Effect of Electrical Stimulation on Physical and Organoleptic Properties of Muscovy Duck Meat

Hafid H[1], Napirah A[1], Sarifu SM[1], Rahman[1], Inderawati[1], Nuraini[1], Hasnudi[2]

[1]Department of Animal Science, Universitas Halu Oleo
Jl. HEA. Mokodompit Kampus Anduonohu 93232 Kendari
[2]Departement of Animal Husbandry, Faculty of Animal Husbandry,
Universitas Sumatera Utara, Kampus Padang Bulan 20155 Medan
harapinhafid14@gmail.com

(received 17-09-2018; revised 06-12-2018; accepted 12-12-2018)

ABSTRAK

Hafid H, Napirah A, Sarifu SM, Rahman, Inderawati, Nuraini, Hasnudi. 2018. Pengaruh stimulasi listrik pada sifat fisik dan organoleptik daging itik Muscovy. JITV 23(4): 202-209. DOI: http://dx.doi.org/10.14334/jitv.v23i4.1914

Penelitian ini bertujuan untuk mempelajari pengaruh lama stimulasi listrik terhadap sifat fisik dan organoleptik daging itik *Muscovy*. Penelitian ini menggunakan 20 ekor itik *Muscovy* betina, umur 1,5-2 tahun. Itik dibagi menjadi 5 kelompok perlakuan untuk 4 kali ulangan. Perlakuan adalah lama stimulasi listrik: 0, 5, 10, 15 dan 20 menit. Hasil penelitian menunjukkan bahwa lama stimulasi listrik tidak mempengaruhi (P>0,05) susut masak tetapi secara signifikan mempengaruhi (P<0,05) keempukan, warna, rasa, aroma, pH dan *juiciness* daging itik *Muscovy*. Perlakuan terbaik adalah lama stimulasi 20 menit.

Kata Kunci: Daging Itik *Muscovy*, Stimulasi Listrik, Sifat Fisik, Sifat Organoleptik

ABSTRACT

Hafid H, Napirah A, Sarifu SM, Rahman, Inderawati, Nuraini, Hasnudi. 2018. Effect of electrical stimulation on physical and organoleptic properties of Muscovy duck meat. JITV 23(4): 202-209. DOI: http://dx.doi.org/10.14334/jitv.v23i4.1914

This research was aimed to study the effect of electrical stimulation period on physical and organoleptic properties of Muscovy duck meat. This research used 20 female Muscovy ducks, 1.5-2 years of age. The ducks were divided into 5 groups treatments for 4 replications. The treatments were period of electrical stimulation: 0, 5, 10, 15, and 20 minutes. The result showed that period of electrical stimulation did not affect (P>0.05) cooking loss but significantly affected (P<0.05) the tenderness, color, flavour, aroma, pH, and juiciness of duck meat. The best treatment was 20 minutes stimulation.

Key Words: Muscovy Duck Meat, Electrical Stimulation, Physical Properties, Organoleptic Properties

INTRODUCTION

Muscovy duck is one of poultry family that has been developed for both meat and eggs producers. In term of human nutritional, the quality of Muscovy duck meat is almost similar to beef, chicken, sheep, and goats. Muscovy duck meat has a high nutritional value, cheaper price and lower fat. Even so, the duck meat is less attractive because of rough meat fiber (Randa et al. 2002; Hafid et al. 2015). Physical quality of muscovy duck was affected by ante mortem and post-mortem factors, such as species, sex, age, muscle location, preserving methods, period and temperature of storage, packaging, and others treatments (Soeparno 2009; Hafid 2011).

Tenderness is the most important palatability factor that affect consumer acceptance against poultry meat. The older the age, the lower the tenderness of meat. The tenderness process occurred during the change of meat's physical and chemical compound, such as rigormortis process which was related to muscle ATP content. The depletion of ATP will cause the overtopping between actin miofilamin and myosin miofilamen. Then, they will locked together to form a permanent bond, actomyosin, that cause muslces became rigid and cannot be moved. This is the cause of meat became hard (Hafid et al. 2017; Soeparno 2009).

Electrical stimulation is one of the ways to improve the meat tenderness. Electrical stimulation will accelerate the post-mortem glycolysis that occurs during conversion muscle into meat, so that speed up the decline in pH as well as speeding up the release of the protease enzyme (Hafid et al. 2014). Electrical stimulation can change the characteristics of the palatability of meat and has been proven to decrease the post-mortem pH, improve tenderness, increase the post-mortem glycolysis rate, and prevent muscle shortening due to cold temperatures (Aberle et al. 2001). Hafid et al. (2014) and Hafid & Syam (2012) reported that applying 20 volt electrical stimulation during 2 minutes could increase the tenderness, color, and texture of duck meat

Researches on electrical stimulation on animal meat had been done either on large animal or poultry, but not on Muscovy duck. Especially from traditional rearing patterns ranging in age from 1.5 to 2 years. The aim of this research was to study the effect of electrical stimulation on physical and organoleptic properties of Muscovy duck. The result of this research was expected to increase the palatability of Muscovy duck. In particular, in order to change people's perceptions of Muscovy ducks as inferior birds whose flesh smelled rancid and tough. Thus Muscovy duck farming will be developed more because it is an alternative raw material for the culinary industry in the future.

MATERIALS AND METHODS

Time and place

This research taken place in Animal Production Science and Technology Laboratory, Faculty of Animal Science, Universitas Halu Oleo, Kendari.

Material

The study used 20 female Muscovy ducks, 1.5-2 years of age. The muscovy ducks were obtained from breeder in Konda, South Konawe Sub District. Dual Tracking Supply electrical stimulator in the form of an adapter with electricity as energy source, knives, forks, plates, water bath, polyethylene plastic, pH meter, tissue, glass, bowl, and stationery were used.

Research procedure

This research was conducted with 2 phases such as material preparation, and samples preparation. Electrical stimulation was given by creating an electrical flow in certain voltage (20 volt) and certain period of stimulation. The positive pole of electric stimulator was set on Muscovy duck neck, and the negative pole was set on Muscovy duck shank.

The Muscovy ducks were slaughtered according to Islamic sharia, which is cut on the artery, jugular venous, and throat then separated between carcass and non-carcass parts. Immediately after the cuts without waiting for rigormortis process, the carcass samples were collected. The carcass samples were taken from breast meat, and then given electrical stimulation. Then, water and water bath were prepared for boiling process.

All treatments were applied systematically and repeated 4 times. Samples were placed in polyethylene plastic and labelled for organoleptic test. The given label was folded lengthwise. The plastic was folded to prevent direct contact with water during boiling process, according to the instructions of Soekarto & Hubeis (1992).

Samples were boiled in a water bath with a temperature of 80°C for 45 minutes. Water bath was used to get a stable heating temperature during boiling process. Then, the samples were taken and cooled at room temperature. If there was liquid on the meat surface, it can be dried using suction paper (Hafid et al. 2014). For organoleptic test, samples were cut to the size of 1x1 cm. Organoleptic test used 10-15 semi trained panelist according to instructions in Soekarto & Hubeis (1992). Organoleptic assessment used an assesment scale from 1 to 5 as described in Table 1

Experimental design

This research used a completely randomized design (Gasperz 2010) with 5 treatments and 4 replications. The treatments were 20 volt electrical stimulation in various period : 0 minutes (control), 5 minutes, 10 minutes, 15 minutes, and 20 minutes.

Table 1. Hedonically scale on organoleptic test

Variables	Hedonical Scale	Criteria
Tenderness	1	Very tender
	2	Tender
	3	Medium
	4	Hard
	5	Very hard
Color	1	White
	2	Pale white
	3	Pinkish
	4	Bright red
	5	Dark red
Texture	1	Highly preferred
	2	Preferred
	3	Enough preferred
	4	Not preferred
	5	Highly not preferred
Flavour	1	Highly preferred
	2	Preferred
	3	Enough preferred
	4	Not preferred
	5	Highly not preferred
Juiciness	1	Very Juicy
	2	Juicy
	3	Juicy enough
	4	Rather juicy
	5	Dry
Texture	1	Very smooth
	2	Smooth
	3	Medium
	4	Rough
	5	Very rough

(Hafid & Syam 2012); (Hafid et al. 2015)

P0 = Without electrical stimulation
P1 = 5 minutes electrical stimulation
P2 = 10 minutes electrical stimulation
P3 = 15 minutes electrical stimulation
P4 = 20 minutes electrical stimulation

The used formulation was described as follow:

$Y_{ijk} = \mu + A_i + \varepsilon_{ij}$

While : Y_{ijk} = Value of observed variable
μ = Mean
A_i = Effect of electrical stimulation
ε_{ij} = Error

Measured variables

The measured variables were:

1. Physical Properties, consisted of:
   a. Meat pH, was measured using a digital pH meter.
   Meat pH test was done using Bouton et al. (1971) methods as described by Soeparno (2009). Ten grams of meat samples were mashed and mixed with 10 ml of aquadest then stirred until homogenized. pH meter then cleaned using aquadest and put into a 7 pH of buffer for calibration. Each meat solution was measured its pH three times and the results were averaged.
   b. Cooking loss.
   The cooking loss measuring was done following Syam et al. (2013) methods. The meat was boiled in a temperature of 80°C during 45 minutes, cooled on room temperature, and then cooled on lower temperature ± 0°C. The samples then dried up using tissue paper. Samples then weighed to obtain its weight.
2. Organoleptic Properties
   a. The color of boiled meat was determined following instruction of Hafid et al. (2014) and Hafid & Syam (2012). The color was classified into 5 categories: white, pale white, pink, bright red and dark red.
   b. Meat tenderness was determined based on Hafid et al. (2014) instructions. The tenderness was classified into 5 categories: very tender, tender, medium, hard, and very hard.
   c. Flavour (level of deliciousness) was determined following Hafid et al. (2014) instructions which was classified from highly preferred to highly not preferred.
   d. Texture was determined following Hafid et al. (2014) instruction which was classified into 5 categories: very smooth, smooth, medium, rough, and very rough.
   e. Juiciness was determined following (Hafid et al. 2014) instruction which was classified into 5 categories: very juicy, juicy, juicy enough, dry, very dry.

Data analysis

The obtained data were analyzed using analysis of variance and continued using least significant different test based on Gasperz (2010).

RESULTS AND DISCUSSION

pH

The average of Muscovy duck meat pH were presented in Table 2.

Result of variance analysis showed that stimulation period did not affect (P>0.05) Muscovy duck meat pH. This result was similar with Lukman (2010) who explained that the pH value of meat will never reach under 5.3. This was caused by the enzymes involved in anaerobic glycolysis, which was not actively working. Likewise with Khasrad et al. (2018) who reported that the duration of electrical stimulation did not affect the pH of meat.

According to Buckle et al. (1987) and Garcia (2009), the reached final pH has a major influence on the meat quality. The higher pH caused meat to have a closed structure or solid with a dark purple color, less tasty, and more condition that allow the development of microorganisms.

The decline in the value of post-mortem muscle pH was also determined by the rate of post-mortem glycolysis and reserves of meat glycogen, normally was 5.4 up to 5.8 (Soeparno 2009). (Lee et al. 2000) explained that a stressed animal would have a lower glycogen reserves and ATP so that the animal energy would deplete shortly after died and the level of Ca^{2+} in the sarcoplasmic would quickly increase. High level of Ca^{2+} will trigger the overhaul of glycogen in a short time, so rigormortis will occur faster while pH remains high.

Cooking loss

Cooking loss is a heavy percentage of meat lost due to cooking and is a function of cooking time and temperature. Meat with a low cooking shrinkage has a relatively better quality than meat with a high percentage of cooking losses, this is because the loss of nutrients during the cooking process will be less (Komariah et al. 2009). Cooked meat is an indicator that shows the freshness of meat, where new meat is finished slaughtering will have a low cooking loos.The average of cooking loss of Muscovy duck meat stimulated with electricity, were presented in Table 3.

Result of the study showed that electrical stimulation period did not give a significant effect (P>0.05) on cooking loss of Muscovy duck meat. In this

Table 2. The average of pH of muscovy duck meat stimulated electrically with different period

Replication	Electrical stimulation period (minutes)				
	Control	5	10	15	20
I	5.75	5.53	5.39	5.66	5.59
II	5.75	5.51	5.61	5.91	5.61
III	5.83	5.77	5.95	6	6.62
IV	6.04	5.56	5.31	6.09	5.94
Average	5.84±0.14	5.59±0.12	5.57±0.29	5.92±0.19	5.94±0.48

Table 3. The average of cooking loss of muscovy duck meat stimulated electrically with different period

Replication	Electrical stimulation period (minutes)				
	Control	5	10	15	20
I	42.5%	28.98%	37.23%	25.75%	46.06%
II	39.56%	42.2%	47.87%	46.23%	43.67%
III	43.63%	40.95%	29.03%	41.09%	48.14%
IV	35.8%	50%	28.57%	45.71%	29.85%
Average	40.37±3.50%	40.53±8.68%	35.68±9.05%	39.70±9.58%	41.93±8.26%

Table 4. The average of meat tenderness of muscovy duck meat stimulated electrically with different period

Replication	Electrical Stimulation Period (Minutes)				
	Control	5	10	15	20
I	2.67	2.87	2.27	2.07	1.67
II	3.27	2.6	2.2	2.27	1.53
III	3.33	3.07	2.6	1.93	1.8
IV	2.8	2.8	2.6	1.93	1.73
Total	12.07	11.34	9.67	8.2	6.73
Average	3.02±0.33[c1)]	2.83±0.19[c]	2.42±0.21[b]	2.05±0.16[ab]	1.68±0.11[a]

[1)] Different superscript in the same row showed a significant difference (P<0.01)

study, the cooking loss of Muscovy duck meat ranged from 40.37 to 41.93%. (Aalhus et al. 1994), Agbeniga & Webb (2014) and Tkacz et al. (2018) which states that electrical stimulation has a negative effect on the loss of water content at the end of cooking and roasting meat products.

If compared with cooking loss of laying ducks stimulated with electricity, the cooking loss ranged from 6.99 to 21.78%. The cooking loss obtained in this study was in a normal level. This result was in accordance with Soeparno (2009) explanation that generally, the cooking loss of meat varied between 1.5 to 54.5% with a range of 15-40%.

The result showed that there were variations in the cooking loss value. Although there were variations, but these differences were not statistically significant or were considered the same. This variation could be due to the husbandry and feeding system of Muscovy duck. The ducks in this study were derived from traditional farm which their maintenance system was difficult to controlled (Hafid et al. 2015).

According to Soeparno (2009), the lower cooking loss would make the meat quality become well. This result was corroborated by Hafri et al. (2008), that meat which had lower cooking loss, under 35%, would have a good quality due to the possibility of nutrients discharge during cooking was also low.

In accordance with the statement, this research data showed that Muscovy duck meat quality was quite good if compared with laying duck meat, because the highest cooking loss in this research was 41.93%. These values belong to a good-quality level.

Tenderness

Tenderness and texture were the most important determining factor of meat quality. Consumers prefer meat that is tender because it's easier for processing and enhance the taste (Soeparno 2009). Meat tenderness is strongly influenced by the pattern of maintenance, where livestock that have physical activity such as being maintained freely without being tied up will have a larger size of muscle fibres with more and thicker connective tissue (Hafid 1998). The average of meat

Table 5. The average of muscovy duck meat's color stimulated electrically with different period

Replication	Electrical Stimulation Period (minutes)				
	Control	5	10	15	20
I	1.87	2	1.8	1.8	1.6
II	2	2	1.73	1.8	1.6
III	1.87	1.73	1.8	1.67	1.47
IV	2.2	1.87	2.4	1.4	1.47
Total	7.94	7.6	7.73	6.67	6.14
Average	1.99±0.16[b1)]	1.90±0.13[b]	1.93±0.31[b]	1.67±0.19[a]	1.54±0.08[a]

[1)] Different superscript on the same row showed a significant difference (P<0.01)

Table 6. The average score of muscovy duck meat's texture stimulated electrically with different period

Replication	Electrical Stimulation Period (minutes)				
	Control	5	10	15	20
I	3.53	2.73	2.47	1.53	1.53
II	3.6	3	2.67	1.87	1.67
III	3.6	2.93	2.2	1.8	1.47
IV	2.27	2.87	2.73	1.73	1.47
Total	13	11.53	10.07	6.93	6.14
Average	3.25±0.65[d1)]	2.88±0.11[c]	2.52±0.24[b]	1.73±0.15[a]	1.53±0.09[a]

[1)] Different superscript on the same row showed a significant difference (P<0.01)

tenderness of Muscovy duck meat stimulated with electricity were presented in Table 4.

The result of this study showed that period of electrical stimulation gave a significant effect (P<0.01) on Muscovy duck meat tenderness. Twenty minutes stimulation showed the best result on meat tenderness than 0, 5, and 10 minutes stimulation, but it was not different with 15 minutes stimulation. This result is in accordance with Davel et al. (2003) who get the influence of electrical stimulation, as well as (Yong et al. 2007) who get a shear force value of electrically stimulated meat that is lower than 10% than that which is not stimulated or 10% less. Likewise with this result was in accordance with the result that obtained (Hafid et al. 2014) who found a significant effect of 10 volt/2 minutes and 20 volt/2 minutes electrical stimulation on duck meat tenderness compared with its control.

According to Soeparno (2009), the longer the electrical stimulation also increased the value of meat tenderness. This was due to the longer the stimulation and the more glycolysis occur causing the more lactic acid formed. The formation of more lactic acid will cause a decrease in meat pH. This will cause protein denaturation and meat structure will become more tender.

Electrical stimulation can accelerate the rigormortis process through increasing glycolysis process. Glycolysis process will increase the amount of formed lactic acid. The more lactic acid, the pH of meat will decrease and cause denaturation of proteins. This will make the meat becomes more tender.

Color

Color is one factor that affect the consumer like or dislike against meat as well as the determinants of the meat quality. The meat color can be detected using sense of sight. Factors that determining meat color is concentration of meat myoglobin pigment. According to Abustam (2012) the color of meat is an important quality trait for the meat industry and household consumers. In the meat industry, the color of meat is assessed as the physical appearance of meat received by consumers and at the retail level the color of the meat causes a high level of acceptance. Consumers tend to associate color with the level of freshness of the meat. The average of Muscovy duck meat's color can be seen in Table 5.

The result showed that 15 and 20 minutes period of electrical stimulation gave a significant effect (P<0.01) on meat color. This was because of the electrical stimulation that could reduce the bonding formation of rough fibres on the muscle surface and caused the color become light. The result showed that stimulation period during 15 and 20 minutes give the best effect compared with 0, 5, and 10 minutes stimulation. Froning and Uijttenboogaart (1988) reported that the breast muscles of chicken carcasses which were electrically stimulated were significantly darker, with bright values if hot boning was done at 60 minutes or earlier.

Texture

Meat texture is a condition of meat that can be detected by mastication. The main textural characteristics of meat are firmness (toughness or

Table 7. The average score of Muscovy duck meat's flavor stimulated electrically with different period

Replication	Electrical Stimulation Period (minutes)				
	Control	5	10	15	20
I	2.93	2.53	2.4	2.2	1.67
II	2.87	2.73	2	1.93	1.8
III	2.67	2.2	2	2.13	1.67
IV	2.4	2.4	2	2.07	1.6
Total	10.87	9.86	8.4	8.33	6.74
Average	2.72±0.24 [c1)]	2.47±0.22[c]	2.10±0.20[b]	2.08±0.11[b]	1.69±0.08[a]

[1)] Different superscript on the same row showed a significant difference (P<0.01)

Table 8. The average of juiceness score of muscovy duck meat juiceness stimulated electrically with different period

Replication	Electrical stimulation period (minutes)				
	control	5	10	15	20
I	2.2	2.47	2.2	2.07	3.13
II	2.27	2.53	2	2.33	3
III	3	2.67	2.47	2.8	3.2
IV	1.73	2	1.93	3.27	3.53
Total	9.2	9.67	8.6	10.47	12.86
Average	2.30±0.52[a1)]	2.42±0.29[a]	2.15±0.24[a]	2.62±0.53[ab]	3.22±0.23[b]

[1)] Different superscript on the same row showed a significant difference (P<0.01)

degree of tenderness), cohesiveness and juiciness. The texture of meat is influenced by the cook time and temperature (Freeman & Freeman 2015; Hafid 2017). The average score of Muscovy duck meat's texture can be seen in Table 6.

The result showed that period of electrical stimulation affected significantly (P<0.01) on the texture of Muscovy ducks meat. Stimulation during 15 and 20 minutes gave the best texture if compared with 0, 5, and 10 minutes stimulation.

Muscovy duck meat that had been stimulated with electricity to different period of time had relatively different textures. In this case, panellist acceptance of Muscovy duck meat ranges from medium to very smooth textures. This is related to the level of texture roughness increased to age increasing. Muscle with small fibres does not show the texture roughness with age increasing. Muscular of male animal have a rougher textures than female animal. Types of animal also affect the muscular textures. Connective tissue of young animal contained the lower reticulin and cross-ties than the collagen of connective tissue of older animal (Soeparno 2009). Salm et al. (1981) reported that electrical stimulation significantly improved meat color, firmness and texture as well as lowering temperature in the muscles after 24 hours of postmortem.

Flavor

Flavor is one factor that determining the meat quality and can be detected by tongue. Meat flavor is a complex phenomenon related to the compounds that are soluble and volatile. Involves organ tasting and smell in its judgment. Flavors vary based on: meat cuts and the level of fat infiltration (marbling), the rate of change that occurs during maturation, some zootechnic characters and how to serve dishes (Abustam 2010; Hafid 2017). The average of flavor score of Muscovy duck meat stimulated with electricity can be seen in Table 7.

The result showed that electrical stimulation period gave a significant effect (P<0.05) on flavor of Muscovy duck meat. Twenty minutes stimulation showed the best flavor score of all treatments. This result was similar to the report of Syam et al. (2013). According to Syam et al. (2013), laying hen meat that had been stimulated using electricity with various voltage, has a relatively same flavor, so the consumer acceptance did not differ. In this case, consumer acceptance against laying hen meat ranged from rather like to like.

Prasetyo et al. (2013), Hafid et al. (2017) and Hafid (2017) explained that generally, meat flavor was affected by fat content. One of the parameters to assess the taste is to evaluate the fat content of the meat.

Juiciness

Juiciness is the ability of meat to release juices (liquid meat) during mastication. Juiciness is a factor that is considered in the assessment of meat quality, together with tenderness can explain up to more than 80% of consumers' choices in developed countries on meat quality. Soft meat in general at the first bite will produce juice that is quite significant. There is a good correlation between the releases of meat juice with tenderness. Wetness varies based on pH, maturation and stress factors (Abustam 2010; Hafid 2017). The average of juiciness score of Muscovy duck meat juiciness are presented in Table 8.

The result showed that electrical stimulation had a significant effect (P<0.05) on Muscovy duck meat juiciness. Twenty minutes of electrical stimulation gave the good juiciness score and significantly different to 0, 5, and 10 minutes stimulation. However, juiciness of Muscovy duck meat stimulated during 20 minutes did not differ with those with 15 minutes stimulation. This result was similar to Abustam (2010) who explained that high voltage caused high loss of meat juice in functional properties and muscle unity compared with stimulation using low voltage. The effect of electrical stimulation might be varied depend on stimulation condition.

Meanwhile, the results of the study by Davel et al. (2003) found that the consumer acceptance score (panelists) of juiciness, tenderness, taste and overall acceptance were not significantly affected by carcass electrical stimulation. Both samples from electrically stimulated and non-stimulated carcasses are highly accepted by consumers.

CONCLUSION

Electrical stimulation significantly improves the quality of Muscovy duck meat, especially for tenderness, color, texture, aroma, taste, and juiciness of muscular duck meat, but not on pH parameters and cooking loos. Twenty minutes of electrical stimulation with a power of 20 V, showing the best effect on tenderness, color, texture, and taste.

ACKNOWLEDGEMENT

Gratitude and appreciation were given to the Dean of the Faculty of Animal Science of the University Halu Oleo, Chair of the Department of Animal Science with permission and support, as well as Animal Science laboratory technicians and students who have helped carry out the research.

REFERENCES

Aalhus JL, Jones SDM, Best DR, Robertson WM, Lutz S. 1994. The efficacy of high and low voltage electrical stimulation under different chilling regimes. Can J Anim Sci. 74:433-442.

Aberle ED, Forest JC, Hendrick HB, Judge MD, Merkel RA. 2001. Principles of meat science. San Fransisco (USA): W.H. Freeman and Company.

Abustam E. 2012. Ilmu daging: Aspek produksi, kimia, biokimia dan kualitas. Cetakan Pertama. Makassar (Indones): Masaguna Press.

Agbeniga B, Webb EC. 2014. Influence of electrical stimulation on carcass and meat quality of Kosher and conventionally slaughtered cattle. S Afr J Anim Sci. 44:58-63.

Bouton PE, Ford AL, Harris PV, Shaw FD. 1978. Effect of low voltage stimulation of beef carcasses on muscle tenderness and pH. J Fd Sci. 43:1392-1396.

Buckle KA, Edwards R, Fleet G, Wooton M. 1987. Ilmu pangan. Hari P, Adiono, translater. Yogyakarta (Indones): Universitas Indonesia Press.

Davel M, Bosman M, Webb E. 2003. Effect of electrical stimulation of carcasses from Dorper sheep with two permanent incisors on the consumer acceptance of mutton: review article. S Afr J Anim Sci. 33:206-212.

Freeman C, Freeman C. 2015. Texture analysis for assessing meat tenderness: Tenderness, juiciness, flavours. England: AMETEK Brookfield. Stadium Way, Harlow, Essex CM19 5GX.

Froning GW, Uijttenboogaart TG. 1988. Effect of post-mortem electrical stimulation on color, texture, pH, and cooking losses of hot and cold deboned chicken broiler breast meat. Poult Sci. 67:1536-1544.

Garcia L. 2009. Functional properties and utilization of high pH beef (Dissertation). [Texas (USA)]: Texas A&M University.

Gasperz V. 2010. Metode rancangan percobaan. Bandung (Indones): Penerbit CV. Armico.

Hafid H. 1998. Kinerja produksi sapi australian commercial cross yang dipelihara secara fedlot dengan kondisi bakalan dan lama penggemukan yang berbeda (Thesis). [Bogor (Indones)]: Bogor Agricultural University.

Hafid H. 2011. Pengantar evaluasi karkas. Cetakan Pertama. Kendari (Indones): Unhalu Press.

Hafid H. 2017. Pengantar pengolahan daging. Cetakan Pertama. Bandung (Indones): Alfabeta Bandung.

Hafid H, Mujianto D, Agustina, Inderawati, Nuraini. 2017. The effect of storage time in the refrigerator to the quality of organoleptic beef. ADRI Int J Biol Educ. 1:29-36.

Hafid H, Nuraini, Inderawati. 2014. Sifat organoleptik daging itik afkir yang diberi perlakuan stimulasi listrik. Prosiding Seminar Nasional Optimalisasi Sumber Daya Lokal pada Peternak Rakyat Berbasis Teknologi. Makassar (Indones): Universitas Hasanuddin. p. 182-193.

Hafid H, Nuraini, Inderawati. 2015. Potensi produksi karkas itik lokal afkir yang berasal dari peternakan rakyat di sulawesi tenggara. Prosiding Seminar Nasional Teknologi Peternakan dan Veteriner. Bogor (Indones): Indonesian Center for Animal Research and Development. p. 443-447.

Hafid H, Syam A. 2012. Pengaruh aging dan lokasi otot terhadap kualitas organoleptik daging sapi. Bul Peternak. 31:209.

Hafri Y, Hidayati, Elfawati. 2008. Kualitas daging sapi dengan kemasan plastik PE (polyethylen) dan plastik PP (polypropylen) Di pasar arengka kota pekanbaru. J Peternak. 5:22-27.

Khasrad, Sarbaini, Arfai, Rusdimansyah. 2018. Effect of post-mortem electrical stimulation on meat quality of Pesisir cattle (indigenous cattle of West Sumatera). Pak J Nutr. 17:441-445.

Komariah, Rahayu S, Sarjito. 2009. Physical characteristics of beef, buffalo and lamb meat on different postmortem periods. Bul Peternak. 33:183-189.

Lee S, Norman J, Gunasekaran S, van Laack RLJ, Kim B, Kauffman R. 2000. Use of electrical conductivity to predict water-holding capacity in post-rigor pork. Meat Sci. 55:385-389.

Lukman DW. 2010. Nilai pH daging. Bogor (Indones): Bagian Kesehatan Masyarakat Veteriner, Fakultas Kedokteran Hewan, Institut Pertanian Bogor.

Prasetyo H, Padaga MC, Sawitri ME. 2013. Kajian kualitas fisiko kimia daging sapi di pasar Kota Malang. J Ilmu Teknol Hasil Ternak. 8:1-8.

Randa S, Wahyuni I, Joseph G, Uhi HT, Rukmiasih, Hafid H, Parakkasi A. 2002. Efek pemberian serat tinggi dan vitamin-E terhadap produksi karkas dan non karkas itik Mandalung. Prosiding Seminar Nasional Teknologi Peternakan dan Veteriner. Bogor (Indones): Indonesian Center for Animal Research and Development. p. 261-264.

Salm CP, Mills EW, Reeves ES, Judge MD, Aberle ED. 1981. Effect of electrical stimulation on muscle characteristics of beef cattle fed a high energy diet for varying lengths of time. J Food Sci. 46:1284-1285.

Soekarto S, Hubeis M. 1992. Petunjuk laboratorium metode penelitian indrawi. Bogor (Indones): Pusat Antar Universitas Pangan dan Gizi, Institut Pertanian Bogor.

Soeparno. 2009. Ilmu dan teknologi daging. Yogyakarta (Indones): Gadjah Mada University Press.

Syam A, Soeparno, Rusman. 2013. Efek lama stimulasi dan tegangan listrik terhadap komposisi kimia, kualitas fisik, dan sensori daging ayam petelur afkir. Bul Peternak. 37:26.

Tkacz K, Więk A, Żywica R, Banach JK. 2018. The effects of beef carcasses high voltage electrical stimulation and roasting methods on tenderness and water retention of beef. Tech Sci. 21:103-116.

Yong SK, Lee CN, DuPonte M., Fukumoto G. 2007. Improving tenderness of forage-finished beef using a low-voltage electrical stimulator. Food Saf Technol. 22:1-6.