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Analysis of The Effects of Tropical Fruit Extracts on the Physicochemical, Tenderness, and Organoleptic Characteristics of Buffalo Meat

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Abstrak: Daging kerbau merupakan sumber protein sangat penting di berbagai wilayah, namun menghadapi tantangan terkait kualitas seperti oksidasi, perubahan warna, dan penurunan kelembutan. Penelitian ini mengidentifikasi dampak perendaman daging kerbau dalam ekstrak Melinjau, pepaya, dan nanas terhadap sifat fisikokimia (warna, kandungan protein, lemak, dan kelembutan) serta karakteristik organoleptik (warna, aroma, tekstur, kelembutan, dan juiciness). Sampel daging kerbau direndam dalam ekstrak buah selama berbagai durasi, diikuti dengan analisis warna, kandungan protein (metode Kjeldahl Macro) dan lemak (metode Monjonnier), kelembutan, dan kualitas sensori. Hasil penelitian menunjukkan efek signifikan pada warna, dengan ekstrak Melinjau dan pepaya meningkatkan kecerahan dan mengurangi kemerahan. Perendaman dengan ekstrak pepaya dan nanas meningkatkan kelembutan, sementara ekstrak Melinjau meningkatkan juiciness. Kandungan protein sedikit menurun, namun kandungan lemak berkurang secara signifikan, terutama dengan ekstrak pepaya. Evaluasi sensori menunjukkan bahwa ekstrak Melinjau menghasilkan kelembutan dan juiciness yang lebih baik, sementara ekstrak pepaya dan nanas juga meningkatkan kelembutan. Hasil penelitian ini menunjukkan bahwa ekstrak buah tropis dapat digunakan untuk meningkatkan kualitas daging kerbau dengan memperbaiki kelembutan, mengurangi kandungan lemak, dan memperpanjang umur simpan. Metode pengawetan alami ini menawarkan alternatif yang potensial untuk bahan tambahan sintetis, yang berkontribusi pada peningkatan sifat sensori dan produk daging kerbau yang berkualitas lebih tinggi.

Kata kunci: Ekstrak buah tropis; karakteristik fisiokimia; karakteristik organoleptik; kualitas daging kerbau.

Abstract: Buffalo meat is an essential protein source in many regions but faces quality challenges, including oxidation, discoloration, and reduced tenderness. This study investigates the impact of soaking buffalo meat in extracts from Melinjau, papaya, and pineapple on its physicochemical properties (color, protein, fat content, and tenderness) and organoleptic characteristics (color, aroma, texture, tenderness, and juiciness). Buffalo meat samples were soaked in fruit extracts for varying durations, followed by analysis of color, protein (Kjeldahl Macro Method) and fat content (Monjonnier Method), tenderness, and sensory qualities. The results showed significant effects of soaking on

color, with Melinjau and papaya extracts improving lightness and reducing redness. Soaking with papaya and pineapple extracts enhanced tenderness, while Melinjau extract increased juiciness. Protein content decreased slightly, but fat content was significantly reduced, particularly with papaya extract. Sensory evaluation revealed that Melinjau extract produced the most favorable tenderness and juiciness, while papaya and pineapple extracts also improved tenderness. These findings suggest that tropical fruit extracts can be used to enhance buffalo meat quality by improving tenderness, reducing fat content, and extending shelf life. This natural preservation method offers a potential alternative to synthetic additives, contributing to better sensory properties and higher-quality buffalo meat products.
Keyword: Tropical fruit extracts; physicochemical characteristics; organoleptic characteristics; buffalo meat quality.

1. Introduction

Buffalo meat is one of the important sources of animal protein in various parts of the world. Global buffalo meat production reached approximately 4.3 million tons in 2019, with more than 90% from Asia (especially India, Pakistan, and China) [1]. In many developing countries, buffalo are raised not only for labor and milk but also for meat, which is often obtained from older animals after their productive period has ended [1], [2], [3]. Furthermore, buffalo meat contributes to protein food security; for example, in Indonesia, buffalo meat production reached around 22 thousand tons in 2023 [4]. Additionally, buffalo meat is a good source of essential nutrients such as iron and zinc [1], [5], [6].

Buffalo meat is known to be highly nutritious with a lean protein content comparable to beef (around 19–24% protein) and lower fat and cholesterol levels; thus, it has been referred to as one of the "healthiest" red meats for consumption [1], [7], [8]. Nevertheless, efforts to optimally utilize buffalo meat still face quality challenges. Buffalo meat tends to be darker in color and has a tougher texture compared to beef, especially due to the large number of slaughtered buffalo that are older with a high proportion of connective tissue and low collagen solubility [1], [9]. This condition results in low tenderness of buffalo meat and unsatisfactory carcass yield. Additionally, like other red meats, buffalo meat is prone to quality deterioration after slaughter due to lipid oxidation and pigment changes [10]. Lipid oxidation is the main cause of non-microbiological meat quality deterioration, which triggers rancidity (off-odor) and a decrease in nutritional value [11], [12]. The myoglobin pigment in buffalo meat is easily oxidized to metmyoglobin, which is brownish in color, causing the bright color of the meat to fade quickly during storage [12], [13]. Research shows that without antioxidant treatment, the red color of buffalo meat will quickly diminish; the addition of antioxidants such as vitamin C can maintain the bright red color and prevent discoloration during cold storage [14], [15]. Similarly, the tenderness of the meat can continue to decline as rigor mortis and postmortem changes progress, making poorly handled buffalo meat at risk of becoming increasingly tough and less favored by consumers [16]. Challenges such as oxidation, color changes, and loss of tenderness emphasize the need for proper handling and preservation techniques to maintain the quality of handled buffalo meat post-slaughter. Without proper care, buffalo meat can quickly spoil and become unsuitable for consumption.

In line with the above issue, the current trend in the food industry is moving towards the use of natural ingredients as meat preservatives. Consumer concerns about health risks from synthetic preservatives (such as nitrites, butylated hydroxyanisole (BHA), and butylated hydroxytoluene (BHT)) have driven efforts to find safer and "natural" alternatives [11], [17], [18]. Clean labels and preference for organic food have made plant extracts, including fruit extracts, increasingly considered as substitutes for synthetic additives [19]. Natural ingredients rich in bioactive compounds (such as natural antioxidants and antimicrobials) can help inhibit oxidative and microbiological damage to meat, thereby extending its shelf life [20]. Various studies have explored natural antioxidant sources from plants (spices, herbs, and fruits) to be applied to meat products [19]. Falowo et al. [11] state that oxidation in meat remains a challenge for the industry, and the use of bioactive plant compounds is a sustainable option to maintain meat quality while reducing health risks from synthetic antioxidants. In other words, extracts of natural ingredients have the potential to improve sensory quality and suppress spoilage rates [18]. In this context, tropical fruit extracts stand out as candidates for natural preservatives because they generally contain a combination of antioxidant compounds (vitamins, polyphenols) and active proteolytic enzymes. The use of fruit extracts as marinades or meat soaking agents is also relatively easy to apply in the processing chain, making it attractive to researchers and industry practitioners as a more consumer-friendly preservation method.

Some tropical fruits have great potential to improve the quality and shelf life of meat. Three of them that are the focus of this research are melinjau, papaya, and pineapple. The melinjau fruit (*Gnetum gnemon*) is known to be rich in antioxidant phytochemical compounds. Melinjau seed/fruit extracts are reported to contain high levels of polyphenols, flavonoids, and tannins, including resveratrol and its derivatives. These compounds are very good at getting rid of free radicals, which means that melinjau could be a good source of natural antioxidants to keep meat from lipid oxidation [21], [22]. In addition, several studies have found that the skin of melinjo/melinjau seeds has antimicrobial activity against certain foodborne bacteria, adding to its benefits in meat preservation [23]. Meanwhile, papaya fruit (*Carica papaya*) has long been used as a traditional meat tenderizer because it contains the protease enzyme papain. Papain breaks down myofibrillar proteins and collagen in meat [15] and is a cysteine protease type proteolytic enzyme. This enzyme is effective in breaking down muscle fibers and connective tissue, thereby significantly improving the tenderness of the meat. Papain is even produced commercially and has become one of the most commonly used exogenous enzymes in the meat tenderizing industry [15]. In addition to papain, papaya latex also contains other protease enzymes (such as chymopapain) and antioxidants like vitamin C and carotenoids that can contribute to the color stability of meat. The use of papaya extract or papaya leaves for marinating meat has been proven to improve texture without compromising flavor, as long as the concentration and duration of marination are well-controlled. As for the pineapple (*Ananas comosus*), it contains the enzyme bromelain, which is a mixed protease that also has the ability to break down the protein in meat tissue. Bromelain is abundant in the pulp and core of the fruit as well as the pineapple stem and has long been used as a natural meat tenderizer [15]. Commercially, bromelain is used not only in the food industry (meat tenderization, protein processing) but also in the pharmaceutical field due to its anti-inflammatory properties and other biological activities [15]. Like papain, bromelain is effective in reducing the shear force of meat; the addition of dry bromelain powder has been proven to lower the toughness of old beef and increase the peptide content resulting from protein hydrolysis, which means the meat becomes more tender [15]. Besides enzymes, pineapples also contain organic acids and vitamins (e.g., vitamin C) that can act as antioxidants. Therefore, the combination of proteolytic and antioxidant properties in papaya and pineapple has the potential to improve the physical properties (texture, tenderness, and water-holding capacity) while maintaining the chemical quality of the meat (prevent fat oxidation and pigmentation). One more benefit of these natural ingredients is that they add to the flavor. Soaking meat in fruit extracts can improve its flavor and juiciness through the marinating process, as long as it's not too much. For example, Naveena et al. [24] and Mohd. Azmi [15] found that using enzymes with plant extracts like ginger and *kachri* (a type of wild melon) on old buffalo meat made it more tender, juicy, and acceptable overall, similar to commercial papain treatment. Interestingly, in that study, ginger extract produced the highest sensory evaluation, surpassing papain [15], [24]. This indicates that each type of fruit/plant has a unique composition of enzymes and bioactive compounds that can differently affect the tenderization results and organoleptic characteristics. The choice of enzyme for tenderization should be carefully selected based on the specific characteristics desired in the final product.

Although various studies have shown the promising potential of papaya, pineapple, and other natural extracts on meat quality, there is a research gap regarding the application of these tropical fruit extracts on buffalo meat. Most previous studies have only focused on one type of ingredient or one type of meat. For example, marinade studies generally use single extracts such as papaya or pineapple on beef or chicken, so specific information for buffalo meat and the use of melinjau extract is still limited. The reported results also vary. Variation in effects on meat quality can be reported with differences in fruit types, extract concentrations, and application methods. (soaking time, temperature, and pH). Widowati [25] and Zuki et al. [26] found that soaking beef in papaya extract for 60 minutes resulted in the best tenderness and sensory properties compared to pineapple or ginger extract for the same duration. On the other hand, another study shows that 30% pineapple extract can significantly improve the physical quality of buffalo meat [27], or in another research, is free range chicken meat [28]. On the other hand, using too many proteolytic enzymes can be bad. If protease action is not controlled, the meat could become too tender (too soft or spongy) from breaking down too many proteins [15]. However, the interaction between enzymes in mixed extracts has the potential to produce a more optimal synergistic effect. The absence of data regarding the impact of this combination on buffalo meat represents a knowledge gap that needs to be filled. The variability of these findings indicates the need for an in-depth study to determine the optimal conditions for using fruit extracts in efforts to improve the quality of buffalo meat. Until now, there has been no comprehensive report on the effect of soaking with a mixture of melinjau, papaya, and pineapple extracts on the characteristics of buffalo meat. The lack of adequate scientific data in this area constitutes a research gap that needs to be bridged.

Based on the analysis results that have been conducted, this study aims to analyze the impact of soaking buffalo meat in melinjau, papaya, and pineapple extracts on physicochemical characteristics (such as color, protein and fat content, and tenderness) as well as organoleptic properties (color, aroma, texture, tenderness, and juiciness). By utilizing extracts from local tropical fruits, this research is expected to produce methods for improving the quality of buffalo meat without relying on synthetic chemicals. Practically, the findings of this research can be beneficial for the meat processing industry and local farmers: soaking buffalo meat in extracts of melinjau, papaya, and pineapple has the potential to improve meat tenderness, maintain color brightness and aroma freshness, and reduce the oxidation rate, thereby extending its shelf life. This means that processed buffalo meat products can have better sensory quality and a longer shelf life, which in turn increases the economic value of buffalo meat.

2. Research Methods

a. Sample Preparation

The raw materials used in the study include aged buffalo meat, young *melinjau* fruit, young papaya, and young pineapple. The buffalo meat, branded "Allana", is sourced from a frozen meat store in Kajang and imported from India. Young *melinjau* fruit, aged 45 days, is sourced from Bandar Baru Bangi. The fruit is extracted using a ratio of 100g sample to 100 ml water to obtain a liquid extract. Papayas are procured from gardens around Universiti Kebangsaan Malaysia (UKM), while young pineapples are obtained from the Bandar Baru Bangi market. Both papaya and pineapple juices undergo the same preparation process as that of pineapple juice.

b. Tropical fruits juice and extract preparation

The seeds are removed from the melinjau fruit. A 100g sample of the fruit is weighed and mixed with 100 ml of distilled water. The mixture is then blended using a Waring Blender for 1 minute at low speed and 2 minutes at high speed. The resulting juice is filtered through muslin cloth. Papaya and pineapple juices are prepared using the same method as the melinjau juice. The juice from melinjau, papaya, and pineapple is filtered using a gas vacuum filter with Whatman No. 1 filter paper. The filtered juice is then placed in a petri dish and frozen at -20°C for 2 hours to form an ice slab. This frozen sample is subsequently dried using a Freeze Dryer for 48 to 72 hours until it becomes a dry powder.

c. Precipitation of TCA

The TCA precipitation procedure was conducted using a modified Bergmeyer [29] method. Three sets of test tubes, each containing 10 tubes, were prepared. Each test tube received 2.5 ml of casein buffer and 0.5 ml of 1% juice and extract from melinjau fruit, papaya, and pineapple. The mixtures were incubated at 37°C for 0, 10, 20, 30, 40, 50, 60, 70, 80, and 90 minutes. Subsequently, 2.5 ml of TCA was added to each test tube. After 30 minutes, the samples were filtered using Whatman No. 1 filter paper. The absorbance of the

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clear filtrate was measured at 280 nm using a Thermo Spectronic Helios α instrument. The absorbance at 280 nm was plotted against the sample type.

d. Use of Enzymes and Cooking

The use of protease enzymes and meat cooking followed a modified method of Cook et al. [30]. Frozen meat was thawed in a refrigerator at 4°C for 24 hours to remove excess water. The meat was then cut into pieces measuring 10 cm in length, 20 mm in height, and 20 mm in width. Each 200g portion of meat was placed in a plastic container. Subsequently, 100 ml of juice from melinjau fruit skin, papaya, and pineapple was added to the meat and soaked at room temperature for 20, 40, and 60 minutes, with the meat turned every 10 minutes to ensure complete soaking. The meat was then rinsed and placed in an aluminium pan with 400 ml of water and boiled on a gas stove at an external temperature of 100°C until the internal temperature of the meat reached 75°C, for a duration of 30 minutes. The meat was cooled at room temperature for 30 minutes before analysis.

e. Color Determination

Color was determined using a Minolta Chroma Meter (Model CR-100, Japan), which provided L (brightness), a (redness), and b (yellowness) values.

f. Determination of Protein Content

Protein content was determined using the Kjeldahl Macro Method (AOAC 1990) with a Kjeldahl Vapodest Instrument (Gerhardt model). The cooked and cooled meat from treatment 3.3 was stored in a freezer at -20°C prior to analysis. The meat was thawed in a refrigerator at 4°C for 24 hours, then ground until smooth using a Waring Blender. A 1.0 gram sample was weighed on nitrogen-free Whatman No. 1 filter paper and placed in a digestion tube with 1 teaspoon of catalyst powder and 20 ml of concentrated sulfuric acid. The sample was heated at 420°C on an electric heater in a fume chamber until the solution became clear. After cooling at room temperature for 10 minutes, the solution was distilled using the Kjeldahl Vapodest and titrated with 1N HCl until a pink color formed. The protein content percentage was determined by multiplying the obtained value by a conversion factor of 6.25.

% Nitrogen = {(ml HCl x 0.1) – (ml standard NaOH x 0.1)} x 1.4007/g sample

% Protein = % Nitrogen x 6.25

g. Fat Determination

Cooked and cooled meat was stored in a freezer at -20°C prior to analysis. The meat was thawed in a refrigerator at 4°C for 24 hours, then ground using a Waring Blender. Fat content in the meat was assessed using the Monjonnier Method.

h. Tenderness Test

Cooked meat was left at room temperature for 30 minutes, then stored in a refrigerator at 4°C for 24 hours before testing for tenderness using a TA-xT2i Texture Analyzer (Stable Microsystems Ltd, London). The Texture Analyzer was activated, equipped with a 50 kg load cell, and calibrated with a 10 kg weight. A Warner-Bratzler probe was installed to determine the maximum shear force of the meat. The meat's hardness was measured as shear force under pressure (gF), with readings shown as "pressure" versus time in seconds. Each sample formulation was tested three times.

i. Sensory Test

Assessment exercises and sensory tests were conducted according to the method of Butler et al. [31].

j. Sensory Assessment Training

Six evaluators (three men and three women, aged between 20 and 40 years), all Chemical and Nuclear Science students at the Faculty of Science and Technology, Universiti Kebangsaan Malaysia, participated in the training. The training was conducted three times, with sessions held once every 7 days. During the first session, evaluators were introduced to the concept of meat tenderness and familiarized with the meat attributes to be evaluated. In the second session, evaluators identified reference samples and assessed attributes such as color, smell, elasticity, softness, and juiciness.

k. Meat Sensory Evaluation

Meat sensory evaluation was conducted after 7 days of training using a 15 cm scale [31]. Cooked meat was cooled to room temperature (28°C) for 30 minutes and cut into 10 mm squares. Evaluations took place at 10:00 a.m., assessing color, smell, tenderness, and juiciness. Each assessor received two samples cut along the grain. Sensory evaluation aimed to determine the optimal tenderness of meat soaked in melinjau, papaya, and pineapple juice for 40 minutes. The 40-minute soaking time was selected based on tenderness test results using the TA-xT2i Texture Analyzer (Stable Microsystems Ltd, London), which indicated optimal meat tenderness at this duration for melinjau fruit juice.

l. Statistical Analysis

Data were analyzed using SAS (SAS 1986) with ANOVA REGRESSI analysis. Significant differences ($p < 0.05$) were further examined using Duncan's multiple range test.

3. Results and Discussion

The results and discussion are presented in a sequential manner, displaying the results and discussion regarding the physicochemical tests, tenderness, and organoleptic tests. The physicochemical tests conducted are related to color (lightness, redness, and yellowness) and the percentage of protein and fat content. The tenderness test was conducted using texture testing methods, and the organoleptic test was carried out by expert panelists. This is done with the aim of providing a comprehensive overview of the research that has been conducted. The results of the physicochemical tests related to color, in this case, the impact of soaking buffalo meat in melinjau, papaya, and pineapple juice, are shown in Table 1.

Table 1. The average values of lightness, redness, and yellowness of meat soaked in juice of melinjau, papaya, and pineapple

	Immersion time (min)	**Control**	**Melinjau**	**Papaya**	**Pineapple**
Lightness	0		47.700^{B}	47.700^{A}	47.700^{AB}
	20	$^{ab}47.700$	$^{a}50.537^{A}$	$^{ab}46.573^{A}$	$^{b}43.763^{B}$
	40	$^{b}47.700$	$^{b}47.980^{B}$	$^{b}46.187^{A}$	a50.000^{A}
	60	$^{a}47.700$	$^{b}43.697^{C}$	$^{ab}46.040^{A}$	$^{b}44.687^{B}$
Redness	0		$^{a}6.357$	$^{ab}6.357$	a6.357
	20	6.357^{A}	$^{ab}5.760^{AB}$	$^{c}5.073^{AB}$	$^{a}6.257^{B}$
	40	6.357^{A}	$^{ab}6.020^{A}$	$^{bc}5.650^{A}$	$^{a}5.810^{A}$
	60	6.357^{AB}	b5.417^{B}	$^{a}6.997^{A}$	$^{a}5.737^{B}$
Yellowness	0		a9.190	$^{ab}9.190$	$^{b}9.190$
	20	9.190^{A}	$^{a}10.263^{A}$	$^{b}8.953^{A}$	$^{ab}9.443^{A}$

Immersion time (min)	Control	Melinjau	Papaya	Pineapple
40	9.190^{A}	^{a}9.937^{A}	^{ab}10.047^{A}	^{a}10.263^{A}
60	9.190^{B}	^{b}7.327^{C}	^{a}11.830^{A}	^{a}10.393^{AB}

a, b, c: Different letters in the same column indicate significant differences at p < 0.05.
A, B, C: Different letters in the same row indicate significant differences at p < 0.05.

Table 1 indicates that soaking time significantly affects (p<0.05) the lightness (L) values of meat soaked in melinjau, papaya, and pineapple juice. According to Ismail et al. [32]], protease enzymes influence color changes in the product. Both the type of juice and soaking time significantly impact (p<0.05) meat lightness, with notable differences (p<0.05) observed at 20 and 60 minutes of soaking in melinjau juice.

Moreover, the results show that there are also significant differences in the lightness values of meat soaked in papaya and pineapple juice at different time intervals. This suggests that the type of juice used for soaking plays a crucial role in determining the color changes in the meat. Additionally, the findings support the idea that protease enzymes present in the juices contribute to these color changes.

Table 1 also shows that soaking time significantly affects (p<0.05) the redness (a) values of meat soaked in melinjau, papaya, and pineapple juice. That soaking meat in a 0.1% papain solution impacts meat redness. Both the type of juice and soaking time significantly influence (p<0.05) meat redness, with significant differences (p<0.05) observed at 60 minutes for melinjau juice and 20 minutes for papaya juice.

These results suggest that the type of juice used for soaking meat can have a significant impact on the color changes that occur. The results of this study demonstrate that protease enzymes play a significant role in these changes. The results also showed that longer soaking times using melinjau juice led to more pronounced color changes.

Additionally, Table 1 reveals that soaking time significantly affects (p<0.05) the yellowness (b) values of meat soaked in melinjau, papaya, and pineapple juice. Protease addition affects the yellowness of meat. The type of

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juice and soaking time significantly affect ($p<0.05$) meat yellowness, with significant differences ($p<0.05$) observed at 60 minutes for melinjau juice and at 40 and 60 minutes for pineapple juice. Overall, the study suggests that the type of fruit juice used for soaking and the duration of soaking time both play a crucial role in affecting the color changes in meat. The findings indicate that melinjau juice, in particular, has a significant impact on the yellowness values of the meat, especially when soaked for longer periods. These results can be valuable for meat processors and manufacturers looking to enhance the color and overall quality of their products through natural methods such as fruit juice soaking. The results of the physicochemical tests related to the percentage of protein and fat content are shown in Table 2.

Table 2. The average protein and fat (%) of meat samples soaked in melinjau, papaya, and pineapple juice

	Immersion time (min)	Control	Melinjau	Papaya	Pineapple
Protein	0		$^{a}17.647$	$^{a}17.647$	$^{a}17.647$
	20	17.647^{A}	$^{a}13.955^{A}$	$^{a}16.079^{A}$	$^{a}15.116^{A}$
	40	17.647^{A}	$^{a}16.442^{A}$	$^{a}15.227^{A}$	$^{a}15.222^{A}$
	60	17.647^{A}	$^{a}13.690^{B}$	$^{a}15.495^{AB}$	$^{a}14.132^{AB}$
Fat	0		$^{a}1.750$	$^{a}1.750$	$^{a}1.750$
	20	1.750^{A}	$^{ab}1.413^{AB}$	$^{ab}1.209^{AB}$	$^{b}0.942^{B}$
	40	1.750^{A}	$^{bc}1.000^{B}$	$^{b}0.875^{B}$	$^{b}1.471^{A}$
	60	1.750^{A}	$^{c}0.954^{B}$	$^{ab}1.288^{B}$	$^{b}0.942^{B}$

a, b, c: Different letters in the same column indicate significant differences at $p < 0.05$.
A, B, C: Different letters in the same row indicate significant differences at $p < 0.05$

The statistical analysis in Table 2 indicates that soaking time does not significantly affect ($p > 0.05$) the protein content of meat soaked in melinjau, papaya, and pineapple juice. The protein content in meat soaked in melinjau juice decreased by 6.83% to 22.42% (from 17.65 g/100 g to 16.44-14.03 g/100 g), in papaya juice by 8.89% to 13.74% (from 17.65 g/100 g to 16.08-15.23 g/100 g), and in pineapple juice by 8.59% to 14.34% (from 17.65 g/100 g to 16.13-15.11 g/100 g). This decrease aligns with the findings of Elisabet et al. (1999), who observed a reduction in protein content from 22.5% to 12.0% in meat mixed with pineapple juice and cooked at 60°C for 30 minutes and then boiled for 5 minutes.

Additionally, Table 2 shows that both juice type and soaking time significantly influence ($p>0.05$) protein content, with a significant difference ($p<0.05$) observed at 60 minutes of soaking in melinjau juice. The decrease in protein content suggests that soaking meat in melinjau juice negatively affects meat quality by reducing the primary nutritional value—protein. However, there is no significant difference ($p<0.05$) in the protein content of meat soaked in melinjau juice compared to those soaked in papaya and pineapple juices.

The reduction in protein content is attributed to the breakdown of proteins into amino acids by protease enzymes. It is important to consider that the reduction in protein content in the fruit juices may not have the same effect on meat as observed in the study, as different proteins may react differently to protease enzymes. Additionally, the cooking methods and conditions used in the study may not accurately reflect real-world scenarios.

Furthermore, the statistical analysis in Table 2 reveals that soaking time significantly affects ($p<0.05$) the fat content of meat soaked in melinjau, papaya, and pineapple juice. The fat content in meat soaked in melinjau juice decreased by 19.25% to 45.49%, with a significant reduction ($p<0.05$) observed at 40 minutes (1.00g/100g) and 60 minutes (0.95g/100g) compared to the control. The fat content in meat soaked in papaya juice decreased by 26.40% to 50.00%, with a significant reduction ($p<0.05$) observed at 40 minutes (0.87 g/100 g) compared to the control. Similarly, the fat content in meat soaked in pineapple juice decreased by 15.94% to 52.49%, with significant reductions ($p<0.05$) observed at 20 minutes and 60 minutes (0.95 g/100 g) and 40 minutes (1.47 g/100 g) compared to the control. Overall, the amount of fat in meat that was soaked in melinjau, papaya, and pineapple juices went down by 15.90% to 52.49%. Meat that was mixed with pineapple juice and cooked at 60°C for 30 minutes and then at 100°C for 13 minutes had 54.20% less fat. The highest reduction in fat content was observed in meat soaked in papaya juice, amounting to 52.49%. While the reduction in fat content is significant, it is important to consider other factors, such as tenderness, which may be affected by soaking meat in fruit juices. The results of the tenderness test are shown in Table 3.

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Table 3. The average tenderness value (KgF) of meat samples soaked in melinjau, papaya, and pineapple juice

Soaking time (min)	Control	Melinjau	Papaya	Pineapple
0		^{a}19.909	^{a}19.909	^{a}19.909
20	19.909^{A}	^{b}10.177^{C}	^{ab}17.528^{AB}	^{b}14.994^{B}
40	19.909^{A}	^{b}9.507^{D}	^{b}16.160^{B}	^{b}12.820^{C}
60	19.909^{A}	^{b}10.594^{D}	^{ab}16.744^{B}	^{b}13.363^{C}

a, b, c: Different letters in the same column indicate significant differences at $p < 0.05$.
A, B, C: Different letters in the same row indicate significant differences at $p < 0.05$

The statistical analysis presented in Table 3 reveals that soaking time significantly affects ($p<0.05$) the tenderness of meat soaked in papaya juice, while the type of juice used also has a significant impact ($p<0.05$) on meat tenderness. However, the tenderness of meat soaked in melinjau and pineapple juices is not significantly influenced by soaking time, as extending the soaking period does not result in a significant increase in meat tenderness ($p<0.05$).

The optimal tenderness of meat soaked in melinjau juice is achieved at 40 minutes (9.507 kgf), which is significantly different ($p<0.05$) from the control (19.909 kgf), but no significant difference ($p>0.05$) is observed at 20 and 60 minutes. In the case of papaya juice, meat tenderness significantly improves ($p<0.05$) at 40 minutes (16.160 kgf) compared to the control (19.909 kgf). This improvement in tenderness is primarily influenced by soaking time, with significant differences ($p<0.05$) observed only at 40 minutes compared to the control but not at 20 and 60 minutes ($p>0.05$).

Similarly, the tenderness of meat soaked in pineapple juice significantly increases ($p<0.05$) compared to the control. However, since lengthening the soaking time does not result in a further increase in tenderness, this improvement is unaffected. The optimal tenderness of meat soaked in pineapple juice occurs at 40 minutes (12.820 kgf), with no significant difference ($p > 0.05$) observed at 20 and 60 minutes.

According to Bickerstaffe et al. [33], meat tenderness is categorized into five groups: 1) very tender (2.0 to 4.9 KgF), 2) tender (5.0 to 7.9 KgF), 3) neutral (8.0 to 10.9 KgF), 4) tough (11.0 to 14.9 KgF), and 5) very tough (>15 KgF). Soaking meat in melinjau juice can increase tenderness from very tough to a more acceptable or neutral level, while papaya and pineapple juices move the meat from the very tough category to tough. Although soaking in pineapple juice can reduce toughness from very tough to tough, it does not reach the tender category.

The statistical analysis further indicates that the tenderness of meat soaked in melinjau, papaya, and pineapple juices differs significantly ($p<0.05$) from the control. Additionally, soaking meat in melinjau juice shows a significant difference ($p<0.05$) compared to papaya and pineapple juices. While soaking meat in pineapple juice may not reach the tender category, it still significantly improves tenderness compared to the control. The statistical analysis demonstrates that melinjau juice has a greater impact on meat tenderness than papaya and pineapple juices, suggesting it may be a more effective tenderizer.

The results of the physicochemical and tenderness tests have shown varied outcomes. However, there is another test that greatly affects the quality of the meat, namely the organoleptic test. The results of the organoleptic test are shown in Table 4.

Table 4. Average sensory test values of meat soaked for 40 minutes in the juice of melinjau fruit, papaya, and pineapple

Sample	Color	Aroma	Texture	Tenderness	Juiciness
Control	4.0^{a}	8.0^{a}	10.0^{a}	3.0^{a}	6.0^{a}
Melinjau	2.8^{ab}	5.3^{a}	9.3^{a}	5.0^{a}	6.5^{a}
Papaya	2.8^{ab}	7.0^{a}	8.3^{a}	3.0^{a}	6.1^{a}
Pineapple	2.3^{b}	5.4^{a}	8.1^{a}	4.8^{a}	5.0^{a}

a, b, c: Different letters in the same column indicate significant differences at $p < 0.05$.
A, B, C: Different letters in the same row indicate significant differences at $p < 0.05$

Color

Color plays a crucial role in the initial acceptance of meat products by consumers. The results showed that the mean color score of meat soaked in melinjau juice and papaya juice was not significantly different ($p > 0.05$) from the control. However, the mean color score of meat soaked in pineapple juice was significantly different ($p < 0.05$) from the control. The study found that meat soaked in melinjau juice and papaya juice had similar color scores, suggesting they may be equally appealing to consumers. In contrast, meat soaked in pineapple juice had a significantly different color score, indicating it may not be as visually appealing to consumers compared to the control [34].

Aroma

In addition to color, aroma also plays an important role in determining the quality of meat. Fat oxidation can affect the aroma and taste of meat. The mean aroma scores of meat soaked in melinjau juice (5.3), papaya juice (7.0), and pineapple juice (5.4) did not differ significantly ($p > 0.05$) from the control. However, the consumer panel showed a preference for meat soaked in papaya juice over the others. The preference of the consumer panel for meat soaked in papaya juice suggests that aroma may have a more significant impact on perceived quality than the statistical analysis indicates [7].

Texture

Meat texture can be perceived through tactile senses (hands and mouth). The mean texture scores of meat soaked in melinjau juice (9.3), papaya juice (8.3), and pineapple juice (8.1) did not differ significantly ($p > 0.05$) from the control. While texture can be perceived through tactile senses, it is important to consider that consumer preference for meat soaked in papaya juice may be influenced by factors beyond just texture, such as flavor and aroma. The statistical analysis showing no significant difference in texture scores does not necessarily negate the impact of other sensory aspects on overall perceived quality.

Tenderness

Tenderness is one of the key attributes in determining meat quality [35]. The mean tenderness scores of meat soaked in melinjau juice (5.0), papaya juice (3.0), and pineapple juice (4.8) did not differ significantly ($p>0.05$) from the control. However, meat soaked in melinjau juice exhibited better tenderness compared to papaya and pineapple juices, consistent with tenderness tests performed using the TA-TXi Texture Analyser from Stable Microsystems Ltd., London. The study found that meat soaked in melinjau juice showed superior tenderness compared to meat soaked in papaya and pineapple juices, despite no significant differences in mean tenderness scores [36]. Another study demonstrated that marinating poultry meat with pineapple juice significantly improves its organoleptic qualities. In this study, spent hen meat soaked in Ananas comosus juice had higher sensory scores for tenderness, juiciness, and overall acceptability compared to unmarinated meat [28].

Juiciness

Juiciness plays a significant role in delivering the desired taste and is closely related to meat tenderness. The mean juiciness scores of meat soaked in melinjau juice (6.5), papaya juice (6.1), and pineapple juice (5.0) did not differ significantly ($p>0.05$) from the control. Nevertheless, meat soaked in melinjau juice demonstrated the highest juiciness, which aligns with the study on meat tenderness. This suggests that the soaking method using melinjau juice not only enhances tenderness but also contributes to a juicier texture in the meat compared to other fruit juices. Additionally, the high juiciness score of meat soaked in melinjau juice indicates that this method could be a promising technique for improving the overall sensory experience of the meat product, making it more desirable for consumers seeking both tenderness and juiciness in their meat. The findings show that specific soaking techniques can have an impact on the sensory attributes of tenderness and juiciness. Further research is needed to explore the potential benefits of using melinjau juice as a marinade for meat to improve overall perceived meat quality.

4. Conclusion

This study demonstrates that soaking buffalo meat in extracts of melinjau, papaya, and pineapple significantly impacts its physicochemical properties and organoleptic characteristics. Soaking with melinjau and papaya extracts improved the meat’s color lightness, while papaya and pineapple extracts enhanced its tenderness. Additionally, these fruit extracts contributed to a noticeable reduction in fat content, with papaya extract showing the most significant decrease. Although there was a slight reduction in protein content, the soaking process helped maintain the meat’s sensory qualities, improving its juiciness and tenderness. Sensory evaluations showed that melinjau extract had

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the best effect on tenderness and juiciness, with papaya and pineapple extracts also providing significant improvements compared to the control. These findings highlight the potential of using tropical fruit extracts as a natural alternative for preserving and enhancing buffalo meat quality. By reducing the reliance on synthetic additives, this research contributes to the production of higher-quality buffalo meat products that are tastier, more tender, and have a longer shelf life, benefiting both the meat processing industry and consumers.

6. Reference

[1] L. Di Stasio and A. Brugiapaglia, "Current Knowledge on River Buffalo Meat: A Critical Analysis," *Animals*, vol. 11, no. 7, p. 2111, Jul. 2021, doi: 10.3390/ani11072111.
[2] B. M. A. O. Perera, "Reproductive cycles of buffalo," *Anim Reprod Sci*, vol. 124, no. 3–4, pp. 194–199, Apr. 2011, doi: 10.1016/j.anireprosci.2010.08.022.
[3] N. B. Maheswarappa, K. Mohan, and R. Banerjee, "Establishing Water Buffaloes as a Promising Source of Red Meat in Pursuit of Sustainable Animal Proteins for a Better World," *Meat and Muscle Biology*, vol. 8, no. 1, Dec. 2024, doi: 10.22175/mmb.17001.
[4] I. Lintang, "Daging Kerbau Terbanyak di Indonesia," Inilah.com. Accessed: Mar. 17, 2025. [Online]. Available: https://www.inilah.com/daerah-dengan-produksi-daging-kerbau-terbanyak-di-indonesia
[5] A. Tamburrano *et al.*, "Biochemical and nutritional characteristics of buffalo meat and potential implications on human health for a personalized nutrition," *Ital J Food Saf*, vol. 8, no. 3, Oct. 2019, doi: 10.4081/ijfs.2019.8317.
[6] L. S. Rodrigues *et al.*, "A Review of the Nutritional Aspects and Composition of the Meat, Liver and Fat of Buffaloes in the Amazon," *Animals*, vol. 14, no. 11, p. 1618, May 2024, doi: 10.3390/ani14111618.
[7] K. Younis, "Utilization of Fruit Wastes as A Source of Dietary Fibre in Buffalo Meat Products and Its Quality Evaluation," Thesis, Aligarh Muslim University, Aligarh, 2016. Accessed: Mar. 20, 2025. [Online]. Available: https://core.ac.uk/download/pdf/144528345.pdf
[8] G. S. Diwakar, "Effect of Dietary Supplementation of Palm Stearin on Growth Performance, Rib Eye Area and Back Fat Thickness in Murrah Buffalo Calves," Thesis, Deemed University, 2024. Accessed: Mar. 20, 2025. [Online]. Available: https://krishikosh.egranth.ac.in/server/api/core/bitstreams/409894b5-128e-4635-8bf1-159655a9db76/content
[9] N. B. Maheswarappa, M. Muthupalani, K. Mohan, R. Banerjee, A. R. Sen, and S. B. Barbuddhe, "Buffalo Meat Quality and Structure," in *Asiatic Water Buffalo: A Sustainable and Healthy Red Meat Source*, Singapore:

Springer Nature Singapore, 2022, pp. 63–81. doi: 10.1007/978-981-19-2619-8_7
[10] R. Ramanathan *et al.*, "Biochemical changes of postmortem meat during the aging process and strategies to improve the meat quality," in *Meat Quality Analysis*, A. K. Biswas and P. K. Mandal, Eds., Elsevier, 2020, pp. 67–80. doi: 10.1016/B978-0-12-819233-7.00005-7.
[11] A. B. Falowo, P. O. Fayemi, and V. Muchenje, "Natural antioxidants against lipid–protein oxidative deterioration in meat and meat products: A review," *Food Research International*, vol. 64, pp. 171–181, Oct. 2014, doi: 10.1016/j.foodres.2014.06.022.
[12] A. C. Orădan, A. C. Tocai (Moțoc), C. A. Rosan, and S. I. Vicas, "Fruit Extracts Incorporated into Meat Products as Natural Antioxidants, Preservatives, and Colorants," *Processes*, vol. 12, no. 12, p. 2756, Dec. 2024, doi: 10.3390/pr12122756.
[13] S. Luzardo, "Effect of packaging during storage time on retail display shelf-life of beef strip loins from two different production systems," Thesis, Colorado State University, Colorado, 2016. Accessed: Mar. 20, 2025. [Online]. Available: https://www.proquest.com/openview/4cf5e16c310fc31bb2cabd7348023fb9/1?cbl=18750&pq-origsite=gscholar
[14] A. R. Sen, M. Muthukumar, B. M. Naveena, and D. B. V. Ramanna, "Effects on colour characteristics of buffalo meat during blooming, retail display and using vitamin C during refrigerated storage," *J Food Sci Technol*, vol. 51, no. 11, pp. 3515–3519, Nov. 2014, doi: 10.1007/s13197-012-0882-x.
[15] S. Mohd Azmi, P. Kumar, N. Sharma, A. Sazili, S.-J. Lee, and M. Ismail-Fitry, "Application of Plant Proteases in Meat Tenderization: Recent Trends and Future Prospects," *Foods*, vol. 12, no. 6, p. 1336, Mar. 2023, doi: 10.3390/foods12061336.
[16] E. C. Bate-Smith, "The Physiology and Chemistry of Rigor Mortis, with Special Reference to the Aging of Beef," in *Advances in Food Research*, 1948, pp. 1–38. doi: 10.1016/S0065-2628(08)60204-9.
[17] C. Novais *et al.*, "Natural Food Colorants and Preservatives: A Review, a Demand, and a Challenge," *J Agric Food Chem*, vol. 70, no. 9, pp. 2789–2805, Mar. 2022, doi: 10.1021/acs.jafc.1c07533.
[18] E. Teshome, S. F. Forsido, H. P. V. Rupasinghe, and E. Olika Keyata, "Potentials of Natural Preservatives to Enhance Food Safety and Shelf Life: A Review," *The Scientific World Journal*, vol. 2022, pp. 1–11, Sep. 2022, doi: 10.1155/2022/9901018.
[19] G. Manessis, A. I. Kalogianni, T. Lazou, M. Moschovas, I. Bossis, and A. I. Gelasakis, "Plant-Derived Natural Antioxidants in Meat and Meat Products," *Antioxidants*, vol. 9, no. 12, p. 1215, Dec. 2020, doi: 10.3390/antiox9121215.
[20] M. Aziz and S. Karboune, "Natural antimicrobial/antioxidant agents in meat and poultry products as well as fruits and vegetables: A

review," *Crit Rev Food Sci Nutr*, pp. 1–26, Jul. 2017, doi: 10.1080/10408398.2016.1194256.

[21] B. Kunarto, S. Sutardi, S. Supriyanto, and C. Anwar, "Antioxidant Activity of Melinjo Ketan (Gnetum gnemon L., 'Ketan') Seed Extract at Various Ripening Stages and Ethanol Solvent Concentration," *Int J Adv Sci Eng Inf Technol*, vol. 9, no. 4, pp. 1344–1351, Aug. 2019, doi: 10.18517/ijaseit.9.4.9376.

[22] A. Sukohar, M. Iqbal, R. Triyandi, and Sahidin, "Melinjo Seeds (Gnetum gnemon L.) Antioxidant Activity and Cytotoxic Effects on MCF-7 Breast Cancer Cells: A Study Based on Tracing of Resveratrol Compound," *J Pharm Bioallied Sci*, vol. 16, no. 1, pp. 16–23, Jan. 2024, doi: 10.4103/jpbs.jpbs_878_23.

[23] C. Dewi, R. Utami, and N. H. R. Parnanto, "Aktivitas antioksidan dan antimikroba ekstrak melinjo (Gnetum gnemon L.)," *Jurnal Teknologi Hasil Pertanian*, vol. 5, no. 2, pp. 74–81, 2012.

[24] B. M. Naveena, S. K. Mendiratta, and A. S. R. Anjaneyulu, "Tenderization of buffalo meat using plant proteases from Cucumis trigonus Roxb (Kachri) and Zingiber officinale roscoe (Ginger rhizome)," *Meat Sci*, vol. 68, no. 3, pp. 363–369, Nov. 2004, doi: 10.1016/j.meatsci.2004.04.004.

[25] E. Widowati, "Pengaruh Lama Perendaman Daging Sapi dengan Ekstrak Pepaya, Nanas, dan Jahe terhadap Kualitas Fisik dan Sensoris Daging Sapi," Skripsi, Universitas Gajah Mada, 2011. Accessed: Mar. 17, 2025. [Online]. Available: https://etd.repository.ugm.ac.id/penelitian/detail/171335

[26] N. M. M. Zuki *et al.*, "Effect of High-Pressure Processing and Bromelain Application on The Quality Characteristics of Buffalo Meat," *Malaysian Applied Biology*, vol. 54, no. 2, pp. 83–91, 2025.

[27] J. P. Jahidin and M. Monica, "Efek Penggunaan Ekstrak Buah Nanas (Ananas comosus L. Merr) terhadap Kualitas Fisik Daging Kerbau," *Jurnal Ilmiah Ilmu-Ilmu Peternakan*, vol. 21, no. 1, pp. 47–54, Oct. 2018, doi: 10.22437/jiiip.v21i1.4725.

[28] Nuraini, H. Hafid, P. Patriani, S. Sepriadi, and S. H. Ananda, "Organoleptic properties of Free-range chicken meat with the pineapple fruit juice marination," *IOP Conf Ser Earth Environ Sci*, vol. 782, no. 2, p. 022078, Jun. 2021, doi: 10.1088/1755-1315/782/2/022078.

[29] H. U. Bergmeyer, *Methods of Enzymatic Analysis*, 2nd ed., vol. 2. Elsevier Inc., 1974.

[30] C. J. Cook, S. M. Scott, and C. E. Devine, "Measurement of nitric oxide and the effect of enhancing or inhibiting it on tenderness changes of meat," *Meat Sci*, vol. 48, no. 1–2, pp. 85–89, 1998, doi: 10.1016/S0309-1740(97)00079-X.

[31] G. Butler, L. M. Poste, D. A. Mackie, and A. Jones, "Time-intensity as a tool for the measurement of meat tenderness," *Food Qual Prefer*, vol. 7, no. 3–4, pp. 193–204, Jul. 1996, doi: 10.1016/S0950-3293(96)00031-6.

[32] B. Ismail, H. Mohammed, and A. J. Nair, "Influence of Proteases on Functional Properties of Food," 2019, pp. 31–53. doi: 10.1007/978-981-13-3263-0_4.

[33] R. Bickerstaffe, A. E. D. Bekhit, L. J. Robertson, N. Roberts, and G. H. Geesink, "Impact of introducing specifications on the tenderness of retail meat," *Meat Sci*, vol. 59, no. 3, pp. 303–315, 2001, doi: 10.1016/S0309-1740(01)00083-3.

[34] Nuraini, H. Hafid, P. Patriani, S. Sepriadi, and S. H. Ananda, "Organoleptic properties of Free-range chicken meat with the pineapple fruit juice marination," *IOP Conf Ser Earth Environ Sci*, vol. 782, no. 2, p. 022078, Jun. 2021, doi: 10.1088/1755-1315/782/2/022078.

[35] C. T. Boleman, D. R. McKenna, W. S. Ramsey, R. K. Peel, and J. W. Savell, "Influence of feeding vitamin D3 and aging on the tenderness of four lamb muscles," *Meat Sci*, vol. 67, no. 2, pp. 185–190, Jun. 2004, doi: 10.1016/j.meatsci.2003.09.010.

[36] D. J. McClements, J. Weiss, A. J. Kinchla, A. A. Nolden, and L. Grossmann, "Methods for Testing the Quality Attributes of Plant-Based Foods: Meat- and Processed-Meat Analogs," *Foods*, vol. 10, no. 2, p. 260, Jan. 2021, doi: 10.3390/foods10020260.