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TENDERNESS LEVEL AND SENSORY ANALYSIS OF BUFFALO MELTIQUE MEAT INJECTED WITH VARIOUS OILS AND MARINATED WITH PAPAIN

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Abstract
Buffalo meat has a high nutritional value but tends to have a tough texture. Therefore, processing methods such as the meltique technique are needed to tenderize buffalo meat. The aim of this study was to evaluate the tenderness and sensory characteristics of buffalo meltique meat injected with different types of fats (beef tallow, Wagyu fat, coconut oil, and palm oil) combined with papain enzyme. The treatments were applied to sirloin cuts of buffalo meat and assessed through physical (tenderness and texture profile) and sensory (hedonic and quality) analysis. The design used in texture analysis was a completely randomized design with five treatments and three replications. Sensory tests were analyzed using the non-parametric Kruskal-Wallis test. The results showed that all fat-injected treatments significantly improved meat tenderness (P<0.05) compared to the control. Texture profile analysis revealed a decrease in hardness, gumminess, and chewiness, particularly in treatments that incorporated Wagyu fat and palm oil. Hedonic tests showed no significant differences in color and flavor. Palm oil and Wagyu fat treatments resulted in higher consumer preference scores for texture and aroma. These findings suggest that combining fat emulsion injection and papain marination is an effective strategy to improve the tenderness and consumer acceptance of buffalo meat.
Keywords: buffalo, meat, meltique, papain, tenderness

TINGKAT KEEMPUKAN DAN ANALISIS SENSORI DAGING KERBAU MELTIQUE YANG DISUNTIK DENGAN BERBAGAI MINYAK DAN DIMARINASI DENGAN PAPAIN

Abstrak
Daging kerbau memiliki nilai gizi yang tinggi tetapi cenderung bertekstur alot, sehingga diperlukan metode pengolahan seperti teknik meltique untuk mengempukkan daging kerbau. Tujuan penelitian ini adalah untuk mengevaluasi keempukan dan karakteristik sensoris daging kerbau meltique yang diinjeksi dengan berbagai jenis lemak (lemak sapi, lemak Wagyu, minyak kelapa, dan minyak sawit) yang dikombinasikan dengan enzim papain. Perlakuan tersebut diterapkan pada potongan sirloin daging kerbau dan dinilai melalui analisis fisik (keempukan dan profil tekstur) dan sensoris (hedonik dan kualitas). Rancangan yang digunakan dalam analisis tekstur adalah rancangan acak lengkap dengan lima perlakuan dan tiga kali ulangan. Uji sensoris dianalisis menggunakan uji Kruskal-Wallis non-parametrik. Hasil penelitian menunjukkan bahwa semua perlakuan yang diinjeksi lemak secara signifikan meningkatkan keempukan daging (P<0,05) dibandingkan dengan kontrol. Analisis profil tekstur menunjukkan penurunan kekerasan, kekenyalan, dan kekenyalan, terutama pada perlakuan yang menggunakan lemak Wagyu dan minyak sawit. Uji hedonik tidak menunjukkan perbedaan signifikan dalam warna dan rasa. Perlakuan minyak sawit dan lemak Wagyu menghasilkan skor preferensi konsumen yang lebih tinggi untuk tekstur dan aroma. Hasil pada penelitian ini menunjukkan bahwa kombinasi injeksi emulsi lemak dan marinasi papain merupakan strategi yang efektif untuk meningkatkan keempukan dan penerimaan konsumen terhadap daging kerbau.
Kata kunci: kerbau, daging, meltique, papain, keempukan

INTRODUCTION

Buffalo meat is one source of animal protein that has the potential to be developed as an alternative to beef. According to Naveena and Kiran (2014), buffalo meat has similar composition, quality, and organoleptic properties to beef, but its advantage lies in its lower fat, cholesterol, and calorie content. Buffalo meat is more economically priced due to several factors, including the lower production costs associated with buffalo compared to cattle, and the relatively low market demand for buffalo meat.

Buffalo meat is known to have a coarser texture and darker color than beef, which poses challenges in buffalo meat processing. Buffalo meat is generally considered tough because it is slaughtered at an older age, resulting in coarse muscle fibers, white fat, and a taste similar to beef, but with a stronger odor (prengus) (Warsito *et al*., 2015). 2-year-old young buffalo and 4-year-old cattle produce the same meat characteristics (Mendrova *et al*., 2016).

The problem with buffalo meat can be solved by proper processing, one of which is making meltique meat. Meltique refers to a specialized technique that involves injecting fat into the muscle fibers, creating a marbling effect similar to that of wagyu beef. This technique not only increases the tenderness and juiciness of the meat but also adds a unique flavor, making it an attractive alternative for consumers seeking quality meat at a lower price (Apriantini *et al*., 2024). Animal and vegetable fats that can be used in making meltique meat include coconut oil, palm oil, beef tallow, and Wagyu fat. Generally, meltique meat in the market was made using beef meat injected with animal fat (such as wagyu fat and beef fat) or canola oil. However, canola oil was imported from other countries at a high price. Therefore, this study aims to utilize local oils, such as coconut oil and palm oil, to produce a cost-effective meltique meat. The above oils help in producing a layer of fat on the muscle fibers, which creates a fatty texture, as in meat that has high marbling.

Injection of vegetable and animal fats into buffalo meat is an effective strategy to improve marbling [Apriantini *et al*., 2025; Sari, 2025]. The mechanism involves the incorporation of exogenous fat into muscle tissue, where it is stored as intramuscular fat. This process is influenced by the fatty acid composition of the injected fat, which modulates lipid metabolism, gene expression, and adipocyte activity. The result is a more tender, juicy, and flavorful product with better consumer acceptance (Azmi *et al*., 2021). Apart from using the meltique technique, additional processing can be done using papain enzyme found in papaya. The papain enzyme exhibits proteolytic activity that effectively breaks peptide bonds in myosin proteins, thereby altering the structure of myofibrils and producing meat that is more tender and easier to chew (Juwita *et al*., 2022). A combination of the meltique technique, involving fat emulsion injection, enhances meat marbling and juiceness, and Papain application, a proteolytic enzyme derived from papaya extract to improve meat texture by breaking down myofibril proteins in order to enhance meat tenderness, can improve the quality of buffalo meat so that it has meat characteristics that resemble wagyu beef. This study aims to determine the physical and sensory characteristics of meltique buffalo meat when injected with various fats and papain.

MATERIALS AND METHODS

The raw materials used were buffalo meat (*Bubalus bubalis*) from the sirloin section with a slaughter age of ± 2 years, as well as coconut oil, palm oil, commercial beef tallow, Wagyu tallow, papain obtained from young papaya fruit, maltodextrin, carboxymethyl cellulose (CMC), and carrageenan. The testing materials used include pH 4 and pH 7 buffer solutions, as well as distilled water. The method of meltique meat production is based on a prelab test to find methods and formulations that suit the characteristics of buffalo meat with papain. The testing process began with sample preparation, which included meat preparation, marination of meat with papain, meat injection, and roasting.

Papain extraction and its application to Buffalo meat

Papain enzyme is obtained from papaya fruit extract. The preparation of papaya fruit extract begins with peeling the skin of the papaya fruit. Then, the papaya fruit is cut into square pieces and blended until smooth, without the addition of water. The surface of the buffalo meat was coated with a fruit extract at a concentration of 30% of the meat's weight and put in a container. After coating with the fruit extract, the meat was covered with plastic wrap and marinated for 30 minutes at room temperature.

Procedure for making meltique meat steak

The vegetable and animal fat emulsion formulation used, based on preliminary results, was 78.5% water, 20% fat, and 1.5% emulsifier consisting of maltodextrin, carrageenan, and carboxymethyl cellulose

(CMC) at 0.5% each. The amount of emulsion used was 50% of the meat weight. The emulsion formulation for 1 kg of meat requires a total of 500 ml of emulsion. The fats and oils used in this study were mixed with emulsifiers in a food processor, and water was added gradually until the mixture reached a thick consistency. The meat was then evenly injected with the emulsion mixture over its entire surface using a comb-shaped meat injector tool with a total of 3 hollow needles and 27 non-hollow needles, each 7 cm in length. The injected meat was vacuum sealed and then frozen in a freezer at -20°C. Frozen meat was thawed and then cut to a thickness of approximately 3 cm. Meat samples were grilled using a grill for 8-10 minutes (4-5 minutes each side), and the internal temperature of the meat was 65°C. Grilling using medium heat with medium well doneness.

Tenderness and Texture Analysis

The analysis of tenderness level was carried out by measuring meat tenderness using *the Warner-Bratzler method*. Texture profile analysis was performed according to the AOAC method (2005) using a Texture Analyzer (Perten Instrument, TVT6700) manufactured in Sweden.

Sensory Analysis

Sensory analysis, including hedonic test and hedonic quality, using the method of Setyaningsih *et al.* (2010). The hedonic test on roasted Meltique buffalo meat includes four attributes expressed on a preference scale. The attributes tested in the hedonic test are taste, color, aroma, and texture. A scoring test is conducted, expressed in numerical form, with a range of 1 to 5. The scale used is: 1 = dislike, 2 = slightly dislike, 3 = neutral, 4 = slightly like, 5 = very like. The hedonic quality test on roasted meltique buffalo meat was conducted by scoring the test with a score scale ranging from 1 to 5. The hedonic quality test attributes include the intensity of color brightness, the intensity of meltique meat flavor, the intensity of oil aroma in the meat, and the intensity of meltique meat texture. Observations were made using a hedonic quality scale, with scoring for the intensity of color brightness, as follows: 1 = pink, 2 = red, 3 = brownish red, 4 = brown, and 5 = dark brown. The intensity of meltique meat flavor is rated as follows: 1 = Not felt at all, 2 = Not felt, 3 = Neutral, 4 = Slightly felt, 5 = Very felt. The intensity of meltique meat aroma is 1 = very smelling of animal fat, 2 = slightly smelling of animal fat, 3 = Scented of buffalo meat, 4 = Slightly smelling of vegetable fat, 5 = Very smelling of vegetable fat. The texture of the meat is 1 = very rough, 2 = rough, 3 = neutral, 4 = soft, 5 = very soft.

Statistical Analysis

The design used in this study was a completely randomized design (CRD) with five treatment factors and three replications. The treatments consisted of grilled buffalo meat, buffalo meat injected with beef fat and papain, buffalo meat injected with wagyu fat and papain, buffalo meat injected with palm oil and papain, and buffalo meat injected with coconut oil and papain. The statistical model used was according to Steel and Torrie (1997) as follows. Statistical analysis was performed using ANOVA, followed by Tukey's post-hoc test (Steel & Torrie, 1997). Organoleptic test was analyzed using the Kruskal-Wallis non-parametric test (Steel & Torrie, 1997).

RESULTS AND DISCUSSION

Tenderness Analysis

Meat tenderness is influenced by components such as connective tissue, muscle fibers, and intramuscular fat. Based on Table 1, the tenderness of papain-marinated meltique buffalo meat injected with various fats showed significant differences ($P<0.05$). All injected treatments had lower shear force values than the control (1.98 ± 0.15 kg/cm²), indicating increased tenderness. No significant difference was found between plant-based and animal-based fat injections, suggesting similar effects. These results showed that injecting both vegetable oil and animal fat into buffalo meat can increase its tenderness. The increase in tenderness through the vegetable oil and animal fat emulsion injection technique is likely due to the formation of artificial marbling in buffalo meat. Furthermore, puncturing the meat with meat injector needles during the injection of vegetable oil and fat animal emulsion can also affect the tenderness of buffalo meat. Wood *et al*. (2008) stated that the presence of marbling in meat separates muscle fibers and opens up the muscle structure with fat, thus making the meat more tender.

Moreover, the papain enzyme can tenderize meat, whether it contains plant-based or animal-based fat. Papain enhances tenderness by breaking down muscle proteins, while the injected fat improves texture by filling muscle gaps and reducing chewing resistance (Juwita *et al*., 2022). Biochemically, the process of meat tenderization is by degrading quaternary structure proteins into simpler structures (Maghfiroh *et al*., 2017).

Texture Profile Analysis

Table 1 presents significantly different results (P<0.05) for the Springiness parameter, which indicates a sample's ability to return to its original shape after being subjected to pressure, or in other words, the elastic properties of a food (Souppez *et al*., 2025). The lower the springiness number, the better and more elastic the resulting meat will be. The best springiness was found in the T2 treatment with a value of 0.54 mm, while the control meat had the highest value at 0.95 mm. Animal fat tends to disrupt the protein matrix, accelerating protein hydrolysis and reducing springiness.

Chewiness is the energy required to chew food until it is soft enough to swallow. Chewiness refers to the softness or texture of a product. Differences in oil injection can affect the chewiness of meat. This is due to the different oil contents (Indiarto *et al*. 2012). The lower the chewiness number, the better and easier the meat is to chew. Table 1 presents significantly different results (P>0.05), with T2 meat exhibiting the lowest chewiness value at 1,494 N and K meat showing the highest chewiness value at 2,060 N. This may be due to the greater stability of the emulsion injection provided by animal fat, resulting in a softer chewiness. Moreover, animal fat, such as beef fat and wagyu fat, has the same characteristics as buffalo fat; thus, the injection can increase the composition of intramuscular fat in buffalo meat. Based on the study of Sasaki *et al.* (2012), the increasing intramuscular fat can improve both chewiness and hardness.

Gumminess refers to the energy required to break down semi-solid food until it can be swallowed (Novaković and Tomašević, 2017). The lower the gumminess value, the better and chewier the resulting meat will be. The results were significantly different (P<0.05), with T2 emulsion injection having the lowest value at 668.3 N and the highest value at 1,932 N in the control meat. Gumminess is predominantly composed of unsaturated fatty acids, forming a lubricating layer between fibers, inhibiting the formation of a dense protein matrix, which can reduce adhesion between fibers (gumminess).

Hardness is a parameter that describes the maximum force required to compress or crush a food sample. The lower the hardness number, the better and more tender the meat. The results were significantly different (P<0.05), with the lowest value of 483 N for the T2 emulsion injection and the highest value for the control meat at 1732 N. Hardness decreased due to the addition of animal and vegetable fat emulsion injections through two main mechanisms: muscle fiber lubrication and protein interaction. Beef tallow, coconut oil, and palm oil, which are rich in saturated fatty acids, form stable emulsions with meat proteins, thereby softening the muscle fiber structure and reducing hardness. Meanwhile, the T2 emulsion injection resulted in a hardness value of 483 N. This finding aligns with research by Sari *et al*. (2025), which revealed that emulsion-injected meat (meltique meat) exhibited a lower texture profile compared to non-meltique meat, making it more palatable to consume. Cohesiveness refers to the strength of the internal bonds that comprise a material. The lower the cohesiveness number, the better and more tender the meat. There was no significant difference (P>0.05) in cohesiveness. This result implies that the internal bond strength within the meat matrix was not affected by emulsion injection (Sari *et al*., 2025)

The data in Table 1 show that the value of papain marination with fat and oil injection treatment decreased. These results occurred due to the addition of emulsions, in the form of vegetable and animal oils, to meltique meat injection, which has a significant effect on the levels of springiness, gumminess, chewiness, and hardness of meltique buffalo meat. In line with research (Wardaya and Tugiyanti, 2020), which suggests that meat tenderness is influenced by meat fat content, the higher the meat fat content, especially intramuscular fat, the greater the increase in meat tenderness. Papain, as a proteolytic enzyme, influences the decrease of springiness, gumminess, chewiness, and hardness values of meltique buffalo meat. The proteolytic activity of papain can hydrolyze peptide bonds in myosin and actin (myofibril proteins), thereby imparting tenderness to meat marinated with papain. This is supported by the statement of Juwita *et al*. (2022), which states that papain enzymes, when extracted and applied to raw meat with a soaking time of 20 minutes, will produce soft meat.

Hedonic Test

Hedonic test results for color, aroma, taste, and texture parameters were conducted on each meat sample with various treatments. The data in Table 2 show results that are not significantly different (P>0.05) for the parameters of color, aroma, and taste. Color is one of the important physical parameters in a product because it affects consumer liking of the food product. Although there is a change in the color of the meat after processing, the level of consumer preference for meltique buffalo meat does not affect it. Color changes can occur due to processing that can affect the stability of myoglobin pigments (Samual *et al*., 2014).

The aroma parameter is one of the crucial factors influencing panelists' preference for food products (Azmi *et al*., 2021). Although there was no significant difference in the level of panelists' liking of the aroma of roast buffalo meat products with meltique buffalo meat, the aroma of meltique buffalo meat with various injections gave higher scores because the processed meat did not give a pungent odor from the buffalo itself. This can be caused by the aroma given off by the injection material, which can eliminate the pungent odor of the meat itself.

Taste is one of the primary factors influencing panelists' favorability of food products. The difference in the taste of the different meat treatments comes from the fat injection in the meat. Panelists like meltique meat than control. Increasing the fat content in the meat can impart a different savory taste and mitigate the strong flavor of the meat (Hirai *et al*., 2023).

A significant difference (P<0.05) was observed in the texture parameter, where panelists preferred fat-injected meat over the control. The highest texture value was found in grilled buffalo meltique with palm oil injection, indicating that palm oil had a significant effect on the texture of buffalo meat and increased panelists' liking. Panelists preferred the soft texture of the meat because it was easier to consume (Sari *et al*., 2025).

Hedonic Quality

Based on the results of the hedonic quality test for the color parameter, significant differences were observed (P<0.05). Meltique buffalo meat has a color that ranges from 2.63 to 3.83, with meat injected with palm oil and papain showing the highest value, and meat with coconut oil and papain injection showing the lowest value. The color of the uninjected buffalo meltique roast was generally brownish red, as was the case with the commercial and palm oil-injected buffalo meltique roast. Whereas meat with wagyu beef fat and coconut fat injection tended to be more reddish. The aroma parameter yielded significantly different results (P<0.05). In the treatment using animal fat injection, the product showed the aroma of animal fat, as well as the use of vegetable fat injection, which gave the aroma of vegetable oil to the buffalo meltique. Vegetable fat has a lighter and sometimes slightly sweet aroma. According to Fabre *et al*. (2006), vegetable fats contain higher concentrations of hydrophobic compounds, leading to a greater release of esters such as ethyl hexanoate. This is due to their more polar nature, which facilitates the release of lighter aroma compounds. Animal fats have a heavier and richer aroma. According to Relkin *et al* (2004), the aroma of animal fats is characterized by a higher release of hydrophilic compounds such as diacetyl, which are more effectively released from less polar emulsions. This is due to its unique fatty acid and triacylglycerol composition, giving it a stronger aroma.

In the taste parameter, there was no significant difference (P>0.05). Overall, the meat in all treatments showed that the typical taste of the meat had values ranging from 3 to 4 (pronounced). Studies on Japanese Black cattle have shown that higher intramuscular fat (IMF) levels intensify the sweetness and grilled/roasted taste, while reducing undesirable flavors such as gamey and blood flavors (Hirai *et al*., 2023). Similarly, in

Xinjiang, brown cattle with higher IMF content exhibited an improved taste profile characterized by sweet, green, fruity, and waxy aromas (Ma *et al*., 2024). However, the taste of meat injected with various fats and papain did not diminish the flavor of the meat.

The meat texture had significantly different results ($P < 0.05$), with the meat injected with wagyu fat having the highest value. Meat injected with various oils gave a different texture compared to meat without injection. Indeed, factors that affect these properties can come from both intrinsic and extrinsic sources. Both species, nations, ages, processes, and biochemistry that occur in food and meat processing (Anjalani, 2020). So that each treatment of meltique buffalo meat given different fat additions also produces different properties. Papain attacks connective tissue and myofibril proteins, which increases the content of hydroxyproline and free amino acids in meat cuts (Istrati, 2008), thereby causing a soft and tender texture in meltique buffalo meat.

Table 1. Tenderness and texture analysis of buffalo meltique meat

Variable	Treatments				
	C	T1	T2	T3	T4
Tenderness (kg/cm^2)	1,98 ± 0,15^b	1,33± 0,01^a	1,32 ± 0,04^a	1,30 ± 0,00^a	1,31 ± 0,04^a
Springiness (mm)	0,95 ± 0,06^a	0,61 ± 0,21^b	0,54 ± 0,07^c	0,61 ± 0,09^b	0,72 ± 0,00^b
Cohesiveness (mm)	0,63 ± 0,01	0,59 ± 0,03	0,66 ± 0,01	0,56 ± 0,01	0,63 ± 0,02
Gumminess (N)	1932,61 ± 60,1^a	972,73± 20,6^b	668,3 ± 733,3^c	982,42 ± 11,3^b	1063,3 ± 85,9^{ab}
Chewiness (N)	2060± 30,5^a	1669± 21^b	1494 ± 13^c	1662 ± 10,1^b	1827 ± 60,4^{ab}
Hardness (N)	1732±49,1^a	464 ± 116^c	483 ± 54,2^c	588 ± 66,8^{bc}	624 ± 39,2^b

Notes: *Different letters in the same row indicate significantly different results (P<0.05). C= Roast buffalo meat without injection (control); T1= Roast buffalo meat with commercial beef tallow injection (Australian Grass Fed); T2= Roast buffalo meat with Wagyu beef tallow injection T3= Roast buffalo meat with coconut oil injection; T4= Roast buffalo meat with palm oil injection.*

Table 2. Organoleptic test of buffalo meat meltique

Parameters	C	T1	T2	T3	T4
Hedonic Test					
	Treatments				
Color	3,11 ± 1,18	2,89 ± 1,18	3,37 ± 1,21	3,35 ± 1,10	3,60 ± 1,17
Aroma	2,63 ± 0,97	3,09 ± 0,98	3,17 ± 1,10	3,09 ± 0,98	3,26 ± 1,04
Taste	2,89 ± 1,35	3,17 ± 1,12	3,00 ± 1,14	3,49 ± 0,89	3,29 ± 0,99
Texture	2,26 ± 1,15^b	3,43 ± 1,07^a	2,94 ± 1,16^{ab}	3,17 ± 1,10^a	3,40 ± 1,12^a
Hedonic Quality					
	Treatments				
Color	3,57 ± 1,24^{ab}	2,83 ± 0,95^{bc}	3,34 ± 1,16^{abc}	2,63 ± 1,17^c	3,83 ± 1,25^a
Aroma	3,17 ± 1,15^b	2,86 ± 1,09^c	2,63 ± 1,19^c	4,26 ± 0,61^a	4,23 ± 0,55^a
Taste	3,91 ± 1,04	3,66 ± 1,00	3,74 ± 0,78	3,89 ± 1,02	3,89 ± 0,72
Texture	2,26 ± 1,15^b	3,43 ± 1,07^a	2,94 ± 1,16^{ab}	3,17 ± 1,10^a	3,40 ± 1,12^a

Notes: *Different letters in the same row indicate significantly different results (P<0.05). C= Roast buffalo meat without injection (control); T1= Roast buffalo meat with commercial beef tallow injection (Australian Grass Fed); T2= Roast buffalo meat with Wagyu beef tallow injection T3= Roast buffalo meat with coconut oil injection; T4= Roast buffalo meat with palm oil injection.*

CONCLUSIONS

The combination of fat emulsion injection and papain enzyme marination significantly enhanced the tenderness and sensory quality of buffalo meltique meat. All fat sources used (beef tallow, Wagyu fat, coconut oil, and palm oil) resulted in a lower shear force compared to the control, indicating improved tenderness. Texture profile analysis further demonstrated reductions in hardness, chewiness, and gumminess. Sensory evaluation revealed that meat injected with Wagyu fat and palm oil achieved higher panelist preference, particularly in terms of texture and aroma.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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