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Physical Characteristics of Three Types of Muscles with Different Aging Times

Karakteristik Fisik Tiga Jenis Otot dengan Lama Pelayuan yang Berbeda

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ABSTRACT

The demand for premium beef continues to increase along with changes in the lifestyle of upper middle class, increasing tourists and expatriates from abroad. Local cattle usually cannot produce premium beef, but aging can improve the quality of meat. This study aimed to characterize the physical quality (pH, cooking loss, water holding capacity, and tenderness) of bali beef with different aging times. This study used three types of muscles, which is *Longissimus dorsi, Gluteus medius*, and *Semitendinosus* from bali beef aged ± 3 years and body weight of ± 350 kg. Samples were aged at cold temperatures for 1, 21, and 42 days. A completely randomized design with a 3x3x4 factorial was used in this study. Least Square Means test was applied if the data obtained is significantly different. The results showed that the three types of muscle produced relatively the same physical properties, except for cooking loss. The *Longissimus dorsi* and *Semitendinosus* muscles were aged for 21 days to show the best results of meat tenderness.

Keywords: aging, bali cattle, physical qualities

ABSTRAK

Permintaan daging sapi premium terus meningkat seiring dengan terjadinya perubahan gaya hidup masyarakat menengah ke atas, meningkatnya wisatawan dan ekspatriat dari mancanegara. Sapi lokal biasanya tidak bisa menghasilkan daging premium, tetapi hal ini dapat diatasi dengan cara pelayuan. Tujuan dari penelitian ini adalah mengetahui kualitas fisik (pH, susut masak, daya mengikat air, dan keempukan) daging sapi bali dengan lama pelayuan yang berbeda. Penelitian ini menggunakan tiga jenis otot yang berbeda yaitu *Longissimus dorsi*, *Gluteus medius* dan *Semitendinosus* dari daging sapi bali yang berumur ±3 tahun dan bobot badan ±350 kg. Sampel dilayukan pada suhu dingin selama 1, 21 dan 42 hari. Penelitian ini menggunakan rancangan acak lengkap pola faktorial 3x3x4. Apabila data yang diperoleh berbeda nyata, maka akan dilanjutkan dengan uji *least square means*. Hasil penelitian menunjukkan bahwa ketiga jenis otot menghasilkan sifat fisik yang relatif sama, kecuali susut masak. Otot *Longissimus dorsi* dan *Semitendinosus* yang dilayukan selama 21 hari memperlihatkan hasil keempukan daging yang terbaik.

Kata kunci: kualitas fisik, pelayuan, sapi bali

INTRODUCTION

The demand for premium quality meat continues to grow along with changes in the lifestyle of the middle and upper-class society, increasing tourists and expatriates from abroad. A person's lifestyle can be shown by his consumption pattern of premium food products (Oktafikasari and Mahmud 2018). Consumers who have a high lifestyle will be willing to buy premium products (Dewi and Gosal 2020). The premium meat must be imported from abroad to meet the needs of special markets such as hotels, restaurants and supermarkets. Indonesian beef does not meet the premium quality criteria, especially from the aspect of meat tenderness, because some Indonesian cattle contain *Bos* *javanicus* blood or are slaughtered at an old age. Priyanto *et al.* (2015) stated that imports of beef to meet market needs are still ongoing because Indonesian cattle are still unable to produce premium quality meat. Imported meat has several advantages, namely it is more tender and has a high degree of marbling, so it is highly favored by consumers.

Native Indonesian cattle, namely bali cattle, are still a mainstay for meeting domestic meat needs, even though the productivity and quality of meat are still low (Priyanto *et al.* 2015). Bali cattle are superior cattle because they have high reproductive power, heavy carcass weight and low-fat percentage, are easy to develop, and adapt quickly to new environments (Batan *et al.* 2018). According to Zulkharnaim *et al.* (2010), bali cattle are germplasm-producing quality cattle that need to be maintained because of their superiority, which is not shared by other cattle breeds. The carcasses produced by slaughtering bali cattle are quite high, 53-56% of their body weight. Previous studies have shown that *Bos Taurus* have a more tender level of meat tenderness, which is 2.2 kg/cm² compared to *Bos javanicus*, which is 4.3 kg/cm² (Safitri 2018). The toughness of the meat can be overcome by storing it at a particular time and temperature, or it is called aging.

Aging is handling fresh meat after slaughter by hanging or storing the meat for a particular time under controlled environmental conditions in a cold room with a temperature of 0-4 °C and a relative humidity of 75-80%. There are various opinions regarding the aging time, the most common range is 14-40 days. Such aging produces the desired results (Dashdorj *et al.* 2016). Aging usually takes 21 days. During the aging process, the calpain enzymes in the meat work to produce more tender meat. Aging of the *Longissimus dorsi* muscle for 14, 21, 28 and 42 days increased the tenderness of the beef by 2.80 kg/cm², 2.58 kg/cm², 2.58 kg/cm² and 2.20 kg/cm² (Lepper-Blilie *et al.* 2016). The longer the aging of the meat, the increased tenderness. Aging of meat has been known to improve the quality of beef and buffalo, but aging of native Indonesian beef is still rarely done. Based on these problems, a study aimed to characterize the physical quality of bali beef with different muscle types and aging time.

MATERIAL AND METHODS

Tools and Materials

The tools used were showcase, knife, thermometer, 35 kg ballast, pH meter HANNA HI 99163, digital scales SF 400, a warner-bratzler (WB) Chatillon capacity 50 kg x 100 GMS and a cooling room. The material used is ±3 years old bull bali beef which has body weight of ±350 kg. Samples were cut with a weight of 250 g, as many as 36 samples. Four replicates were used in this study. Sampling was carried out on three types of muscles, namely the *Longissimus dorsi*, *Gluteus medius* and *Semitendinosus*. Other materials were distilled water, vacuum plastic, buffer solution, filter paper and tissue.

Procedure

The procedure for handling cattle before slaughter follows the handling of cattle in slaughterhouses. Cattle are given a rest period of 3 days before being slaughtered. Before cattle were slaughtered, an antemortem inspection was carried out to ensure the cows are healthy and to avoid spreading infectious diseases (zoonoses). Cattle were slaughtered with the help of restraining boxes at 10.00 pm and then skinned, removed viscera, postmortem inspection, carcass splitting and sample cutting. The parts were taken as samples were the *Longissimus dorsi, Gluteus medius and Semitendinosus* muscles. Samples were weighed at 250 g for each observation. Each treatment used four replicates. The sample was then inserted and hung in a show case with a temperature of 16-20 °C for ± 24 hours to pass through the rigor mortis phase. Rigor Mortis is the phase that occurs after the animal is slaughtered, and the muscles are still contracting, resulting in muscle stiffness.

The samples were then brought to the slaughterhouses for aging 1, 21 and 42 days under controlled environmental conditions in a cold room with a temperature of 0 °C and a relative humidity of 75-80%. The process of aging meat in this study is by wet-aging. The meat is cut, then put into a plastic bag and vacuumed to remove air. Vacuum packaging can protect the meat from microbes and air exchange from outside to maintain meat quality. The storage process with a constant temperature is carried out in order to keep the meat moist and not dry. With this, the meat's texture will be softer, also called tender. The next stage after the meat's aging is measuring the sample according to the observed variables. The variables observed in this study were tenderness, pH, water holding capacity and cooking loss.

The pH value. The AOAC method (2005) was used to measure meat's pH value. The pH value was measured using a pH meter HANNA HI 99163. The pH meter electrode was placed into the first calibration buffer. The pH 7 buffer was used first. The screen waited until it displayed pH 7, then the calibration was continued using pH 4, and the screen waited until it displayed pH 4. The electrode is inserted into the sample of the meat being tested. Wait for the stability indicator on the LCD until it disappears, and the LCD displays the pH value. Then, the electrode tip was rinsed thoroughly using distilled water after use to remove cross-contamination.

Water holding capacity. Measurement of water holding capacity was carried out by the compressive method according to Hamm (1972). As much as 0.3 g of meat was placed between two Whatman-41 filter paper and clamped with a pressure gauge of the Chattlon brand with a pressure of 35 kg for 5 minutes. The wetted area is obtained from the difference between the filter paper's outer and inner circle areas. The measurement of the circle was carried out using a Hruden brand planimeter. The weight of water released during pressing can be calculated using the formula:

$$\text{mg water} = \frac{\text{wet area (cm}^2\text{)}}{0{,}0948} - 8{,}0$$

$$\text{\% Free water} = \frac{\text{mg water}}{\text{sample weight}} \times 100\%$$

$$\text{Water holding capacity} = \text{\% water content} - \text{\% free water}$$

Cooking loss. The method (Soeparno 2005) is used in measuring cooking losses. Meat is cut into samples weighing ± 100 grams. The samples used were first weighed before boiling, and a bimetal thermometer was inserted into the meat. The sample is then boiled until the internal temperature of the meat is 81 °C. The meat is removed and left to stand at room temperature until the weight is constant. Samples were re-weighed until constant to get the weight of the meat after it was cooked. The calculation of the weight lost during cooking is as follows:

$$\text{\% Cooking loss} = \frac{\text{weight before cooking} - \text{weight after cooking}}{\text{weight before cooking}} \times 100\%$$

Tenderness. Beef tenderness was measured using a warner-bratzler (WB) breaker with units of kg cm^{-2}. A 200 g sample of meat was pierced with a bimetallic thermometer and boiled in boiling water until the internal temperature was 81 °C. The meat samples were then cooled for 60 minutes. The meat is streaked in the direction of the meat fiber, then the breaking strength is measured with a Warner Bratzler shear force (WBSF) tool, and the tenderness of the meat is read on the scale of the tool (Hopkins 2011).

Data Analysis

The results of this study used a completely randomized design with a 3x3x4 factorial pattern, with the first factor being the aging time (1, 21, 42 days) and the second factor being the type of muscle (*Longissimus dorsi, Gluteus medius* and *Semitendinosus*) with four replications. The mathematical model of this research is:

$$Yijk = \mu + \alpha i + \beta j + (\alpha\beta)ij + \varepsilon ijk$$

Information:
Yijk : observation on the i-level muscle type factor, the j-level aging factor, and the k-repetition
μ : general mean
αi : the effect of the factor of the type of muscle on the i level
βj : the influence of the old factor of aging at the j th level
(αβ)ij : effect of interaction between muscle type and aging time
εijk : effect of trial error

RESULTS AND DISCUSSION

Aging is the most common method used to improve the quality of meat. Aging at abattoirs is generally carried out at room temperature, while at abattoirs with more complete facilities, the aging is carried out by storing the meat in a closed room at 0-4 °C for 48 hours. Aging in a closed room is done after the meat has passed the rigor mortis phase. Meat after going through the rigor period will be tender, but before going through the rigor period, there will be a decrease in the tenderness of the meat (Zahro *et al.* 2021). Wet-aging is aging using vacuum packaging on meat that can produce stable and maximally by maintaining the hygienic value of the meat. The wet-aging biochemical process in beef has much influence on changes in the level of physical quality of the meat. Testing the physical quality of the meat includes pH, cooking loss, water holding capacity and tenderness.

Tenderness

Meat tenderness is the most important determinant of meat quality (Lapase *et al*. 2016). Tenderness can be measured by the breaking power value of the warner-bratzler (WB). The longer the aging of the meat, the increased tenderness. Data regarding the average warner-bratzler value of bali beef are presented in Table 1.

The results showed that the meat treated with different aging *had a* significant effect ($P<0.05$) on the tenderness of the meat, while the type of muscle treatment not significant ($P>0.05$) on the tenderness of the bali beef. The warner-bratzler value of wet-aged meat for 1, 21 and 42 days decreased respectively from 6.98 kg/cm², 3.40 kg/cm² and 3.13 kg/cm². This increase in tenderness is probably due to the proteolysis process caused by the proteolytic enzyme in the form of the calpain enzyme. These enzymes can lyse meat tissue, so meat experiences a reduction in breaking power value and causes improvement in tenderness. Kiran *et al.* (2015) also stated that the factors that affect the tenderness of meat are genetic factors, species and breed of cattle, age, management, sex, stress, aging and additives.

Wet-aging has advantages over other aging methods. Economically (reducing meat weight and lower trimming), production (fewer space requirements, more efficient production process) and microbial (longer shelf life without damaging palatability). The wet-aging process can also increase the tenderness of the meat with the help of calpain enzymes. Factors that affect aging include species, breed of cattle, age, sex, genetic selection, post-slaughter handling and aging conditions (Kim *et al.* 2018). Wet-aging time is one of the variables that influence the success of wet-aging. Wet-aging done at the right time will produce meat with optimal quality. Warner and Ha (2017) also stated that the aging time between 7, 21 and 35 days for striploin and ribs in Australian beef could increase the tenderness score of 67.38, 69.49 and 69.80, respectively. This statement indicates that the longer the aging process will increase the tenderness along with the aging time. Shi *et al.* (2020) stated that aging causes a decrease in the cohesiveness of the meat caused by damage to the internal myofibrillar structure, which causes a decrease in the binding strength between the internal molecules in the meat.

Treatment duration appropriate wet-aging can optimize the calpain enzyme in forming the final result of tender meat. The activation of the μ-calpain enzyme in meat occurs 3 days after slaughter causing proteolysis of the myofibril protein. Then 7 days after cutting both calpain enzymes (μ-calpain and m-calpain) started to lyse myofibril proteins. Myofibrils in muscles that undergo

Table 1. Average tenderness of meat with different aging times (kg/cm²)

Aging Time (Days)	Muscle Type			Average
	Longissimus dorsi	*Gluteus medius*	*Semitendinosus*	
1	7.18 ± 0.43	6.95 ± 1.07	6.83 ± 0.86	6.98 ± 0.77a
21	3.30 ± 0.55	3.60 ± 0.53	3.30 ± 0.22	3.40 ± 0.44b
42	2.98 ± 0.17	3.23 ± 0.05	3.18 ± 0.64	3.13 ± 0.36b
Average	4.48 ± 2.03	4.58 ± 1.86	4.44 ± 1.86	

Different superscript letters in the same column indicate a significant difference (P<0.05)

structural changes during the wet-aging treatment will cause changes in the physical quality of the meat. Physical quality in the form of breaking power value of aging-treated meat will decrease due to proteolysis (Bhat *et al.* 2018). Based on Suryati *et al.* (2008) stated that very tender meat had a warner-blatzer shear force (<3.30 kg/cm²), tender (3.30-5.00 kg/cm²) slightly soft (5.00-6.71 kg/cm²), rather tough (6.71- 8.42 kg/cm²), tough (8.42-10.12 kg/cm²) and very tough (> 10.12 kg/cm²). Based on these categories, Bali beef treated with wet-aging treatment for one day was classified as rather tough, wet-aging treatment for twenty one days was classified as tender, and the wet-aging treatment for forty two days was classified as very tender. Kiran *et al.* (2015) stated that the factors affecting meat tenderness were different aging times.

The pH Value

The principle of measuring pH is knowing acid and base conditions. The pH value of meat is an indicator of the physical properties, which is used as a reference in assessing meat quality. Data regarding the average pH of bali beef with 1, 21 and 42 days of aging are presented in Table 2.

The results showed that the different aging times not significant (P>0.05) on the pH of the meat. It is because the pH value of the meat at aging 1, 21 and 42 days were already at the ultimate pH so that during the aging period, the pH does not decrease. Usually, the ultimate pH is obtained when glycogen is no longer found in meat. The ultimate pH was reached after muscle glycogen was depleted, after the glycolytic enzymes become inactive at low pH or after glycogen is no longer sensitive to glycolytic enzyme attacks (Rusdimansyah and Khasrad 2012). Gramatina *et al.* (2019) stated that the pH value of meat depends on the glycogen content present. More glycogen will result in the decomposition of lactic acid in the meat, which results in a decrease in the pH value.

The results showed that the average pH of bali beef was in the range of 5.64-5.74. It proves that the pH value of the meat is still in the normal pH range. The pH value of the meat, indicating the rigor mortis process has been completed at the isoelectric point range of 5.4-5.8 (Kurniawan *et al.* 2014). Purwasih and Azzahra (2018) also stated that the pH value is closely related to the characteristics of meat in processing, tenderness and meat storage. The average normal pH value for beef steak is approximately 5.75. The results showed that different muscle types not significant (P>0.05) on the pH of the meat. It is presumably because different types of muscle were stored at low temperatures so that they can inhibit the decrease in pH. Rahim (2009) states that different types of muscle in beef that have been aged do not affect the pH of the meat.

Water Holding Capacity

Water holding capacity is an indicator to measure the ability of meat to bind water. Water holding capacity can be interpreted as the ability of meat to retain its water content while subjected to external treatment such as cutting, cooking, grinding and processing (Mendrofa *et al.* 2016). Data on the average water holding capacity of bali beef with 1.21 and 42 days of aging are presented in Table 3.

The study results show that different muscle types not significant (P > 0.05) the water holding capacity of bali beef. It is because the three types of muscles experience almost the same damage to the internal myofibrillar structure, so they have the same level of tenderness, and the ability of the muscles to bind water is not significantly different. Merthayasa *et al.* (2015) stated that the factors affecting meat water's holding capacity include pH, cattle breed, temperature and humidity, aging, age and intramuscular fat. The average water holding capacity in this study was in the range of 28.6-34.70%. Based on the research results, meat's average water holding capacity is still in the range of normal water holding capacity. Naveena *et al.* (2011) also stated that beef water's holding capacity was 22.00-37.00%. Meat that has good protein integrity will have a strong water holding capacity. The higher the amount of water that comes out, the lower the water holding capacity (Merthayasa *et al.* 2015).

The results showed that the meat was treated with different aging significant effects (P<0.05) on the water holding capacity of bali beef. The average value of

Table 2. Average pH of meat with different aging times

Aging Time (Days)	Muscle Type			Average
	Longissimus dorsi	*Gluteus medius*	*Semitendinosus*	
1	5.66 ± 0.14	5.69 ± 0.04	5.74 ± 0.05	5.69 ± 0.09
21	5.62 ± 0.09	5.70 ± 0.05	5.71 ± 0.03	5.67 ± 0.07
42	5.65 ± 0.13	5.79 ± 0.27	5.78 ± 0.11	5.74 ± 0.18
Average	5.64 ± 0.11	5.73 ± 0.15	5.74 ± 0.07	

Table 3. Average water holding capacity of meat with different aging times (%)

Aging Time (Days)	Muscle Type			Average
	Longissimus dorsi	*Gluteus medius*	*Semitendinosus*	
1	28.57 ± 1.29	27.72 ± 1.07	29.60 ± 2.80	28.63 ± 1.88b
21	30.73 ± 1.73	31.52 ± 1.30	30.33 ± 1.06	30.86 ± 1.36b
42	34.20 ± 8.87	34.00 ± 2.63	35.70 ± 2.96	34.70 ± 5.13a
Average	31.18 ± 5.35	31.09 ± 3.16	31.88 ± 3.60	

Different superscript letters in the same column indicate a significant difference (P<0.05)

Table 4. Average cooking loss for meat with different aging times (%)

Aging Time (Days)	Muscle Type			Average
	Longissimus dorsi	*Gluteus medius*	*Semitendinosus*	
1	56.30 ± 13.66	53.10 ± 4.55	46.40 ± 4.75	51.90 ± 9.01
21	53.75 ± 14.93	54.91 ± 14.91	51.34 ± 8.16	53.33 ± 11.92
42	62.28 ± 4.82	50.00 ± 0.00	43.05 ± 6.99	51.78 ± 9.41
Average	57.40 ± 11.49a	52.70 ± 8.41ab	46.90 ± 7.09b	

Different superscript letters in the same column indicate a significant difference (P<0.05)

water holding capacity during aging on days 1, 21 and 42 experienced a successive increase of 28.63%, 30.86% and 34.70%. The increase in water holding capacity after 24 hours of aging is thought to be due to changes in the ions bound by meat protein during aging. The redistribution of ions that occurs causes the replacement of divalent ions in the protein chain with monovalent ions so that a reactive group in the protein is released to bind water resulting in an increase in water holding power (Dewi 1998). Sunarlim and Setiyanto (2001) stated that in aging meat, the holding capacity of water increases because the decrease in pH after the rigor mortis process causes the breakdown of ATP and myosin actin protein bonds so that bivalent ions such as and can be replaced by valence ions. As a result, there is a void, and it is filled again by water so that the holding power of water increases.

Cooking Loss

Cooking loss is the percentage of meat weight lost due to cooking which also functions as a determinant of cooking time and temperature. Water and fat will melt out when heated so that the weight of the meat decreases (Mendrofa *et al.* 2016). Data on the average cooking loss of bali beef with 1.21 and 42 days of wilting are presented in Table 4.

The results showed that different types of muscle had a significant effect (P<0.05) on meat cooking loss. It is because each part of the meat has a different length of muscle fiber sarcomeres. Shorter muscle fibers can increase cooking loss. Kiran *et al.* (2015) stated that the average cooking loss value of meat could be influenced by the length of the muscle fiber sarcomeres, the length of the muscle fiber pieces, the status of myofibril contraction, the size and weight of the meat sample, and the cross-section of the meat. The results showed that different aging times not significant (P>0.05) on the cooking loss of meat. The increase in the average value of cooking losses occurred on the 21st day from 51.90% to 53.33%. Wyrwisz *et al.* (2016) stated that the increase in the cooking loss was due to proteolytic enzymes, which would damage the protein structure in the meat, reduce the value of tenderness, and cause an increase in the value of cooking loss. Rackova and Csekes (2020) stated that the higher the proteolysis that occurs in meat, the higher the cooking losses will be. Damage to the myofibril structure of the meat protein when it is aged can cause a lot of water or liquid in the meat to come out during the cooking process. The average cooking losses in this study were in the range of 46.90-57.40%. The results showed that the average cooking loss for meat was slightly higher than the normal range for cooking loss for meat. Rahim (2009) states that the value of cooking losses for meat varies between 15-54%. This situation is related to the low average value of water holding capacity, so the cooking losses are high. Obuz *et al.* (2014) stated that the value of cooking losses in wet aging would be higher than dry aging because dry aging has many water shortages during the aging process.

CONCLUSION

The three types of muscle produced relatively the same physical properties, except for cooking loss. A combination of 21 days of aging treatment and muscle type (*Longissimus dorsi, Semitendinosus*) showed the best tenderness of the beef and efficient aging time.

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