Meat Research
Vol 3, Issue 6: 1-7, Article 76
ISSN: 2790-1971
https://doi.org/10.55002/mr.3.6.76

http://www.bmsa.info/meatresearch

[1]Department of Animal Science, Bangladesh Agricultural University, Mymensingh.

[2] Department of Animal Production, Gono Bishwabidyalay, Savar, Dhaka.

***Corresponding author:**

Prof. Dr. Md. Abul Hashem
E- mail: hashem_as@bau.edu.bd

Keywords:

Rigor states
Physicochemical
Sensory
Microbial
Chevon

Article Info:

Received: 05 October 2023
Accepted: 21 December 2023
Published online: 31 December 2023

Research Article

Are there any differences on the quality attributes of pre and post-rigor chevon?

M Jannat[1], M Ruknuzzaman[2], M Khan[1], M Rahman[1] and MA Hashem[1]*

Abstract

The present study was conducted to find out whether pre-rigor and post-rigor state has significant impact on quality attributes of chevon. For this 10 *Longissimus dorsi* muscles from five Black Bengal goats were collected. Fresh chevon were considered as pre-rigor sample and other five samples were preserved at 4ºC counted as post-rigor samples. Independent t-test was used for analyses the data. The findings demonstrated that among physicochemical characteristics, rigor state had no discernible ($p>0.05$) impact on water holding capacity (WHC) and cooking loss (CL). However, post-rigor chevon drip loss was substantially higher ($p<0.05$) than pre-rigor chevon drip loss whereas pH value was significantly ($p<0.05$) higher in pre-rigor chevon. Higher CIE a*, b*, Hue angle values were found in post-rigor than pre-rigor chevon. Post-rigor chevon had substantially better ($p<0.05$) flavor, tenderness, texture and general acceptability. On the contrary, pre-rigor chevon's TVC, TCC and TYMC microbial count values were all substantially higher ($p<0.05$) than those of the post-rigor chevon. So, it can be sum up that, there are notable differences between pre-rigor and post-rigor chevon in a number of physicochemical and sensory properties. Despite having less drip loss of pre-rigor chevon, post-rigor chevon is more palatable and less contaminated by microbes.

Introduction

One of the most popular red meats in many parts of the world, including Asia, Africa, and Hispanic residents in the USA, is goat meat, often known as "chevon" or "chevron," which has gained increasing appeal globally (Abhijith et al., 2021; Hashem et al., 2013). Due to its distinctive flavor profile, nutritional richness, and variety in culinary applications, it is growing in popularity and is a desired option for consumers looking for better and sustainable protein options (Hossain et al., 2021, 2023a & 2023b). Goats make up about 47% of all ruminant species in Bangladesh and are well adapted to the tropical monsoon climate (DLS, 2023). For consumers, the quality of the meat—including its softness, juiciness, and flavor—is of utmost importance because it directly affects their happiness and plans to make additional purchases (Alam et al., 2011; Sayeed et al., 2023). The rigor mortis process stands out as a crucial stage in meat production among the many other elements that affect meat quality, greatly affecting the sensory qualities and customer acceptability of the finished product (Offer and Knight, 1988; Afroz et al., 2020).

During the pre-rigor phase, meat is relatively flexible and tender, therefore, it is crucial to handle and process it with care to maintain these desirable qualities. Several alterations take place within the muscle while in the pre-rigor and rigor phases. Muscle energy depletion is followed by anaerobic metabolism and lactic acid generation (Alvarez et al., 2019; Islam et al. 2019). The muscle's ionic strength rises because the ion ATP-dependent pumps cannot operate without ATP (Greaser, 1986). Finally, the cell cannot maintain lowering circumstances and calcium pumps quit pumping, inactivating muscular relaxation and triggering rigor mortis (Lonergran et al., 2010; Azad et al. 2022a).

Post-rigor state, on the other hand, refers to the period when muscles have reached their maximum stiffness, resulting in a decrease in tenderness and possibly influencing the overall eating experience. Pre-rigor beef muscle (Sternomandibularis) cooked immediately within around 3 hours of slaughter to be more tender than post-rigor beef muscle (Akhter et al., 2009; Jahan et al., 2018). By contrast, in another study, shear values and the sensory panel assessment revealed that pre-rigor cooked roasts were less tender than post-rigor cooked roasts (Loucks et al., 1984). Before processing, dressed carcasses are typically refrigerated for at least 24 hours in the commercial sector in order to facilitate the boning process, yet, this traditional meat processing has several limitations due to the high cost of power required to cool the meat and the lengthy processing period (Dzudie et al., 2000).

Furthermore, another major drawback of pre rigor processing is a reduction in tenderness induced by pre rigor cooling and consequent cold shortening (Marsh et al., 1968). However, microbial loads of meat cuts tend to be affected by the duration of retail display time.

Studies regarding the effects of rigor state particularly on goat meat in Bangladesh are limited. In Bangladesh chevon is sold as fresh meat. After buying consumers cooked and eat. If there is access meat as fresh they keep at -18°C but never kept on 4°C for chilling or aging which is very important for conversion of muscle to meat. This practice is never followed in Bangladesh at household level. With this view in mind present study has been conducted to investigate the effect of pre-rigor and post rigor state on the physicochemical, sensory attributes and microbial load of chevon.

Materials and Methods

Experimental animal and sample collection

To conduct the experiment, *Longissimus dorsi* muscle of five wether Black Bengal goat of one year of age was purchased from Ganginar Par Market, Mymensingh. After that, the samples were carried to the Animal Science Laboratory, Bangladesh Agricultural University, Mymensingh.

Methodology

Experimental design

Collected *Longissimus dorsi* muscle from five wethers was prepared for experiments and divided in two groups having five replications each. Each sample was 250 g in weight. Among them five samples were used as pre-rigor and another 5 samples were used as post-rigor. Pre-rigor samples were analyzed within 1 h of slaughtering. Another five samples were then refrigerated at 4°C for 24 h and then different tests were performed which was counted as post-rigor.

Physicochemical attributes

Determination of pH

The pH of the pre- and post-rigor chevon was taken by using HANNA Meat pH Meter according to its operating manual.

Water holding capacity

The sample's WHC is stated as the ratio of the sample's weight after centrifugation to its initial weight, using the following formula:

$$\text{Water holding capacity (\%)} = \left[\frac{\text{Sample weight after centrifugation (g)}}{\text{Sample weight before centrifugation (g)}} \times 100\right]$$

Cooking loss

Cooking loss of chevon was measured according to the method as reported by Kondaiah *et al.* (1985) by using the following formula.

$$\text{Cooking loss \%} = \frac{\text{Actual weight - Cooked mass weight}}{\text{Actual weight}} \times 100$$

Above procedure was done in 0 hour and after 24 hour to determine the cooking loss of pre-rigor and post-rigor chevon.

Drip loss

Samples were stored in refrigerator at 4℃ for 24 hours for measuring drip loss. Meat samples were suspended in tightly sealed plastic bag filled with air and kept at 4°C for 24 h (Honikel, 1998) . Drip loss was calculated as a percentage of the weight loss after suspension.

Drip loss was estimated by using following calculation:

$$\text{Drip loss \%} = \frac{\text{Initial weight of the sample - Final weight of the sample}}{\text{Initial weight of the sample}} \times 100$$

Same procedure was done after 24 hour to determine the drip loss of post-rigor chevon.

Instrumental color value

Instrumental color values (CIE L*), redness (CIE a*), and yellowness (CIE b*) were determined by using Konica Minolta colorimeter.

Sensory evaluation

Different sensory characteristics were looked at. The serving order was randomized, and the samples were coded. Ten panelists examined each sample. The sensory questionnaires examined the intensity of the following qualities: color, flavor, texture, tenderness, and overall acceptability on a 5-point balanced semantic scale (weak to strong). The judges assessed the samples in accordance with the stated standards. Ratings are as follows: 1 for bad, 2 for fair, 3 for good, 4 for very good and 5 for excellent (Disha et al., 2020).

Microbial Count of pre-rigor and post rigor chevon

Following ISO (1995), total viable count (TVC), total coliform count (TCC) and total yeast mold count (TYMC) were determined. The total microorganism count values were presented as CFU/g of meat sample. By using log value results were then calculated.

Statistical analysis

Using the SAS Statistical Discovery Software, NC, USA tool, the data were analyzed. Independent t-test was used for analyses the data. The significance of differences between the pre-rigor and post-rigor chevon groups was assessed using the DMRT test. The data were presented as the mean ± SEM, and the 5% level of significance was used to determine the level of significance.

Results and discussion

Pre-rigor and Post-rigor Physical Properties

pH

Pre-rigor and post-rigor pH of chevon represented in Table 1. It was observed that pH of the pre-rigor chevon (6.19) was significantly higher ($p<0.05$) than the pH of post-rigor chevon (5.68). Present finding in pH is the agreement to the findings of Kujero et al. (2020) in which they have also found significant differences in the pH of pre-rigor and post-rigor meat.

The decline in pH is related to the accumulation of lactic acid in the muscle during post-mortem glycolysis (Lawrie, 1991). The pH scale, which measures how acidic or alkaline a solution is, is a key element in determining the quality of meat and runs from roughly 5.2 to 7.0. The pH range of the greatest grade items often tends to be between 5.7 and 6.0, according to (Lonergan and Lonergan, 2005). The postmortem muscular energy metabolism that caused a pH fall due to the buildup of H^+ in the post-rigor state may be the cause of the lower pH values observed (England et al., 2013). As rigor mortis progresses within the muscle tissues, energy reserves deplete, which culminates in the chilling process and termination of blood flow, which lowers the pH and temperature of the muscle (Strydom et al., 2016). The muscle's anaerobic glycolysis produces lactate, which builds up and lowers the intracellular pH of goat meat.

Water holding capacity (WHC)

The water holding capacity of chevon is not substantially affected by rigor state ($p>0.05$). However, the value of water holding capacity was slightly better in pre-rigor state (98.06%) than that of post-rigor (95.88%). This finding is an agreement to the findings of Ezgi and Serdaroglu (2018). Post rigor meat has decreased spacing between filaments and decreased protein functionality; therefore, less free water was retained. The minor difference in the free water contents of the samples in this study may be due to the difference in the pH values of the samples.

Pearce et al. (2011) stated that WHC of meat may be impacted by the magnitude and rate of pH drop postmortem. Myofibrillar proteins' ability to bind water molecules is reduced in the rigor mortis phase due to a decrease in the pH near their isoelectric point and the net charges between myofibrillar proteins, which causes an increase in free extra-myofibrillar water in the muscle (Ijaz et al., 2020).

Table 1. Effect of pre and post-rigor state on physical properties of chevon

Parameter	Pre-rigor (Mean ± SE)	Post-rigor (Mean ± SE)	Level of Significance
pH	$6.19^{a} \pm 0.04$	$5.68^{b} \pm 0.21$	0.05*
Water Holding Capacity (%)	$98.06^{a} \pm 0.55$	$95.88^{a} \pm 0.13$	0.93^{NS}
Cooking Loss (%)	$18.69^{a} \pm 2.89$	$15.70^{a} \pm 2.28$	0.73^{NS}
Drip Loss (%)	$5.15^{b} \pm 0.23$	$6.18^{a} \pm 1.44$	0.04*

$^{a,\,b}$ Mean values with different superscripts within the same row differ significantly ; NS = Non significant ($P>0.05$), * = Significant ($P<0.05$).

Cooking loss

Although it was found that cooking loss in pre rigor meat is slightly higher (18.69%) in compare to post rigor meat (15.70%) but the difference was not statistically significant ($p>0.05$). Cooking loss is a combination of liquid and soluble matters lost from the meat during cooking. According to Santos et al. (1994), the early onset of rigor mortis and high carcass temperatures in PSE pork resulted in the denaturation of muscle sarcoplasmic and contractile proteins, which left the meat with a poor ability to retain water. This was demonstrated by higher drip loss and cooking losses.

Drip loss

Drip loss of goat meat in pre and post-rigor state depicted in Figure 1. It denotes that rigor state has significant impact ($p<0.05$) in the drip loss of chevon. Post-rigor chevon has the higher drip loss (6.18%) than that of the pre-rigor chevon which has comparatively lower drip loss (5.15%).

Current findings is an agreement to the findings of Devine et al. (2014) and they stated that during rigor mortis and resolution, the amount of free water increased, which led to an accumulation of water on the cut surface and higher drip loss.

Pre-rigor and post-rigor instrumental color

Instrumental color value in the scale of lightness (L*), redness (a*) and yellowness (b*) depicted in Figure 2 which is discussed below under the following subheadings:

CIE L* (Lightness)

Although, it was found that post-rigor chevon was slightly lighter in color than pre-rigor chevon but there was statistically significant difference ($p<0.05$). The value for L* was 34.69 and 37.43 in pre-rigor and post-rigor chevon, respectively. L* values in this study gradually increased from pre-rigor to post-rigor. Pre-rigor cuts had lower L* values than rigor mortis and post-rigor cuts. According to Ertbjerg and Puolanne (2017) and Pearce et al. (2011), extracellular space formation, transverse muscle fiber shrinkage, and an increase in light scattering could all be factors in the increase of L*. This investigation was consistent with Offer and Cousins' (1992) observation that the gaps between beef sternomandibularis muscle fibers developed and grew at 24 to 48 h post mortem.

CIE a* (Redness)

Rigor state insignificantly ($p>0.05$) increases the redness (a*) of goat meat. The reading for redness in colorimeter was 14.33 in 0 hr (pre-rigor state) and 15.56 in 24 hr (post-rigor state) meat. The current result is consistent with Ge et al. (2021), which reported a comparable outcome in terms of a* value in lamb meat from both pre- and post-rigor. The improvement in L* and a* over storage agrees with previous findings in chevon (Karami et al., 2011) and beef (Liu et al., 2015).

CIE b* (Yellowness)

Rigor state has a significant effect on the yellowness (b*) of goat meat. With the advancement of storage period b* value significantly increases (p<0.05). Therefore, higher value of b* was recorded in post-rigor state (8.67) while it was lowest in pre-rigor state (5.02) of meat (Table 2). This difference helps to separate pre-rigor and post-rigor chevon by its appearance.

Current result is an agreement to the findings of Ge et al. (2021) in which have found similar result in term of L* value in pre-rigor and post-rigor meat of lamb

Table 2. Effect of pre- and post-rigor state on instrumental color of chevon

Parameter	Pre-rigor (Mean ± SE)	Post-rigor (Mean ± SE)	Level of Significance
CIE L* (Lightness)	$34.69^{a} \pm 0.78$	$37.43^{a} \pm 1.06$	0.12^{NS}
CIE a* (Redness)	$14.33^{b} \pm 1.32$	$15.56^{b} \pm 0.93$	0.61^{NS}
CIE b* (Yellowness)	$5.02^{b} \pm 0.51$	$8.67^{a} \pm 0.18$	0.008**
Hue Angle (HA)/Chroma	$19.32^{b} \pm 1.16$	$44.79^{a} \pm 1.66$	0.037*
Saturation Index (SI)	$15.20^{a} \pm 1.38$	$17.82^{a} \pm 0.89$	0.3^{NS}

$^{a, b}$ Mean values with different superscripts within the same row differ significantly (P<0.05); NS = Non significant (P>0.05), * = Significant (P<0.05) , **= Significant (P<0.01).

Hue Angle (HA)

Hue angle of chevon in pre-rigor and post-rigor state is shown in Table 2. It was observed that hue angle is significantly increased (p<0.05) in the post rigor state (44.79) from pre rigor state (19.32). High hue angle in post rigor state denotes that the color of post rigor meat was more reddish than that of the pre-rigor state meat.

According to research by Jeong et al. (2009) and Suman and Joseph (2013), metmyoglobin buildup and myoglobin oxidation, which were linked to the brown and unappealing color of meat, may have contributed to the increase in b* and hue angle values from pre-rigor to post-rigor in this study. High levels of b* and hue angle values in post-rigor cuts could result in a deviation in the red hue and a less aesthetically pleasing color of the meat.

Saturation Index (SI)

Rigor state has not the significant effect on saturation index of chevon color. The value of saturation index in post rigor state was 17.82 which is slightly but not significantly higher (p>0.05) than the value of pre-rigor state (15.20).

Pre-rigor and Post-rigor sensory evaluation of Chevon

Parameters of sensory evaluation of chevon are presented in Table 1. Sensory parameters of chevon in pre-rigor and post rigor state described below:-

Color

Color of chevon in pre-rigor and post rigor state is presented in Table 1. The data shows that there was significant differences (p<0.05) in the color of pre-rigor and post rigor chevon that implies rigor state has insignificant effect on chevon color. The value of scoring color of pre-rigor chevon was 4.6 and post rigor chevon was 4.0.

Increase lightness or comparatively pale color meat was found in post-rigor state may be due to the denaturation of sarcoplasmic proteins, as well as an increase in free water under a low pH (Hughes et al., 2020; Ijaz et al., 2020) and light scattering and reflectance**.** Dai et al. (2013) also found that the denaturation and precipitation of sarcoplasmic proteins to the myofibrils caused the Longissimus dorsi muscle to increase its lightness.

Flavour

Table 3 shows that rigor state has significantly (p<0.05) effects on the flavor of chevon. The flavor score of pre-rigor chevon was substantially lower (3.8) than that of post-rigor chevon (4.4) but that was not statistically significant (p>0.05). Olfactory organ's perception of specific volatile chemicals results in the scent or odor of meat (Cross et al., 1986; Hashem et al., 2023; Khatun et al., 2022).

Table 3. Effect of pre and post-rigor state on sensory attribute of chevon

Parameter	Pre-rigor (Mean ± SE)	Post-rigor (Mean ± SE)	Level of Significance
Color	$4.6^{a} \pm 0.37$	$4.0^{b} \pm 0.51$	0.02*
Flavour	$3.8^{b} \pm 0.45$	$4.4^{a} \pm 0.40$	0.03*
Tenderness	$3.6^{b} \pm 0.51$	$4.4^{a} \pm 0.40$	0.03*
Texture	$3.8^{b} \pm 0.41$	$4.2^{a} \pm 0.41$	0.05*
Juiciness	$3.8^{a} \pm 0.58$	$4.0^{a} \pm 0.45$	0.34^{NS}
Overall acceptability	$3.6^{b} \pm 0.37$	$4.4^{a} \pm 0.24$	0.002**

$^{a, b}$ Mean values with different superscripts within the same row differ significantly (P<0.05); NS = Non significant (P>0.05), * = Significant (P<0.05) , **= Significant (P<0.01).

Tenderness

Table 3 denotes that chevon preserved for 24 hours (post-rigor) had a significantly high (p<0.05) tenderness value than that of fresh chevon (pre-rigor) and the values were 3.6 and 4.4 in pre-rigor and post-rigor state, respectively. Meat tenderization is caused by the toughening of the meat at the start of the rigor mortis due to the shortening of the sarcomere. The main factors that affect meat tenderness are the connective tissue, the sarcomere length, and the myofibril breakdown. Shrinkage in muscle fibers was associated with an increase in the number of Myofibrillar Proteins (myofibrils) and Collagen per unit area of shear, resulting in toughened meat (Fabre et al., 2018). According to Chaosap et al. (2020), sarcomere length is a key predictor of meat tenderness; it decreases when meat becomes tougher. According to Hertzman et al. (1993), the tenderizing phase is caused by the breakdown of myofibrils.

Texture

Texture of chevon presented in table 4.3. It was observed that the score of texture for post-rigor chevon (4.2) was significantly better (p<0.05) than pre-rigor chevon (3.8). Better texture in post rigor muscle may be caused as sarcomeres are longitudinally shortened and myofibrils are laterally shrunk as a result of postmortem glycolysis and pH drop (Ertbjerg and Puolanne, 2017; Hughes et al., 2020; Lana and Zolla, 2016).

Juiciness

Rigor state has not significant effect (p>0.05) on the juiciness of chevon. The score for juicines of chevon counted as 3.8 in pre-rigor state and 4.0 in post-rigor state.

Overall acceptability

Although there was not significant difference in few sensory parameters of pre-rigor and post rigor chevon, there was significant difference (p<0.05) in overall acceptability between two types of chevon given by the panelists and the score was 3.6 and 4.4 in of pre-rigor and post-rigor chevon, respectively.

Pre-rigor and Post-rigor Microbial Count

Total Viable Bacterial Count (TVC)

Table 4 represents total viable count of pre-rigor and post-rigor chevon. It was found that total viable bacterial count of chevon in pre rigor state was significantly (p<0.05) higher (6.45 ± 0.63 log cfu/g) than that of chevon of pre-rigor state (4.92 ±0.42 log cfu/g). The International Commission on Meat and Meat Tissue (ICMSF) (1985) suggested that the average total viable count of fresh meat tissues should be less than log 6.0 per gram. Present findings of TVC in pre-rigor state are above safety limit and post-rigor chevon has within safety limit total viable count. This findings is nearly similar to the findings of Haque et al. (2008) in which they have found a TVC of ranged from 5.85-6.24 log cfu/g in different goat meat market of Mymensingh. Parvin et al. (2017) has also found similar result in terms of TVC (5.94-6.64 log cfu/g) from the raw chevon collected from different slaughter yard of Mymensingh. However, post-rigor chevon had comparatively low TVC value most probably due to the reduction of microbial counts by low temperatures which slow down or inhibit the growth and reproduction of microorganisms, including bacteria, yeasts, and molds.

During freezing osmotic stress changes the intracellular pH and ion strength, which stops enzymes from working, degrades other proteins, and messes with metabolism. The membranes and membrane transport systems can be totally destroyed, and bacteria can become more vulnerable to oxidative stress as a result bacterial death occurs (Farkas, 2007). Despite the analysis of fresh meat showing the presence of more viable bacteria, proper cooking methods and hygiene could significantly lower the microbial load to a safe level (Azad et al., 2022b; Das et al., 2022; Sarker et al., 2021).

Total Coliform Count (TCC)

The rigor state significantly affects the chevon's total coliform count (p<0.05). Table 4 shows that the total coliform count of the chevon was substantially higher in the pre-rigor condition (2.78 ±0.49 log cfu/g) than in the post-rigor state (1.67±0.12 log cfu/g).

Coliform is a type of bacteria that lives in the intestines and can grow quickly in meat. TCC reveals the meat's sanitary state (Ahmad et al., 2013). The 2016 Compendium of Microbiological Criteria for Food states that meat with coliforms greater than log 2 cfu/g is unsatisfactory and may result in pathogenic conditions. Present findings of coliform count in goat meat in pre-rigor state was above safety limit (2.78 ±0.49 log cfu/g) while post-rigor meat was within the safety limit (2.78 ±0.49 log cfu/g). The presence of coliform bacteria in the fresh chevon sample indicates faecal contamination of the meat, which may have resulted from the handling of the meat in an unhygienic manner during slaughter and processing or from potential contamination from the handlers' skin, mouth, hands, or noses that may have been introduced directly into the meat (Schroeder et al., 2005).

Table 4. Effect of pre- and post-rigor state on microbial count of chevon

Parameters	Pre-rigor (Mean ± SE)	Post-rigor (Mean ± SE)	Level of Significance
TVC (log cfu/g)	6.45^{a} ±0.07	4.92^{b}±0.00	0.0001***
TCC (log cfu/g)	2.78^{a}±0.07	1.67^{b}±0.09	0.002**
TYMC (log cfu/g)	3.25^{a}±0.52	2.19^{b} ±0.35	0.05*

$^{a,\ b}$ Mean values with different superscripts within the same row differ significantly (P<0.05); NS = Non significant (P>0.05), * = Significant (P<0.05) , **= Significant (P<0.01), ***= Significant (P<0.001).

It looks like the results from Parvin et al. (2017) are pretty much the same when it comes to the TCC of raw chevon from different slaughter yards in Mymensingh. They found the nearly same results, with the TCC ranging from 1.41 to 2.63 log cfu/g.

Total Yeast Mold Count (TYMC)

Total Yeast Mold Count of pre-rigor and post rigor chevon is represented in figure 3. It reveals that the colony forming unit in per ml (cfu/ml) of sample in pre-rigor chevon was 3.25 ± 0.52 log cfu/g which is significantly higher (p<0.05) than that of post-rigor chevon which value was counted as 2.19 ± 0.35 log cfu/g. Any food item's overall quality and safety can be determined by looking at the amount of yeast mold present. It has been utilized in numerous food standards, including those of Australia and New Zealand. Foods can deteriorate and decompose to varying degrees due to mould and yeasts. At any time, they can infiltrate and begin to grow on almost any kind of food (Parvin et al., 2017). The interruption of yeast and mold growth by freezing temperature is the cause of the decrease in the amount of YMC in post-rigor chevon.

Conclusion:

From current study it can be concluded that, yes, there is significant difference in physicochemical and sensory attributes between pre-rigor and post-rigor chevon. Although, pre-rigor chevon has less drip loss and slightly better in color, post rigor chevon is comparatively more tender, acceptable and hygienic to consume.

References

Abhijith A, Warner RD, Ha M, Dunshea FR, Leury BJ, Zhang M, Joy A, Osei-Amponsah R, Chauhan SS 2021. Effect of slaughter age and post-mortem days on meat quality of longissimus and semimembranosus muscles of Boer goats. Meat Science, 175: 108466.

Afroz MR, Yu ZN, Islam SMA, Murshed HM, Rahman SM. 2020. Effect of protein supplement on growth and blood parameters of native lamb. Journal of Agriculture, Food and Environment, 1(1): 13-9.

Ahmad M, Sarwar A, Najeeb M, Nawaz M, Anjum A, Ali M, Mansur N .2013. Assessment of microbial load of raw meat at abattoirs and retail outlets. The Journal of Animal and Plant Sciences, 23: 745–748.

Akhter S, Rahman MM, Hossain MM, Hashem MA. 2009. Effects of drying as a preservation technique on nutrient contents of beef. Journal of Bangladesh Agricultural University, 7: 63–68.

Alam MM, Hashem MA, Rahman MM, Hossain MM, Haque MR, Sobhan Z, Islam MS. 2011. Effect of heat stress on behavior, physiological and blood parameters of goat. Progress. Agric. 22: 37-45.

Alvarez C, Morán L, Keenan DF, Mullen AM, Delgado-Pando G. 2019. Mechanical and biochemical methods for rigor measurement: Relationship with eating quality. Journal of Food Quality, 2019: 1-13.

Azad MAK, Sakib MN, Murshed HM, Hashem MA, Ali MS, Habib M, Billah MM. 2022a. Indigenous transport methods: Hormonal responses and physicochemical properties of lamb meat. Meat Research, 2(2): 1-6.

Azad MAK, Rahman MM, Hashem MA. 2022b. Meat microbiota: A conceptual review. Meat Research, 2: 2, Article No. 20. https://doi.org/10.55002/mr.2.3.20

Chaosap C, Sitthigripong R, Sivapirunthep P, Pungsuk A, Adeyemi KD, Sazili AQ. 2020. Myosin heavy chain isoforms expression, calpain system and quality characteristics of different muscles in goats. Food Chemistry, 321: 126677.

Cross HR, Durland PR, Seideman SC. 1986. Muscle as Food, ed. PJ Bechtel.

Dai Y, Miao J, Yuan SZ, Liu Y, Li XM, Dai RT. 2013. Colour and sarcoplasmic protein evaluation of pork following water bath and ohmic cooking, Meat Science. 93(4): 898-905.

Das A, Hashem MA, Azad MAK, Rahman MM. 2022. Edible oil marination in broiler meat for short term preservation. Meat Research, 2: 3, Article 22

Devine C, Wells R, Lowe T, Waller J. 2014. Pre-rigor temperature and the relationship between lamb tenderisation, free water production, bound water and dry matter. Meat Science, 96(1): 321-326.

Disha MNA, Hossain MA, Kamal MT, Rahman MM, Hashem MA. 2020. Effect of different levels of lemon extract on quality and shelf life of chicken meatballs during frozen storage. SAARC Journal of Agriculture, 18(2): 139-156.

DLS. 2023. Department of Livestock Services. Livestock economy at a glance, Ministry of Livestock and Fisheries, Bangladesh.

Dzudie T, Ndjouenkeu R, Okubanjo A. 2000. Effect of cooking methods and rigor state on the composition, tenderness and eating quality of cured goat loins. Journal of Food Engineering, 44(3): 149-153.

England EM, Scheffler TL, Kasten SC, Matarneh SK, Gerrard DE. 2013. Exploring the unknowns involved in the transformation of muscle to meat. Meat Science, 95(4): 837-843.

Ertbjerg P, Puolanne E. 2017. Muscle structure, sarcomere length and influences on meat quality: A review. Meat Science, 132: 139-152.

Ezgi EE, Serdaroğlu M. 2018. Effects of pre and post-rigor marinade injection on some quality parameters of longissimus dorsi muscles. Korean Journal for Food Science of Animal Resources, 38(2): 325.

Fabre R, Dalzotto G, Perlo F, Bonato P, Teira G, Tisocco O. 2018. Cooking method effect on Warner-Bratzler shear force of different beef muscles, Meat Science. 138: 10-14.

Ge Y, Zhang D, Zhang H, Li X, Fang F, Liang C, Wang Z. 2021. Effect of Postmortem Phases on Lamb Meat Quality: A Physicochemical, Microstructural and Water Mobility Approach. Food Sci Anim Resour. 2021 Sep; 41(5): 802–815.

Greaser ML. 1986. Conversion of muscle to meat. In: PJ Bechtel (ed.) Muscle as Food. pp. 37–102. Academic Press, San Deigo, CA.

Haque MA, Siddique MP, Habib MA, Sarkar V, Choudhury KA. 2008. Evaluation of sanitary quality of goat meat obtained from slaughter yards and meat stalls at late market hours. Bangladesh Journal of Veterinary Medicine, 6(1): 87-92.

Hashem MA, Hossain MM, Rana MS, Islam MS, Saha NG. 2013. Effect of heat stress on blood parameter, carcass and meat quality of Black Bengal goat. *Bangladesh J. Anim. Sci*, *42*, 57–61

Hashem MA, Rahman MF, Mustari A, Goswami PK, Hasan MM, Rahman MM. 2023. Predict the quality and safety of chicken sausage through computer vision technology. Meat Research 3 (1), Article 47.

Hertzman C, Olsson U, Tornberg E. 1993. The influence of high temperature, type of muscle and electrical stimulation on the course of rigor, ageing and tenderness of beef muscles. Meat Science, 35(1): 119-141.

Honikel KO. 1998. Reference methods for the assessment of physical characteristics of meat. Meat Science, 49(4): 447-457.

Hossain MA, Rahman MM, Hashem MA. 2023a. Carcass and meat quality attributes of native sheep in Bangladesh: A review. Meat Research, 3: 2, Article 49.

Hossain MA, Rahman MM, Hashem MA. 2023b. Productive performances of native sheep in Bangladesh. Meat Research, 3: 1, Article 43.

Hossain MA, Rahman MM, Rahman MW, Hossain MM, Hashem MA. 2021. Optimization of slaughter age of Jamuna basin lamb based on carcass traits and meat quality. SAARC Journal of Agriculture, 19(2): 257-270.

Lonergan HE, Lonergan SM. 2005. Mechanisms of water-holding capacity of meat: The role of postmortem biochemical and structural changes. Meat Science, 71(1): 194-204.

Hughes JM, Clarke FM, Purslow PP, Warner RD. 2020. Meat color is determined not only by chromatic heme pigments but also by the physical structure and achromatic light scattering properties of the muscle. Comprehensive Reviews in Food Science and Food Safety, 19(1): 44-63.

Ijaz M, Li X, Zhang D, Hussain Z, Ren C, Bai Y, Zheng X. 2020. Association between meat color of DFD beef and other quality attributes. Meat Science, 161: 107954.

Islam SMA, Farzana F, Murshed HM, Rahman SME. 2019. Study on meat quality of native sheep raised in organic and conventional production system. Journal of Meat Science and Technology, 7(1): 1-7.

Jahan I, Haque MA, Hashem MA, Rima FJ, Akhter S, Hossain, MA. 2018. Formulation of value-added beef meatballs with pomegranate (Punica granatum) extractas a source of natural antioxidant. Journal of Meat Science and Technology, 6(1): 12-18.

Jeong JY, Hur SJ, Yang HS, Moon SH, Hwang YH, Park GB, Joo ST. 2009. Discoloration characteristics of 3 major muscles from cattle during cold storage. Journal of Food Science, 74(1): C1-5.

Karami M, Alimon AR, Sazili AQ, Goh YM, Ivan M. 2011. Effects of dietary antioxidants on the quality, fatty acid profile, and lipid oxidation of longissimus muscle in Kacang goat with aging time. Meat Science, 88(1): 102-108.

Khatun MM, Hossain MA, Ali MS, Rahman MM, Azad MAK, Hashem MA. 2022. Formulation of value-added chicken nuggets using carrot and ginger as a source of dietary fiber and natural antioxidant. SAARC J. Agric., 20 (1): 185-196.

Kujero GO, Abiola SS, Daramola J. 2020. Effects of rigor state and muscle type on physicochemical properties, processing and storage stability of two different pig skeletal muscles. Nigerian Journal of Animal Science, 22(3): 338-346.

Lana A, Zolla L. 2016. Proteolysis in meat tenderization from the point of view of each single protein: A proteomic perspective. Journal of Proteomics, 147: 85-97.

Lawrie RA. 1991. Meat Science. 5th ed. Pages 56–60, 188, and 206 in. Pergamon Press, New York, NY.

Liu F, Xu Q, Dai R, Ni Y. 2015. Effects of natural antioxidants on colour stability, lipid oxidation and metmyoglobin reducing activity in raw beef patties. Acta scientiarum polonorum Technologia alimentaria, 14(1): 37-44.

Lonergan EH, Zhang W, Lonergan SM. 2010. Biochemistry of postmortem muscle — Lessons on mechanisms of meat tenderization. Meat Science, 86: 184–195.

Loucks LJ, Ray FE, Berry BW, Leighton EA, Gray DG. 1984. Effects of mechanical tenderization and cooking treatments upon product attributes of pre-and post-rigor beef roasts. Journal of Animal Science, 58(3): 626-630.

Marsh BB, Woodhams PR, Leet NG. 1968. The effects on tenderness of carcass cooling and freezing before the completion of rigor mortis. Journal of Food Science, 33(1): 12-18.

Offer G, Cousins J. 1992. On the mechanism of water holding in meat: the swelling and shrinking of myofibrils. Meat Science, 8(4): 245-281.

Offer G, Knight M. 1988. The structural basis of water-holding in meat. Part I: General principles and water uptake in meat processing. Developments in Meat Science, 4: 53.

Parvin S, Murshed HM, Hossain MM, Khan M. 2017. Microbial assessment of chevon of Black Bengal goat. Journal of the Bangladesh Agricultural University, 15(2): 276-280.

Pearce KL, Rosenvold K, Andersen HJ, Hopkins DL. 2011. Water distribution and mobility in meat during the conversion of muscle to meat and ageing and the impacts on fresh meat quality attributes—A review. Meat Science, 89(2): 111-124.

Rahman MM, Hashem MA, Azad MAK, Choudhury MSH, Bhuiyan MKJ. 2023. Techniques of meat preservation-A review. Meat Research, 3 (3): Article 55.

Santos C, Roseiro LC, Goncalves H, Melo RS. 1994. Incidence of different pork quality categories in a Portuguese slaughterhouse: A survey. Meat Science, 38(2): 279-287.

Sarker MIA, Hashem MA, Azad MAK,Ali MS, Rahman MM. 2021. Food grade vinegar acts as an effective tool for short-term meat preservation. Meat Research, 1:5.

Sayeed MA, Mukta SP, Parvin S, Murshed HM, Rahman M, Azad MAK. 2023. Quality of cattle, buffalo & goat meat keema at different storage temperature. Meat Research, 3(5): 1-10.

Schroeder C, Naugle A, Schlosser W, Hogue A, Angulo F, Rose J. 2005. Emerging Infectious Diseases, 8: 23886-23888.

Strydom P, Lühl J, Kahl C, Hoffman LC. 2016. Comparison of shear force tenderness, drip and cooking loss, and ultimate muscle pH of the loin muscle among grass-fed steers of four major beef crosses slaughtered in Namibia. South African Journal of Animal Science, 46(4): 348-359.

Suman SP, Joseph P. 2013. Myoglobin chemistry and meat color. Annual review of food science and technology, 4:79-499.