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Consumers' Preferences between Natural MD2-Based and Commercial Meat Tenderizers

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Abstract
This study evaluates consumer preference between a natural meat tenderizer made from MD2 pineapple, herbs, and spices, and a commercial product. Sensory evaluation by 25 panelists revealed significantly higher scores for the MD2-based tenderizer in terms of appearance, taste, texture, aroma, and overall acceptability. The superior performance is attributed to bromelain's enzymatic action and the flavor-enhancing properties of herbs. While limited by sample size and scope, the findings support the potential of MD2-based tenderizers as a natural, clean-label alternative, aligning with current consumer trends toward healthier and more natural food products.

Keywords: Meat; Pineapple; Sensory; Tenderizer

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1.0 Introduction

Consumer preference has increasingly shifted toward natural and minimally processed foods, often reflected in the demand for clean labels. Studies highlight that naturalness and transparency are now key quality cues (Aboah & Lees, 2020), with clean-label and additive-free claims strongly influencing acceptance and purchase intentions (Noguerol et al., 2021; Chang & Chen, 2022). Market analyses further confirm this momentum, with the clean-label ingredients sector projected to exceed USD 50 billion and consumers showing greater willingness to pay for certified, additive-free products (Inguglia et al., 2023; Mishu et al., 2024; Zhou et al., 2024). To meet these quality expectations, various tenderization methods have been developed, including mechanical, chemical, and enzymatic treatments. Among these, enzymatic tenderizers have garnered particular interest due to their ability to break down muscle fibers and connective tissue, thereby enhancing meat texture. Commercial tenderizers, based on papain or bromelain, have long been used. However, rising health and safety concerns are shifting preferences towards natural, clean-label alternatives (Noguerol et al., 2021; Cao & Miao, 2022; Chauhan & Rao, 2024). Natural tenderizers derived from fruits and plants offer a promising solution, providing not only functional benefits

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but also additional flavor, aroma, and consumer appeal. Pineapple, particularly the MD2 variety, is an excellent example due to its high content of bromelain, which is an effective proteolytic enzyme capable of hydrolyzing myofibrillar and collagen proteins (Ramli et al., 2021). When combined with traditional herbs and spices, MD2-based tenderizer formulations may enhance not only texture but also taste and aroma, creating a more holistic sensory experience for consumers.

Despite the functional potential of natural tenderizers, limited studies have explored their performance in comparison to commercial products in terms of consumer sensory preferences. As clean-label products become more popular, understanding consumer selection between natural and commercial tenderizers is crucial for product development and industry innovation. The aim of this study is to evaluate and compare consumer preferences for meat treated with a natural MD2 pineapple-based meat tenderizer, focusing on key sensory attributes to determine the potential of natural formulations as a clean-label alternative. The objectives of this study is to assess the sensory attributes including appearance, taste, texture, aroma and overall acceptance of meat samples treated with natural MD2 pineapple-based tenderizer and a commercial tenderizer, to compare consumer acceptance and preference between the two tenderizer treatments using a structured sensory evaluation, to determine the contribution of bromelain and selected herbs and spices in enhancing the quality of meat in terms of tenderness, flavor and aroma, to explore MD2 pineapple-based tenderizers as clean-label alternatives and provide recommendations for industry application.

2.0 Literature Review

2.1 Meat Tenderness and Consumer Expectations

Tenderness remains one of the most vital quality attributes influencing meat consumption and satisfaction. Studies consistently show that consumers primarily judge meat quality based on its tenderness, with flavor and juiciness being secondary considerations (Miller, 2020). The positive association between tender meat and consumer satisfaction has prompted ongoing efforts to develop methods to improve tenderness, both naturally and synthetically. Hwang et al. (2025) emphasized that tenderness not only determines the eating experience but also long-term customer loyalty. If consumers consistently experience tender and flavorful meat, they are more likely to become repeat buyers and brand advocates. This behavioral insight drives the meat industry's interest in developing tenderizing agents that strike a balance between effectiveness, health, and sensory acceptability (Miller, 2020).

Consumer demand for high-quality meat products has consistently increased over the past five years, driven by expectations of tenderness, flavor, and safety as primary determinants of purchase decisions. In 2020, quality cues such as tenderness, freshness (as indicated by color), and labeling were already the strongest drivers of consumer choice in meat markets (Aboah & Lees, 2020). By 2021, the perception of clean labels and naturalness had shaped consumer definitions of quality (Noguerol et al., 2021). In 2022, it was confirmed that clean-label certifications and transparency have a strong influence on purchase intentions, reflecting the growing reliance on health and safety labels as quality indicators (Chang & Chen, 2022). Market evidence in 2023 further demonstrated this trend, with fresh meat volume projected to increase by 7.1% in 2024 and the clean-label ingredients market valued at over USD 50 billion, signaling sustained global demand for high-quality meat (Inguglia et al., 2023). More recently, in 2024, Mishu et al. (2024) highlighted consumers' willingness to pay premiums for certified and antibiotic-free meat, underscoring the strength of this quality-driven demand (Mishu et al., 2024; Zhou et al., 2024). Together, these findings clearly indicate that consumer demand for high-quality meat products continues to grow, with clean-label and natural attributes emerging as central determinants of preference.

Modern consumers increasingly seek clean-label alternatives which are products free from artificial preservatives, synthetic chemicals, and genetically modified organisms. This behavior is driven by rising health consciousness, environmental awareness, and concerns about chemical residues in processed foods (Ramli et al., 2021). Tenderizers made from natural sources such as fruits, herbs, and spices align well with this trend. Among these, pineapple-derived enzymes, especially from MD2 pineapple, are particularly favored because of their dual benefits: tenderization and flavor enhancement. Rani et al. (2024) noted that the MD2 variety, commonly cultivated in Southeast Asia, offers not only high bromelain activity but also desirable sensory attributes like sweetness and aroma that contribute positively to meat palatability.

2.2 Mechanisms of Tenderization

The primary mechanism behind natural tenderization using pineapple is the proteolytic action of bromelain. Bromelain is a cysteine protease enzyme capable of hydrolyzing muscle fiber proteins (actin and myosin) as well as connective tissue proteins such as collagen. This enzymatic activity weakens structural bonds, leading to a softer, more palatable meat texture (Banerjee et al., 2020). MD2 pineapple stands out among cultivars due to its higher bromelain activity. In a comparative study by Ramli et al. (2021), bromelain extracted from MD2 pineapple exhibited significantly greater tenderizing capacity compared to other pineapple types. The high sugar content in MD2 also contributes to improved caramelization and flavor complexity during cooking, enhancing overall meat quality.

Commercial tenderizers often contain a mix of plant enzymes for example, papain from papaya, bromelain from pineapple, and ficin from figs alongside additives like sodium chloride, starch, or phosphates. These synthetic or semi-synthetic formulations are engineered for consistency, rapid action, and extended shelf life (Cao & Miao, 2022). Commercial products offer predictable enzymatic strength, enabling precise dosing and reduced risk of over-tenderization. However, this same strength can be a drawback if misused. Overexposure can lead to disintegration of muscle fibers, resulting in unappealing mushy textures, especially in poultry or thin cuts (Gagaoua et al., 2021). In addition, phosphate-containing commercial tenderizers enhance juiciness and water-holding capacity, but there is growing concern about their long-term health effects, particularly in individuals with renal or cardiovascular conditions (Noguerol et al., 2021; Chauhan & Rao, 2024).

2.3 MD2 Pineapple-Based Tenderizer

MD2 pineapple is a hybrid cultivar known for its superior sweetness, low acidity, and extended post-harvest shelf life. From a functional perspective, it contains higher levels of bromelain compared to older varieties like Cayenne or Queen (Rani et al., 2024). This makes MD2 a potent, dual-purpose tenderizer, contributing both enzymatic action and sensory appeal. In addition to bromelain, MD2 pineapple contains antioxidants like vitamin C, phenolic, and flavonoids. These compounds offer additional health benefits, such as reducing oxidative stress and improving immune response. When used in marinades, these bioactive compounds can help reduce lipid oxidation in meat during storage and cooking (Latoch et al., 2023; Mohd Azmi et al., 2023).

Experimental studies support the efficacy of MD2 pineapple paste or extract in meat tenderization (Latoch et al., 2023). Razali et al. (2023) reported a significant reduction in shear force values in beef samples treated with MD2 paste compared to untreated controls. Optimal margination was 30-60 minutes; longer caused over-softening. In another study, the combined use of MD2 pineapple and local herbs (ginger, garlic, and turmeric) was tested for synergistic effects. Results showed improvements not only in texture but also in flavor profile, microbial stability, and antioxidant activity, attributes highly valued by both consumers and food safety regulators (Latoch et al., 2023; Rani et al., 2024).

Sensory evaluations generally reveal favorable consumer responses to MD2-based tenderizers. Razali et al. (2023) conducted a blind test with 25 panelists, showing that meats marinated with MD2 pineapple paste scored higher in tenderness, flavor, and overall acceptability compared to those treated with commercial tenderizers. Consumers noted the natural fruity aroma and subtle sweetness of the MD2-treated samples as appealing, especially when paired with grilled or pan-fried cooking methods.

2.4 Commercial Meat Tenderizers: Utility and Limitations

Commercial tenderizers enjoy widespread use due to their stability, availability, and standardized enzyme content. Powdered forms make them convenient for both home cooks and industrial scale processors. Dosing instructions are provided to mitigate risks of overuse, and consistent results are one of their strongest advantages (Chauhan & Rao, 2024). In fast-paced food service environments, the rapid action of commercial tenderizers reduces preparation time and improves throughput. However, despite these conveniences, health-conscious consumers are becoming increasingly cautious about artificial additives and synthetic enzymes, especially when they are not clearly labeled (Inguglia et al., 2023).

While commercial tenderizers are effective, their impact on sensory characteristics can vary. Some users report an artificial aftertaste or excessively soft textures when dosage is not accurately measured. Moreover, repeated use of chemical-based tenderizers may lead to negative health outcomes due to the accumulation of sodium or phosphate compounds (Gagaoua et al., 2021; Inguglia et al., 2023). Cao and Miao (2022) discussed potential side effects of phosphate intake, including elevated serum phosphate levels, which may impair bone health and kidney function. This growing body of evidence has motivated some consumers to explore natural alternatives that offer comparable tenderization without these risks.

2.5 Comparative Sensory Evaluation Studies

Numerous studies have compared the performance of natural and commercial tenderizers. Gagaoua et al. (2021) conducted a comprehensive study using beef samples treated with MD2 pineapple extract, a phosphate-based commercial tenderizer, and a papain-based product. The MD2 sample scored highest in overall sensory performance, particularly for tenderness and flavor balance. Participants noted that the natural tenderizer delivered a cleaner, more desirable taste and retained more of the meat's original flavor. Razali et al. (2023) confirmed similar findings in a local consumer trial, where MD2 pineapple-treated meats were preferred over commercially treated counterparts. However, they also highlighted the importance of optimizing marination time to avoid over-tenderization.

Cultural familiarity strongly influences consumer preference. In regions like Southeast Asia, including Malaysia, natural fruit and herb-based marinades are part of traditional culinary practices, making MD2 pineapple a highly acceptable option (Rani et al., 2024). In Western markets, while awareness of fruit-derived tenderizers is growing, adoption may still depend on consumer education and proper labeling. Clean-label trends and increasing awareness of health impacts are shifting attitudes even in markets traditionally reliant on commercial additives. Younger consumers, in particular, show more willingness to experiment with plant-based or functional food ingredients, including natural meat tenderizers.

3.0 Methodology

A convenience sampling method was employed for this study. The sensory evaluation aimed to assess consumer acceptance of a newly developed natural meat tenderizer and compared it with a commercial counterpart. A total of 25 panelists participated in the evaluation. This sample size is typical in hedonic testing, aimed at capturing acceptability rather than population-level inference. According to Stone and Sidel (2020), hedonic sensory tests typically require 20 to 30 untrained participants to provide reliable data on consumer preferences while remaining practical in terms of cost, time, and sample preparation. It is also noted that panels of this size are sufficient to detect meaningful differences in consumer-oriented studies, especially when comparing distinct product formulations such as natural versus commercial tenderizers. Panelists were selected using convenience sampling and included both male and female adults within the age range of 18–55 years, representing typical meat consumers. Varied age, gender and cultural backgrounds were included as these influence sensory preferences. For instance, younger consumers may be more receptive to clean-label and natural product claims, while older participants may prioritize tenderness and texture. Each participant assessed two cooked meat samples, one treated with the commercial meat tenderizer and the other with the MD2 pineapple-based tenderizer formulated with herbs and spices. Six key sensory

attributes were evaluated: color, flavor, appearance, texture, aroma and overall acceptability. A 9-point hedonic scale was used, where 1 represented “extreme dislike” and 9 represented “extreme like”. To prevent taste interference, panelists were instructed to cleanse their palates with water between samples.

4.0 Findings

25 participants contributed to the findings of this study. The findings are shown in Table 1 and Fig. 1 as below:-

Table 1: Average scores of sensory parameters for meat treated with commercial meat tenderizer and meat treated with natural MD2 pineapple-based tenderizer formulated with herbs and spices

Parameter	Commercial meat tenderizer	MD2-based meat tenderizer
Appearance	3.12±1.77	7.12±1.07
Taste	3.04±1.97	6.68±1.64
Texture	2.84±1.71	6.52±2.16
Aroma	2.96±1.71	6.92±1.29
Overall Acceptance	2.88±1.70	6.88±1.58

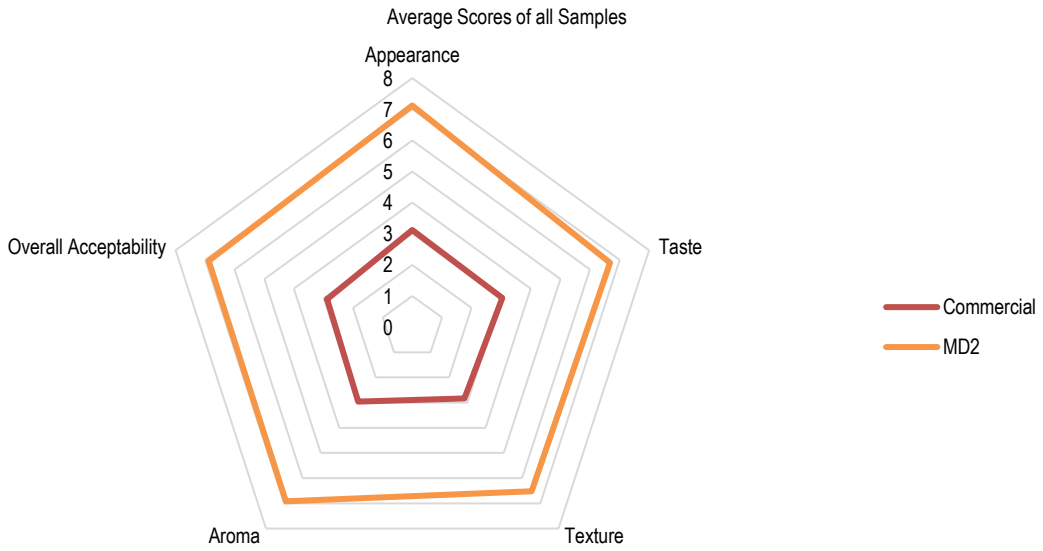

Fig. 1: Average scores of sensory parameters for meat treated with commercial meat tenderizer and meat treated with natural MD2 pineapple-based tenderizer formulated with herbs and spices.

Table 1 and Fig. 1 show average sensory scores of commercial vs. MD2 pineapple-based tenderizers across five key attributes: appearance, taste, texture, aroma, and overall acceptability. For appearance, the MD2-treated sample achieved a notably higher score, scoring 7.12±1.07 on the 9-point hedonic scale, compared to the commercial sample, which scored 3.12±1.77. This indicates that the MD2 sample was visually more appealing to the panelists. In terms of taste, the MD2 sample again outperformed the commercial product, recording a score of 6.68±1.64, while the commercial sample scored 3.04±1.97. This demonstrates a clear difference in palatability between the two treatments. For texture, the MD2-treated meat received a score of 6.52±2.16, more than double that of the commercial sample, which is 2.84±1.71. This suggests that the MD2 treatment produced a more favorable mouthfeel and tenderness. The aroma of the MD2-treated meat also scored substantially higher, scoring 6.92±1.29, compared to the commercial treatment, which was rated 2.96±1.71. This reflects a marked difference in the aromatic qualities of the two products. Finally, in overall acceptability, the MD2 tenderizer recorded a score of 6.88±1.58, while the commercial counterpart received a significantly lower score of 2.88±1.70. This indicates a consistently higher level of acceptance for the MD2-treated samples across the panel. Overall, the MD2 pineapple-based natural tenderizer achieved higher scores in all five sensory attributes, with differences of approximately 3 to 4 points on average compared to the commercial tenderizer. The results show a clear preference among panelists for the MD2 formulation across every sensory criterion assessed.

5.0 Discussion

The sensory evaluation conducted in this study aimed to assess consumer preferences for meat treated with a natural tenderizer made from MD2 pineapple, herbs, and spices, in comparison to a commercial meat tenderizer. The analysis focused on five critical sensory attributes which are appearance, taste, texture, aroma, and overall acceptability and are evaluated by a panel of 25 participants using

a 9-point hedonic scale. The findings revealed that the MD2-based tenderizer was significantly more preferred across all parameters, reflecting the growing appeal of natural, functional ingredients in meat processing.

Appearance is a primary determinant in food selection, as it shapes consumers' initial expectations regarding taste and quality. In this study, meat treated with the MD2-based paste received a substantially higher than the commercially treated meat. This superior appearance may be attributed to the presence of natural sugars in pineapple, which promote Maillard reactions during cooking, thereby enhancing browning and color development (Ramli et al., 2021). Moreover, the herbs and spices in the formulation may have contributed to a more appealing color and surface texture, providing a natural, freshly marinated look, which is often more visually acceptable to consumers compared to processed or chemically treated meats.

Taste is another critical determinant of consumer satisfaction. The MD2-based sample recorded a taste score more than double that of the commercial tenderizer. The enhancement in taste can be attributed to the synergistic flavor contribution of the selected herbs and spices, as well as the pineapple's natural sugars and acids, which can help balance savory notes in meat (Erdem & Gökmen, 2025). Additionally, bromelain, a proteolytic enzyme naturally present in pineapples, not only tenderizes meat but also modifies protein structures, potentially exposing more flavor compounds and improving palatability (Ramli et al., 2021).

Texture was also significantly improved in the MD2-treated sample compared to the commercial product. This can largely be explained by the enzymatic action of bromelain, which breaks down muscle fiber and connective tissue, resulting in a softer, more desirable meat texture (Ramli et al., 2021). Bromelain hydrolyzes peptide bonds in myofibrillar and collagen proteins, facilitating a more tender meat structure without the fibrous toughness often associated with untreated or synthetically treated samples (Mohd Azmi et al., 2023). This enzymatic tenderization is generally safer than chemical tenderizers, which risk over-softening or altering sensory profiles.

In terms of aroma, the MD2-based formulation achieved a score compared to the commercial variant. The pleasing aroma of the natural tenderizer is likely due to the combined volatile compounds from both pineapple and the incorporated herbs and spices. Herbs such as lemongrass, turmeric, or ginger which are commonly used in Southeast Asian meat preparation have well-documented aromatic qualities that enhance the overall smell and perceived freshness of cooked meat (Marc et al., 2022). In contrast, synthetic tenderizers may lack this complex aroma profile and may even carry undesirable chemical odors, detracting from the overall consumer experience.

Finally, the MD2 sample's overall acceptability far exceeded the commercial. This comprehensive score integrates all sensory aspects and reflects the consumer's holistic impression of the product. The natural tenderizer's higher ratings across all individual attributes suggest a positive cumulative effect, leading to a more favorable eating experience. This aligns with recent consumer trends that favor clean-label products made with natural and recognizable ingredients, which are often perceived as healthier and more trustworthy (Cao & Miao, 2022; Chauhan & Rao, 2024).

In summary, the findings of this study support the effectiveness of MD2 pineapple-based meat tenderizers as a natural alternative to commercial products. The enhanced appearance, taste, texture, and aroma are attributed to the presence of bromelain and flavor-enhancing herbs and spices. These results are consistent with prior research emphasizing the functional and sensory advantages of using fruit-based enzymes in meat processing (Rani et al., 2022; Latoch et al., 2023; Mohd Azmi et al., 2023; Razali et al., 2023). However, further investigation is needed to evaluate the shelf-life, microbiological stability, and cost-effectiveness of such formulations before widespread adoption in the food industry.

6.0 Conclusion& Recommendations

Based on the sensory evaluation conducted, it is evident that the natural meat tenderizer formulated using MD2 pineapple, herbs, and spices demonstrated superior performance across all evaluated attributes including appearance, taste, texture, aroma, and overall acceptability when compared to the commercial tenderizer. Bromelain from MD2 pineapple improved texture and enhanced flavor and aroma through enzymatic action and natural aromatic compounds. The significantly higher acceptability scores observed in the natural formulation highlight its potential to meet growing consumer demands for healthier and more flavorful meat products. The study was limited by the evaluation restricted to immediate sensory attributes without assessing factors such as shelf life, microbiological stability or cost implications of large-scale production. In light of these findings, it is recommended that future studies focus on optimizing the formulation for industrial scalability, including evaluations of product shelf-life, storage stability, and microbial safety. Additionally, cost-benefit analyses should be performed to determine the economic viability of commercializing MD2 pineapple-based tenderizers. Overall, this study supports the application of natural functional ingredients in meat tenderization and encourages further research and development to facilitate their adoption within the meat processing industry.

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Paper Contribution to Related Field of Study

This study contributes to the growing body of research on natural meat tenderizers by demonstrating the superior sensory performance of an MD2 pineapple-based formulation. It highlights the functional potential of fruit-derived enzymes and traditional herbs in enhancing meat quality, supporting clean-label trends in food choice behaviors among the public.

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