in the creation of functional foods. This indicates that papaya seeds can be successfully used as a low cost and sustainable raw material in meat tenderization. (Abdel-Hay, et.al 2022) conducted a review of natural ingredient-based marinades and their impacts on meat quality and shelf life. The research discovered that plant based marinades have a significant effect on tenderness, development of flavor, and stability of microbes on meat products. Another point that the authors made was that natural marinades are consistent with the current consumer trend towards healthier

and minimally processed foods. This justifies the application of combined natural systems like papaya seeds in conjunction with spices like coriander, cumin and cardamom in enhancing the quality of meat. (Latoch, et.al 2023)

studied papaya seed extract and found out its antibacterial activity and bioactive chemical properties depending on the processing conditions. The research has emphasized that the papaya seeds have functional compounds which do not only play a role in antimicrobial properties, but also in food preservation. This suggests that papaya seeds have a multifunctional role in meat processing and help in the tenderness and extension of shelf life. (Sani, et.al 2021) examined the hypolipidemic and bioactive properties of the parts of the *Carica papaya* plant and determined that the plant has significant health-promoting properties. It was proposed that papaya-based ingredients can have additional nutritional benefits to food systems when used. This reinforces the significance of the use of papaya seeds as a tenderizer, as well as a functional ingredient, in meat products. (Osama, et.al 2023)

Papaya Seeds as tenderization of meat

Another significant natural source of bioactive compounds and proteolytic enzymes that have been applied in the tenderization of meat is papaya seeds (*Carica papaya*). They are popularly researched as a natural substitute of chemical tenderizers to enhance meat texture, meat quality and shelf life. This is because their efficacy is primarily caused by enzyme activity and phytochemical constituent, which is useful in the disintegration of meat proteins during marination. Actions of papain enzyme and other bioactive compounds primarily cause the tenderizing effect of papaya seeds. These ingredients collaborate to break down muscle proteins, which leads to a better softness in meat and better sensory quality of meat. The application of papaya seed extracts and derivatives in food processing uses is also supported by studies (Gaikwad, et.al 2023).

Papain Enzyme Activity and Mechanism of Action

The principal proteolytic enzyme present in papaya seeds that tenderize meat is called papain. It digests the complex proteins like collagen, actin and myosin into smaller peptides and amino acids. This enzymatic digestion causes weakening of the structure of the muscle fibers, and results in increased tenderness, softness and digestibility of meat. It also helps to improve the quality of meat in storage and processing (Elgadir, et.al 2025).

Advantages of Papaya Seed-Based Tenderization

The tenderization using papaya seeds is a natural, safe and cost-effective procedure, whereas chemical tenderizers are expensive. It improves the quality of meat without the unhealthy residues and promotes the clean-label production of food. It also enhances tenderness and shelf stability, which is why it can be used in the context of modern food processing (Kilemile, and Runyogote, 2024)

Table 1: Comparison of Different Natural Meat Tenderizers

Source	Active Component	Mechanism of Action	Effect on Meat	Additional Benefits
Papaya seeds	Papain enzyme	Breaks down muscle proteins	High tenderization	Antimicrobial, improves shelf life
Pineapple	Bromelain enzyme	Protein degradation	Very high tenderization	Improves juiciness
Ginger	Protease enzymes	Collagen breakdown	Moderate tenderization	Enhances flavor
Garlic	Sulfur compounds	Softens muscle fibers	Mild tenderization	Antibacterial effect

Spices (coriander, cumin, cardamom)	Bioactive compounds	Supports enzymatic action	Indirect tenderization	Flavor, aroma, antioxidant
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(Naveena, et.al 2023)

xt of modern food processing (Kilemile, and Runyogote, 2024).

4. Role of Spices in Meat Processing

Spices are critical to meat processing because they enhance flavor, aroma and overall sensory attributes of meat products. Besides their conventional culinary purpose, spices are also characterized by their useful features like antimicrobial, antioxidant and digestive effects. Spices improve the quality and acceptability of meat when used together with the natural tenderizers such as papaya seeds. The synergies between spices and plant-based substances result in natural and clean-label meat products (Kong, et.al 2021).

Dhaniya (Coriander)

Dhaniya (coriander) has been common in meat preparations in powdered form, because of its light taste and nice aroma. It assists in meat flavoring, as well as, counterbalance strong smells. There are also bioactive compounds in coriander, which have antioxidant and antimicrobial effects and help to increase meat quality and shelf life. It is also helpful in meat diets due to its digestive properties(Mohd Azmi, et.al 2023).

Zeera (Cumin)

Zeera (cumin) is a widely accepted spice in meat processing, with a unique taste and smell. It boosts the general flavor of meat meals and in digestion. Cumin has also been known to have antimicrobial and antioxidant effects, which prevent microbial growth and preservation of meat quality during storage. Its use in spice mixtures helps in sensory and functional enhancement of meat products(Anaduaka, et.al. 2023).

Elaichi (Cardamom)

Elaichi (cardamom) is appreciated because of its strong and pleasant smell which is used to cover unpleasant smell in meat. It adds flavor and enhances overall sensory attributes of meat products. Moreover, cardamom has antimicrobial and digestive effects, and therefore, it can be used to preserve food quality and for enhancing better digestion when used together with meat.(Kumar Paswan et al., 2021)

COMBINED EFFECT OF PAPAYA SEEDS AND SPICES IN MARINATION

Papaya seeds mixed with spices also has a major role to play in enhancing the overall quality of the meat in the process of marination. This technique employs both the enzymatic and functional qualities of natural ingredients in improving meat tenderness, meat flavor, and meat shelf stability. Application of these combinations is becoming popular as an efficient and natural substitute to artificial additives in meat production. (Raj et.al., 2023)

Synergistic Action in Tenderization

Papaya seeds have the proteolytic enzyme papain, which disintegrates the complex muscle protein and connective tissues resulting in better tenderness. The process of overall tenderization appears to be more effective when spices, including dhaniya (coriander), zeera (cumin), and elaichi (cardamom) are added. Whereas papain facilitates the breakdown of proteins, spices are beneficial in facilitating the same by enhancing penetration and interactions during the marination process and lead to a greater softening in the meat(Abdurrahman, et.al. 2025)

Taste, Aroma, and Texture.

The use of the mixture of papaya seeds and spices with meat improves the sensory properties of meat. Papaya seeds help enhance texture by softening of muscle fibers and spices play a role in building flavor and aroma. Coriander and cumin are well balanced, and cardamom gives a nice smell that helps to cover bad smells of meat. This mixture leads to meat products which are more acceptable and palatable to the consumers. (Wierzbicka et.al., 2023)

Natural Preservation Effect

Besides tenderization and sensorial enhancement, the combination also leads to natural preservation. The papaya seeds are rich in bioactive compounds that have antimicrobial effects, whereas the spices have antibacterial and antioxidant effects. They are also effective in reducing the growth of microbes and enhance the shelf life of meat products; this makes the process safer and sustainable(Awad, et.al.2021)

Application in Meat Tenderization Process

Papaya seed with spices are also extensively applied in the tenderization of meat particularly via the process of marination. This is an all natural method that does not only increase tenderness but also the general quality as well as acceptability of meat products. The performance of this process is based on the effective marination processes, such as technique, time, and the meat to be used.(Mohd Azmi, et.al. (2023).

Marination Techniques

One of the most common techniques of applying natural tenderizers to meat is through marination. Here, the papaya seeds are crushed into powder and the spices are used in the form of powder (dhaniya (coriander), zeera (cumin) and elaichi (cardamom) and then sprinkled over the meat. The mixture may also be dissolved in water or other natural liquids to make a paste, which will ensure the coating and absorption is better. This enables the active components to enter the meat surface easily.(Liu, Y.,et al. (2021).

Time and Method of Application.

Marination time is of great importance in the attainment of desirable tenderness. Generally, meat is marinated for a few hours to overnight, depending on the type and toughness of the meat. At this stage, papaya seed enzymes start to decompose the proteins, and spices start to add flavor and aroma

Future Scope

Future research and development has extensive opportunities because papaya seeds and spices are used to tenderize meat. The possibility to create the standardized natural meat tenderizer products in both powder and liquid is strong, and they can be easily applied both at homes and in commercial locations. Future research can be based on the optimal formulation, concentration and storage stability to enhance the consistency and shelf life.Also, the use of such natural tenderizers in the large-scale food processing industries tenderization process can be further enhanced by proper application methods, including uniform coating and the provision of proper storage conditions.(Naveena, and Mendiratta,(2023).

Appropriate Meats (Chicken, Mutton, Beef)

Papaya seeds and spices can be used on all forms of meat such as chicken, mutton, and beef. Softer meats such as chicken need less time to marinate, but harder meats like mutton and beef will be better marinated at a longer period of time. Also it can be investigated to substitute synthetic additives. It is possible to expand research to other types of meat and processing conditions to increase applicability as well. The inclusion of natural ingredients in contemporary food processing methods will help to promote sustainable, safe, and consumer-friendly meat products. (Bekhit., et.al (2021).

Limitations

- Risk of over-tenderization if marination time or enzyme concentration is high
- May result in overly soft or mushy texture of meat
- Storage and stability issues of natural ingredients compared to chemical tenderizers
- Variability in results due to differences in raw materials and preparation methods
- Requires careful control of time and application process for optimal results

9. Conclusion

The current review indicates the important role of papaya seeds and some spices chosen in natural tenderization of meat. Different researches proved that papaya seeds containing high amounts of proteolytic enzymes like papain are very effective in enhancing the tenderness of meat by degrading the complex proteins in muscles. The addition of spices such as dhaniya (coriander), zeera (cumin) and elaichi (cardamom) also increase the sensory attributes of meat such as flavor, aroma as well as general acceptability. Besides enhancing texture, these natural ingredients also add antimicrobial and antioxidant qualities, which are beneficial to food safety and shelf life.

The use of papaya seed-based tenderizers aligns with the increasing demand for clean-label and naturally processed food products. Compared with synthetic tenderizers, natural tenderization methods are safer, environmentally friendly, and more acceptable to health-conscious consumers. Therefore, the combined use of papaya seeds and spices has significant potential for application in both household and commercial meat processing industries. The overall result is that papaya seeds and spices are a safe, cost-effective and environmentally-friendly substitute to chemical tenderizers. This strategy is consistent with the growing consumer desire towards natural and clean-label food products. Therefore, the natural spice-based tenderization may be viewed as a prospective approach to enhance the quality and nutritional value of meat in both domestic and industrial settings. There is limited study on use of papaya seeds powder in spices. Also there has been no study on use of papaya seeds powder as meat tenderizer

REFERENCES

1. Abdel-Hay, M., Farooq, A., & Kamran, F. (2022). *Papaya wastes and by-products: chemistry, processing, and utilization*. In *Handbook of fruit wastes and by-products* (pp. 175-192). CRC Press.
2. Abdurrahman, F., Omar, O. O., & Iswadi, I. (2025). *Analysis of the Effects of Tropical Fruit Extracts on the Physicochemical, Tenderness and Organoleptic Characteristics of Buffalo Meat*. *BIOTIK: Jurnal Ilmiah Biologi Teknologi dan Kependidikan*, 13(2), 141-161.
3. Anaduaka, E. G., Chibuogwu, C. C., Ezugwu, A. L., & Ezeorba, T. P. C. (2023). *Nature-derived ingredients as sustainable alternatives for tenderizing meat and meat products: an updated review*. *Food Biotechnology*, 37(2), 136-165.
4. Awad, A. M., Kumar, P., Ismail-Fitry, M. R., Jusoh, S., Ab Aziz, M. F., & Sazili, A. Q. (2021). *Green extraction of bioactive compounds from plant biomass and their application in meat as natural antioxidant*. *Antioxidants*, 10(9), 1465.
5. Chavan, U. (2018). *Processing of papaya into various products*. *Fruits and vegetable processing training programme*.
6. Elgadir, M., & Mariod, A. (2025). *Effect of selected food additives on quality of meat and meat products, recent advances*. *Agriculture and Food Bioactive Compounds-Online* ISSN: 3068-8051, 2(4), 76-85.
7. Elgadir, M. A., Alhudhaibi, A. M., Abdallah, E. M., & Adiletta, G. (2025). *Plant-based preservation of meat: a critical narrative review of bioactive extracts, essential oils, and next-generation delivery systems*. *Frontiers in Sustainable Food Systems*, 9, 1722227.
8. Elgendy, A. A., Khalifa, H. K., & Abd El-Aziz, M. A. (2025). *Papain (Carica papaya) and Bromelain (Ananas comosus) Enzymes: Potential Roles on Gene Expression of Bacillus cereus Isolated from Minced Meat and Meat Products*. *Egyptian Journal of Veterinary Sciences*, 1-14.
9. Gaikwad, A. B., Tiwari, R. K., Choudhary, P., & Kaur, N. (2023). *A comprehensive review on papaya seed oil extraction and recent applications in food industry*. *Pharma Innov*, 12, 1520-1527.
10. Issa-Zacharia, A., Muhimbula, H. S., Bikuba, A. N., & Matondo, J. D. (2023). *Development of natural liquid and powdered meat tenderizer based on papaya peel, ginger and garlic*. *Journal of Food and Nutrition Sciences* <https://doi.org/10.11648/j.jfns.20241202>.

11. Joshi, D., Dobhal, N., Chauhan, K., Kumar, N., & Rizvi, M. R. (2025). *Unlocking nutritional and functional potential of papaya peel and its industrial applications: an overview. Discover Food.*
12. Kadioğlu, P., Karakaya, M., Unal, K., & Babaoğlu, A. S. (2019). *Technological and textural properties of spent chicken breast, drumstick and thigh meats as affected by marinating with pineapple fruit juice. British Poultry Science, 60(4), 381-387.*
13. Kilemile, W. K., & Runyogote, J. M. (2024). *Stability Assessment of Papaya and Ginger Blend Meat Tenderizer. MUST JOURNAL OF RESEARCH AND DEVELOPMENT, 5(1).*
14. Kong, Y. R., Jong, Y. X., Balakrishnan, M., Bok, Z. K., Weng, J. K. K., Tay, K. C., ... & Khaw, K. Y. (2021). *Beneficial role of Carica papaya extracts and phytochemicals on oxidative stress and related diseases: a mini review. Biology, 10(4), 287.*
15. Latoch, A., Czarniecka-Skubina, E., & Moczowska-Wyrwicz, 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.*
16. Mohd Azmi, S. I., Kumar, P., Sharma, N., Sazili, A. Q., Lee, S. J., & Ismail-Fitry, M. R. (2023). *Application of plant proteases in meat tenderization: Recent trends and future prospects. Foods, 12(6), 1336.*
17. Muhammad Saeed, M. S., Sajjad-ur-Rahman, S. U. R., Shabbir, M. A., Nassrulla Khan, N. K., & Azam Shakeel, A. S. (2017). *Extraction and utilization of papaya extract as meat tenderizer and antimicrobial activity against Salmonella typhimurium.*
18. Osama, M., Ikram, R., Wei, C. R., Khan, N., Shaikh, S., Siyal, F. J., ... & Memon, A. A. Q. (2023). *A preclinical study to evaluate hypolipidemic effects of aerial parts of carica papaya plant. International Journal of Chemical and Biochemical Sciences, 24(5), 311-319.*
19. Pathak, P. D., Mandavgane, S. A., & Kulkarni, B. D. (2019). *Waste to wealth: a case study of papaya peel. Waste and Biomass Valorization, 10(6), 1755-1766.*
20. Patriani, P., Irgiadi, A., & Desnamrina, K. C. (2024). *Effectiveness of Carica (Carica pubescens) marinade on buffalo meat physicochemical. In IOP Conference Series: Earth and Environmental Science (Vol. 1354, No. 1, p. 012010). IOP Publishing.*
21. Sani, M. S. A., Bakar, J., Rahman, R. A., & Abas, F. (2021). *Effect of temperature on antibacterial activity and fatty acid methyl esters of Carica Papaya seed extract. In Multifaceted Protocols in Biotechnology, Volume 2 (pp. 117-132). Cham: Springer International Publishing.*
22. Naveena, B. M., Kiran, M., & colleagues (2023). *Application of Plant Proteases in Meat Tenderization: Recent Trends and Future Prospects. Foods, 12(6), 1336*
23. Kumar Paswan, V., Shekhar Singh, C., Kukreja, G., Shankar Bunkar, D., & Kumar Bhinchhar, B. (2021).
24. Raj, P. M. H., Mandal, P. K., Sen, A. R., Kasthuri, S., & Muthukumar, M. (2023). *Effect of Marination on Meat Quality and Food Safety – A Review. Journal of Meat Science.*
25. Wierzbicka, A., Majewska, K., & colleagues. (2023). *Marinades Based on Natural Ingredients as a Way to Improve the Quality and Shelf Life of Meat: A Review. Foods, 12(19), 3638.*
26. Mohd Azmi, S. I., Kumar, P., Sharma, N., Sazili, A. Q., Lee, S. J., & Ismail-Fitry, M. R. (2023).
27. Liu, Y., Lyon, B. G., Windham, W. R., et al. (2021).
28. Naveena, B. M., Mendiratta, S. K., & Anjaneyulu, A. S. R. (2023)
29. Bekhit, A. E. D. A., Hopkins, D. L., Geesink, G. H., Bekhit, A. A., & Franks, P. (2021).

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