# Physical and sensory properties of meltique beef steak injected with virgin coconut oil emulsion

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**Abstract.** The consumption of animal-based protein in Indonesia remains low, necessitating efforts to increase its intake, particularly through beef. Beef contains complete nutrition content such as essential amino acids, vitamins and minerals (Fe, Zn). However, its thick muscle fibers, make it less tender and more difficult to consume. One potential innovation to improve beef tenderness is the injection of plant-based oil, which results in meltique beef. This study aims to investigate the physical and sensory characteristics of meltique beef injected with Virgin Coconut Oil (VCO) emulsion as a source of animal protein. This study employed a completely random design. Sensory evaluation was conducted using the hedonic test and sensory attribute profiling technique with 25 initiated panellists. Meltique beef injected with VCO emulsion demonstrated the same quality of physical and sensory characteristics comparable to those of wagyu beef and canola oil emulsion in terms of texture, tenderness, and oil content. Therefore, VCO emulsion-injected meltique beef can serve as a preferred and easily consumable protein source due to its soft texture and affordable prices.

## 1 Introduction

Animal protein, derived from animal products, plays a crucial role in the body by maintaining existing tissues and supporting the formation of new ones. It provides a complete range of essential amino acids necessary for growth, cell repair, and other bodily functions [1].

Despite its significant health benefits, animal protein consumption in Indonesia remains relatively low. Research in Indonesia indicates that animal protein sources contribute minimally to the daily diet [2]. According to Susenas (National Socio-Economic Survey) data in 2022, the average consumption of animal protein such as eggs and milk is 15.72 g, meat

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is 7.40 g, and fish/shrimp/squid/shellfish is approximately 15.72 g, showing that the average consumption of animal protein in Indonesia is still less than 50% [3].

Inadequate protein intake can lead to micronutrient deficiencies that affect body health and cognitive abilities. This poor diet quality increases the risk of chronic malnutrition, particularly among vulnerable groups such as pregnant women, children, and toddlers [4].

The World Food and Agriculture Organisation (FAO) recommends an annual per capita beef consumption between 10 and 20 kg. However, beef consumption in Indonesia is only 2.6 to 3 kg per capita per year, significantly below the recommended level [5]. Beef contains high-quality protein with a complete and balanced amino acid profile, along with essential vitamins and minerals such as iron, zinc, and vitamin B12 that support healthy growth. Increasing beef consumption is necessary, but its thick and dense muscle fibers, making it harder to chew compared to chicken. Therefore, processing technology is needed to improve the texture of beef, making it easier to consume [6].

One innovation to produce tender-textured beef is the injection of animal fats and vegetable oils. The process enhances marbling effect, which is white fibers in meat pieces that resemble marble, resulting in a final product known as meltique meat [7]. Traditionally, canola oil is used as the vegetable fat source in meltique beef production. However, canola oil is imported in Indonesia, which increases the production cost. Thus, a locally sourced alternative, such as coconut oil is necessary, as coconut oil is widely produced in Indonesia.

Indonesia is the world's second largest coconuts' producer, with an output of 3.2 million tonnes. Developing coconuts into various useful products can optimize the availability of coconuts in Indonesia [8] . Among the local vegetable oils in Indonesia is Virgin Coconut Oil (VCO), produced by extracting coconut fruit without going through the cooking process. This results in a light, non-greasy oil. VCO contains Medium-Chain Fatty Acids (MCFA), which increases the human body's resistance to disease and contains vitamin E, an antioxidant that protects body cells from oxidative damage [9]. Injecting meat with a VCO emulsion aims to improve the fatty acid profile and improve the balance between saturated and unsaturated fatty acid, thereby enhancing the nutritional quality of beef [10]. VCO has been widely used compared to other coconut oils, making it a promising substitute for canola oil in meltique meat injection as a food source of animal protein. This study aims to investigate the physical and sensory characteristics of meltique beef with VCO emulsion injection as a food source of animal protein.

## 2 Materials and methods

The sample used was sirloin from male Brahman cross (BX) beef meat aged 4-5 years and wagyu meat MB9 from Australia. The injected BX beef came from fresh beef taken from selected suppliers. After trimming, the meat was injected with VCO emulsion and canola oil emulsion, then vacuumed and sealed after it was frozen at -20$^{o}$C. The time interval between injection and meat processing in this study was one month. Formulation was based on 1000 g of meat: Formula one (X1) used 9.09% soy protein isolate (SPI), 45.45% VCO oil, and 45.45% water, while formulation two (X2) contained 18.18% SPI, 90.90% VCO, and 90.90% water. Soy protein isolate (SPI) was used as an emulsifier in the emulsion to create artificial marbling in the meat, bind water and oil, and retain the liquid within the meat fiber. The beef was grilled to a medium-well doneness (65-80 °C for 10 minutes) without additional seasoning.

### 2.1 pH value determination

Approximately 10 g of crushed steak meat was mixed with 100 mL distilled water. The solution was filtered and the pH of the filtrate was measured using a pH meter (Schott Instrument Lab 850) [11].

### 2.2 Cooking loss analysis

The sample was wrapped in plastic, then placed in a water bath and boiled at 80°C for 30 minutes. After boiling, the samples were removed and chilled. The remaining water on the surface of the meat was dried using absorbent paper without pressing [12]. The sample was then weighed, and the percentage of cooking loss was calculated using the following formula:

$$Cooking\ Loss\ (\%) = \frac{\text{initial weight} - \text{final weight}}{\text{initial weight}} x100\%$$

### 2.3 Sensory analysis

Sensory analysis was performed by using the hedonic test and sensory attribute profiling technique involving 25 initiated panellists. The samples consisted of wagyu beef, control beef meat, meltique beef injected with canola oil emulsion with formulas X1 and X2, and meltique beef injected with VCO emulsion with formulas X1 and X2. The panellists completed the questionnaire after they tried each sample. Water and sugar free coffee were served to neutralize the taste and aroma. The analyzed sensory parameters and preference levels are shown in Table 1.

**Table 1.** Sensory test parameter of meltique beef and wagyu beef

| Parameter | Hedonic quality test scale | Hedonic test scale | Value |
|---|---|---|---|
| Beef colour | Pink | Very dislike | 1 |
| | Red | Dislike | 2 |
| | Brownish-red | Somewhat like | 3 |
| | Brown | Like | 4 |
| | Dark brown | Really like | 5 |
| Beef aroma | Very little beef aroma | Very dislike | 1 |
| | Berely any beef aroma | Dislike | 2 |
| | Slight beef aroma | Somewhat like | 3 |
| | Beef aroma | Like | 4 |
| | Very strong beef aroma | Really like | 5 |
| Beef texture | Very coarse | Very dislike | 1 |
| | Coarse | Dislike | 2 |
| | Slightly soft | Somewhat like | 3 |
| | Soft | Like | 4 |
| | Very soft | Really like | 5 |
| Beef tenderness | Very tough | Very dislike | 1 |
| | Tough | Dislike | 2 |
| | Slightly tender | Somewhat like | 3 |
| | Tender | Like | 4 |
| | Very tender | Really like | 5 |
| Beef flavour | Very little beef flavour | Very dislike | 1 |
| | Barely any meat flavour | Dislike | 2 |
| | Slight beef flavour | Somewhat like | 3 |
| | Beef flavour | Like | 4 |

| Parameter | Hedonic quality test scale | Hedonic test scale | Value |
|---|---|---|---|
| | Very strong beef flavour | Really like | 5 |
| Beef elasticity | Very stiff | Very dislike | 1 |
| | Stiff | Dislike | 2 |
| | Somewhat ruberry | Somewhat like | 3 |
| | Chewy | Like | 4 |
| | Very chewy | Really like | 5 |
| Beef oil content | Very non-oily | Very dislike | 1 |
| | Not greasy | Dislike | 2 |
| | Slightly oily | Somewhat like | 3 |
| | Oily | Like | 4 |
| | Very oily | Really like | 5 |
| Beef juiciness | Very no juiciness (very dry) | Very dislike | 1 |
| | No juiciness (dry) | Dislike | 2 |
| | Somewhat juicy | Somewhat like | 3 |
| | Juicy | Like | 4 |
| | Very juicy | Really like | 5 |

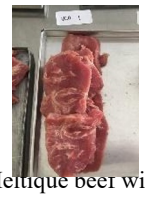
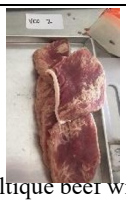
### 2.4 Statistical analysis

This study employed an experimental design with a Complete Random Design, consisting of four controls (wagyu beef, control beef, canola meltique beef formula 1, and canola meltique beef formula 2) with one treatment (one formula) applied at two doses, X1 and X2 of the addition of vegetable oil emulsion (VCO). The treatments were as follows: D0 (positive control, wagyu beef), D1 (negative control, BX beef), D2 (meltique beef with X1 canola oil), D3 (meltique beef with X2 canola oil), D4 (meltique beef with X1 VCO), and D5 (meltique beef with X2 VCO). Data from the physical characteristics test, including pH and cooking loss, were processed using the Statistical Program for Social Science (SPSS) with Anova and Duncan tests. Sensory evaluation was performed using SPSS using the Kruskal Wallis and Mann Whitney tests.

## 3 Results and discussion

### 3.1 Physical characteristics

The comparison of the appearance between Wagyu and other types of beef, both before and after grilling are shown in Figure 1. The figure shows the different marbling of each type of beef.

| Before grilling | | After grilling | |
|---|---|---|---|
|  |  |   |   |
| Wagyu Beef | BX Beef | Wagyu Beef | BX Beef |
|   |   |   |   |
| Meltique beef with X1 Canola | Meltique beef with X2 Canola | Meltique beef with X1 Canola | Meltique beef with X2 Canola |
|  |  |   |   |
| Meltique beef with X1 VCO | Meltique beef with X2 VCO | Meltique beef with X1 VCO | Meltique beef with X2 VCO |

Note: BX = Brahman cross beef, X1 = Formulation one, X2 = Formulation two.

**Fig. 1**. The appearance of Wagyu and meltique beef

Based on Fig 1, before the grilling process, the difference between the marbling of wagyu beef and other types of beef can be observed. Wagyu had a high level of marbling which was evenly distributed in the meat fibers. When grilled, the Wagyu beef had a brown surface with a distinctive aroma from that of natural Wagyu fat. During grilling, the fat in Wagyu melts evenly, producing a soft, tender, and juicy meat surface. BX beef has less marbling compared to other meats. Roasting the BX beef results in a brown surface with a distinctive, though lighter roast beef aroma. However, the texture tends to be tougher compared to other meats. Meltique beef with X1 canola oil showed marbling scattered on its surface. After grilling, the beef had a brownish surface with a soft, tender, and chewy texture. Meltique beef with X2 canola oil had more marbling spread compared to meltique beef with X1 canola oil. Roasting treatment results in a brown surface, with a chewy, tender, and juicy texture. In meltique beef with X1 VCO, marbling was spread more evenly compared to meltique beef with canola oil. The beef had a brown colour with a soft, chewy, and juicy texture. Meltique beef with X2 VCO had more prominent marbling and more even fat distribution compared to meltique beef with X1 VCO. The meat was brown with a tender, soft, chewy, and juicy texture.

**Table 2**. Physical characteristics of treated beef steak

| Formula | pH | Cooking loss |
|---|---|---|
| D0 (Wagyu Beef) | $6.01\pm0.03^{a}$ | $10.6\pm4.99^{a}$ |
| D1 (BX Beef) | $6.39\pm0.10^{bcd}$ | $26.7\pm2.47^{b}$ |
| D2 (Meltique Beef with X1 Canola Oil) | $6.24\pm0.10^{abc}$ | $19.8\pm4.52^{b}$ |
| D3 (Meltique Beef with X2 Canola Oil) | $6.20\pm0.10^{ab}$ | $27.2\pm0.00^{b}$ |

| Formula | pH | Cooking loss |
|---|---|---|
| D4 (Meltique Beef with X1 VCO) | 6.61±0.12$^{d}$ | 22.5±3.53$^{b}$ |
| D5 (Meltique Beef with X2 VCO) | 6.50±0.14$^{cd}$ | 36.0±0.42$^{c}$ |

Note : BX = Brahman cross beef, X1 = Formulation one, X2 = Formulation two.
$^{a,b,c,d}$ Different superscripts in the same column indicate significant differences (P<0.05).

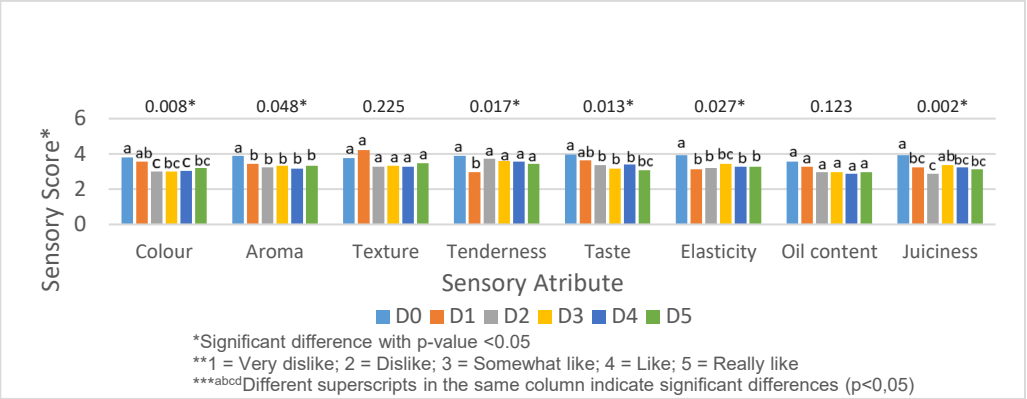
The physical characteristics shown in Table 2 indicate that the pH and cooking loss of meltique beef differ significantly from those of the Wagyu beef. Wagyu beef has a lower pH, owing to its high levels of evenly distributed natural intramuscular fat. Meanwhile, meltique beef processed with injected vegetable oils (VCO and Canola oil) results in changes in the distribution of water and protein in the meat, increasing the pH [13]. VCO contains saturated fatty acids, especially lauric acid, which is stable and not easily oxidized. These fatty acids interact with beef tissues and affect the balance within them. Such interaction can lead to an increase of pH in beef[14]. Meltique beef with VCO injection had a higher pH compared to Wagyu beef, which had natural marbling without additional injection.

Animal proteins generally have a lower pH than plant proteins. This can be caused by differences in the amino acid composition and molecular structure of the two types of protein. In wagyu meat, which is an animal protein source, the pH is lower compared to meltique meat that contains protein from vegetable sources or VCO emulsion. The lower pH in wagyu can be attributed to the saturated fatty acid content in the meat, which is more stable and lower in pH [15].

Meltique beef with canola emulsion has a lower pH value compared to the meltique beef with VCO emulsion. The decrease in pH of the canola meltique beef compared to the meltique beef using VCO could be due to the difference in the content of unsaturated fatty acids present in both. In the case of canola oil, the unsaturated fatty acids are prone to oxidation, which produces acidic compounds such as peroxides and aldehydes. This oxidation process increases the amount of acid present in the oil, which reduces the overall pH. In contrast, VCO has better oxidation stability due to its higher saturated fat content, which tends to be more stable and less prone to oxidation [16].

The cooking loss between Wagyu and the other meats was significantly different. Wagyu beef exhibited a lower cooking loss due to its high marbling, characterized by fine, evenly distributed intramuscular fat that locks in water and minimizes evaporation during roasting. In contrast, Meltique beef, produced through the injection of vegetable fat, showed higher cooking loss. The injected fat accelerates protein denaturation when heated, resulting in more water evaporation during the cooking process [17].

### 3.2 Sensory analysis




Note: D0 = Wagyu beef, D1 = BX beef, D2 = Meltique beef with X1 Canola Oil, D3 = Meltique beef with X2 Canola Oil, D4 = Meltique beef with X1 VCO, and D5 = Meltique beef with X2 VCO.

**Fig. 2**. Acceptability score from hedonic test result of treated meltique beef steak and wagyu

The hedonic test results in Figure 2 illustrate that panelists' acceptance for Meltique VCO and Wagyu in terms of texture, tenderness, and oil content are similar. However, panellists tend to favor bright meat colours. Therefore, wagyu meat which has a lighter flesh colour compared to other meats is more accepted. Heat treatments affected the acceptance of the meat colour parameters from panellists [18], and the addition of oil emulsion increased the intensity of meat colour. The injection of VCO emulsion into beef can increase the intramuscular fat content, resembling marbling Wagyu beef, which influences the texture and tenderness of the beef [19]. The stripe of fat exists within the beef, making it tender and moist, and also increases its flavour.

**Table. 2** Sensory attribute profiling results of treated meltique beef steak and wagyu

| Parameter | Mean ± Standard Deviation | | | | | |
|---|---|---|---|---|---|---|
| | D0 | D1 | D2 | D3 | D4 | D5 |
| Colour* | 3.56 ±1.12$^{a}$ | 2.60 ±1.08$^{b}$ | 3.84±0.37$^{a}$ | 3.52±0.91$^{a}$ | 3.36±1.15$^{a}$ | 3.20±1.22$^{a}$ |
| Beef Aroma | 3.72±0.54$^{a}$ | 3.48±0.87$^{a}$ | 3.32 ±0.94$^{a}$ | 3.48±0.77$^{a}$ | 3.12±0.78$^{a}$ | 3.16±0.98$^{a}$ |
| Beef Texture* | 3.80±0.86$^{ab}$ | 3.00±0.91$^{c}$ | 3.32±1.06$^{ac}$ | 3.96±0.84$^{b}$ | 3.36±0.81$^{ac}$ | 3.24±0.77$^{c}$ |
| Tenderness* | 3.79±1.10$^{ac}$ | 2.88±0.92$^{b}$ | 3.76±1.01$^{ac}$ | 4.24±1.01$^{a}$ | 3.48±0.65$^{c}$ | 3.56±0.87$^{c}$ |
| Beef Taste* | 4.12±0.60$^{a}$ | 3.76±0.77$^{ab}$ | 3.32±0.90$^{c}$ | 3.48±1.00$^{bc}$ | 3.60±0.91$^{bc}$ | 3.32±1.03$^{bc}$ |
| Elasticity* | 4.00±0.86$^{a}$ | 2.96±0.84$^{b}$ | 3.16±0.89$^{bc}$ | 3.60±0.91$^{ac}$ | 3.16±0.74$^{bc}$ | 3.16±0.80$^{bc}$ |
| Oil Content* | 3.84±0.74$^{a}$ | 3.32±0.62$^{b}$ | 2.84±0.89$^{c}$ | 3.64±1.11$^{ab}$ | 3.28±0.93$^{bc}$ | 3.56±0.76$^{b}$ |
| Juiciness* | 4.00±0.76$^{a}$ | 3.16±0.80$^{bd}$ | 2.76±0.92$^{bc}$ | 3.48±1.00$^{ad}$ | 3.24±0.97$^{cd}$ | 3.32±0.85$^{d}$ |

Note : D0 = Wagyu beef, D1 = BX beef, D2 = Meltique beef with X1 Canola Oil, D3 = Meltique beef with X2 Canola Oil, D4 = Meltique beef with X1 VCO, and D5 = Meltique beef with X2 VCO.
$^{a,b,c,d}$ Different superscripts in the same column indicate significant differences (P<0.05).

The hedonic quality test results reveals that VCO meltique beef has the same quality as wagyu beef in terms of colour, aroma, and tenderness. The colour of VCO meltique beef was similar to wagyu and canola meltique beef, which was brownish-red. This occurred because both types of beef had good fat distribution, meltique beef was processed through fat injection, and wagyu had natural marbling. When grilled, the fats in both types of meat melt and turn the surface colour to a distinctive golden brown. In addition, browning on the surface due to the caramelization process causes the outside of the meat to melt [20].

VCO meltique beef had a similar aroma with wagyu beef. The similarity in aroma is due to several chemical factors occurring through the cooking process. When beef is heated, both undergo the Maillard reaction, which is a reaction between amino acids and sugars that produces the typical savoury aroma and complex taste of meat. This reaction occurs with similar intensity as both types of meat contain a large amount of fat, although the origin of the fat is different. In wagyu meat, natural fat (marbling) is incorporated into the meat fibers and melts when heated, creating a distinctive aroma of premium meat. Meanwhile, in meltique meat, fat is injected in the form of virgin coconut oil, which is also infused and spreads into the meat fibers and melts similarly during the cooking process. As a result, the aroma produced by both types of meat is similar due to their similarities in fat absorption and dispersal. Despite the different fat sources, the chemical composition of VCO fat, which is rich in fatty acids, resembles the characteristic aroma of natural Wagyu fat [21].

VCO meltique meat had the similar tenderness as wagyu beef. Beef with added oil tends to have a softer texture compared to meat products without added oil [22]. Oil added to meat in the form of emulsion or injection can reduce the toughness or tension of meat and increase the tenderness and juiciness of meat. The oil used in the injection affected the tenderness level. The use of vegetable oils enhances meat tenderness by retaining moisture and reducing tissue hardness. In this study, it was also known that the tenderness of steak beef was influenced by the injection of VCO, which makes the beef more tender and the texture resembles that of wagyu beef [23]. These results showed that the injection of oil emulsion improved the quality of beef, that it is similar to wagyu beef.

There were also significant differences between VCO meltique beef and wagyu beef in terms of texture, flavor, elasticity, and oil content. In terms of texture, wagyu beef has a soft texture with a distinctive natural marbling pattern, giving it a softer sensation in the mouth. On the other hand, VCO meltique meat has a texture influenced by the vegetable fat injection process, making it less natural than wagyu. In terms of flavor, Wagyu offers a rich and umami taste, due to the intramuscular fat content of the animal. Meanwhile the VCO emulsified meltique meat has a milder flavor that is slightly influenced by the characteristics of VCO. For elasticity, Wagyu has a natural softness with tender flexibility. At the same time, meltique with VCO emulsion tends to have lower elasticity as the injection process affects the tissue structure of the beef. In terms of oil content, Wagyu fat comes from the natural fat of the beef, which is rich in animal fat, while meltique beef with VCO emulsion has vegetable fat content from VCO which differs in chemical composition and nutritional profile [24].

This study has several limitations that need to be considered. First, this study involved organoleptic testing, thus the results could be influenced by the subjectivity of the panellists. Second, the cooking or processing methods used in the study may affect the results. Further research with a wider scope and more in-depth approach is needed to overcome these limitations.

## 4 Conclusion

The VCO-injected meltique beef achieved the same preference level and quality as canola oil meltique beef in all sensory attributes and physical characteristics. In addition, VCO-injected meltique beef also achieved the same level of preference as wagyu beef in terms of texture, tenderness, and oil content, as well as similar quality in terms of colour, aroma, and tenderness. However, it differed from Wagyu beef in pH and cooking loss but similar in texture, tenderness, and oil content. Thus, this study showed that injection of VCO emulsion can help improve the quality of beef, making it similar to meltique canola and wagyu beef.

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