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[1]Department of Animal Science, Bangladesh Agricultural University, Mymensingh, Bangladesh
[2]Graduate Training Institute, Bangladesh Agricultural University, Mymensingh, Bangladesh

***Corresponding author:**

MA Hashem
E-mail: hashem_as@bau.edu.bd

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Research Article

Are there any differences on sensory and physicochemical attributes of pre-and post-rigor broiler meat?

R Khatun[1], I Akter[2], RA Deen[1], D Ghosh[1], MA Hashem[1*]

Abstract

This study investigated the differences in sensory and physicochemical attributes between pre- and post-rigor broiler meat. Five live broilers were collected from the K.R. Market of BAU, Mymensingh, and meat samples were analyzed immediately after slaughter and deboning for pre-rigor conditions, while post-rigor samples were analyzed after 24-hour chilling at 4°C. A 2×2 factorial experiment in a completely randomized design (CRD) was employed for data analysis. Sensory parameters, including color, flavor, texture, tenderness, and overall acceptability, were assessed, along with physicochemical properties such as pH, cooking loss, drip loss, water-holding capacity, and instrumental color measurements (CIE L*, CIE a*, CIE b*, hue angle, and saturation index). The results revealed that sensory attributes of both breast and thigh meat improved significantly ($p<0.05$) after post-rigor aging, indicating better flavor, tenderness, and overall acceptability. Physicochemical analysis showed a significant decrease ($p<0.05$) in pH for both breast and thigh meat, while instrumental color analysis indicated that post-rigor breast meat had significantly higher CIE L* (lightness) and hue angle but lower CIE a* (redness). These findings highlight that post-rigor aging significantly enhances both sensory and physicochemical qualities, making it the more preferable and acceptable treatment. This study provides valuable insights for optimizing meat processing methods to improve consumer satisfaction and meat quality.

Introduction

Meat is an important protein source throughout the world, especially in developing countries. Broiler meat consumption has increased over the decades due to its high protein and low fat content, both of which are crucial traits for a balanced diet (Alam et al., 2015). In comparison to beef, lamb, and pork meat, chicken meat is less expensive, more widely available, and accepted by all communities (Das et al., 2022; Islam et al., 2019). Differences in carcass yield, protein content, and lipid stability between commercial broiler chickens indicate that breed and processing conditions play a vital role in meat characteristics (Murshed et al., 2014; Islam et al., 2018). Investigating pre- and post-rigor meat provides further insights into how processing time affects meat texture, juiciness, and flavor (Ali et al., 2022). Because customer demand for boneless meat has expanded considerably in recent years, the chicken leg and breast muscles are more commercially important than the remainder of the bird carcass. Poultry processing technique (cold or hot boning procedure), postmortem (PM) age, onset of rigor mortis, freezing and thawing duration and temperature, and other factors all play a role in the quality of boneless poultry carcass (Hashem et al., 2022). Poultry flesh, on the other hand, is highly susceptible to lipid and protein oxidation, which is frequently a severe danger to the quality of processed poultry products (Biplob et al., 2024; Hasan et al., 2024; Hossan et al., 2024; Sarker et al., 2024; Rahman et al., 2023). The amount of white/red fiber, myoglobin, glycogen, glycolytic and oxidative enzymes in breast and leg muscles differs, which has a direct effect on the quality of chicken meat. A number of research have been undertaken on the impact of repetitive freezing and thawing with varied time and temperature combinations on the qualitative parameters of poultry meat (Shalginbayev et al., 2022).

Rigor mortis is the stiffening of the muscle after death caused by the creation of a permanent cross bridge between the actin and myosin filaments in the muscle (Y. Ma et al., 2023). Muscle is very extensible during the period immediately following exsanguination. Aerobic metabolism is used to obtain energy in living animals (Koch et al., 2021). In During stressful conditions, blood is directed to vital organs like the liver, where glycogen is broken down into glucose via glycogenolysis to provide energy, and to muscles and the heart, where glucose and oxygen are used in cellular respiration to produce energy, releasing carbon dioxide and water as byproducts (McArdle et al., 2023). After an animal is slaughtered, blood circulation ceases and muscles' oxygen supply is depleted. Muscle can no longer manufacture ATP using oxygen and must resort to anaerobic glycolysis, a process that breaks down sugar without the use of oxygen to produce glycogen (Ren et al., 2024). The transition from pre-rigor to post-rigor in broiler meat is associated with significant changes in muscle structure, pH decline, water-holding capacity, and enzymatic activity, which directly impact tenderness, juiciness, and flavor (Sultana et al., 2023; Ali et al., 2022; Rana et al., 2014).

The breakdown of glycogen generates enough energy to contract the muscles as well as lactic acid. Because there is no blood flow to take the lactic acid away, the acid accumulates in the muscle tissue (Saber et al., 2021). Excessive acidity in meat causes it to lose its water-binding ability, resulting in a pale and watery appearance. Conversely, insufficient acidity leads to tough and dry meat. Muscle contraction is caused by the release of calcium from lactic acid accumulation (Tarek et al., 2018). As glycogen supplies run low, ATP regeneration ceases, and actin and myosin remain locked in a persistent contraction known as rigor mortis (Krompecher, 2023). When the carcass is frozen too soon after death, the proteins remain bonded together, resulting in very tough meat (Tuell et al., 2020). Allowing rigor mortis to occur will force enzymes in muscle cells to break down the overlapping proteins, making the meat soft.The objective of this study was to compare the quality of chicken meat before and after rigor mortis. In this investigation, changes in the sensory attributes, pH, water-holding capacity (WHC), cook loss, drip loss, and meat color of pre- and post-rigor chicken leg and breast muscles were evaluated. Meat that satisfies market demands and customer needs is crucial to achieving these goals and satisfying consumer expectations. In the meat sector, accurate evaluation of meat safety and quality is therefore essential. Information about the quality of meat has been obtained using a variety of techniques, such as instrumental approaches, chemical testing, and sensory analysis (Hossain et al., 2021)

Materials and Methods

Equipment and Instrument Preparation

The required equipment included a plastic pot, refrigerator, crucible, HANNA meat pH meter, digital food-grade thermometer, Minolta colorimeter, water bath, petri dishes, knife, chopping board, water, and tissue paper. All instruments were cleaned with hot water and detergent, autoclaved, and properly dried before use.

Sample Collection and Preparation

Five broiler samples were collected from KR Market, BAU, Mymensingh, at 9:00 AM and immediately transferred to the Animal Science Laboratory, BAU. After slaughter, deboning and cleaning were done to separate breast and thigh portions. Ten samples (5 breast, 5 thigh) were prepared. Pre-rigor analyses were conducted within 90 minutes of slaughter, while the remaining meat batches were stored at 4°C for 24 hours for post-rigor analyses.

Sensory Evaluation

Sensory attributes such as color, flavor, texture, tenderness, and overall acceptability were evaluated by a 7-member trained panel using a 5-point balanced semantic scale (1 = poor, 5 = excellent). Panelists were trained according to American Meat Science Association (AMSA, 1995) guidelines, with evaluations conducted in individual booths under controlled conditions. Samples were analyzed for pre-rigor (0 hours) and post-rigor (24 hours) conditions.

Physicochemical Attributes

pH Measurement

Meat pH was measured using a calibrated HANNA meat pH meter by placing the electrode directly onto meat tissue. Measurements were taken at 0 hours (pre-rigor) and 24 hours (post-rigor).

Cooking Loss

Cooking loss was determined using a hot water bath and a food-grade thermometer by heating meat to an internal temperature of 72°C. Cooking loss was calculated as a percentage of weight loss during cooking (Vujadinović et al., 2014).

$$Cooking\ Loss = \frac{(wt. before\ cooking - wt. after\ cooking)}{wt. before\ cooking} \times 100$$

Drip Loss

Meat samples were stored at 4°C for 24 hours in sealed plastic bags. Drip loss was calculated as a percentage of weight loss after suspension (Kaić et al., 2020).

$$Drip\ Loss = \frac{\text{Initial wt.of the sample} - \text{final wt.of the sample}}{\text{Initial wt.of the sample}} \text{x } 100$$

Water Holding Capacity (WHC)

WHC was assessed centrifuging each 1 g sample at 10,000 RCF for 10 minutes at 4°C. WHC was expressed as the ratio of the sample's weight after centrifugation to its initial weight (Szmańko et al., 2021).

$$Water\ holding\ Capacity = \frac{sample\ weight\ after\ centrifugation(\%)}{sample\ weight\ before\ centrifugation(\%)} \times 100$$

Color Measurement

Color attributes (CIE L*, a*, b*) were measured using a Minolta CR-400 colorimeter. Chroma (C*) and hue angle (h°) were calculated using the formulas $C^* = (\sqrt{a^* + b^*})$ and $h \circ= tan^{-1}(\frac{b^*}{a^*})$.

Statistical Analysis

Data were analyzed using a 2 x 2 factorial design (broiler type and time interval) with SAS Statistical Discovery Software. Differences among means were tested using Duncan's Multiple Range Test (DMRT) (Hashem et al., 2023, 2024).

Results and Discussion

Sensory evaluation

Color

Table 1 and Table 2 highlight the subjective color scores of broiler breast (4.00–5.00) and thigh meat (3.80–4.80), respectively. Post-rigor meat at 24 hours exhibited significantly ($p<0.05$) superior color compared to pre-rigor meat, with aging enhancing visual appeal in both cases. The findings indicate that aging substantially enhances the color quality of both broiler breast and thigh meat. Post-rigor meat consistently demonstrated superior color scores when juxtaposed with pre-rigor samples, thereby underscoring the significance of appropriate storage duration. Factors such as temperature, diet, stress, myoglobin content, and pH influence poultry meat color (King et al., 2023). The results emphasize that proper aging and storage protocols are crucial for optimizing meat quality and meeting consumer preferences (Wideman et al., 2016).

Table 1: Pre- and post-rigor effects on the sensory attributes of broiler breast meat

Parameters	Treatments: Pre-rigor (mean ±SE)	Post-rigor (mean ±SE)	Level of Significance
Color	$4.00^{b}\pm0.32$	$5.00^{a}\pm0.00$	0.02*
Flavor	$2.60^{b}\pm0.24$	$4.60^{a}\pm0.24$	0.0004***
Texture	$3.00^{b}\pm0.32$	$4.60^{a}\pm0.24$	0.003**
Tenderness	$3.00^{b}\pm0.32$	$4.60^{a}\pm0.24$	0.004**
Overall Acceptability	$3.00^{b}\pm0.32$	$4.60^{a}\pm0.24$	0.004**

Sensory Scores were 5 for excellent, 4 for very good, 3 for good, 2 for fair, and 1 for poor. Mean in each row having differentsuperscript varies significantly at values $p<0.05$, SE = Standard error.

Table 2: Pre- and post-rigor effects on the sensory attributes of broiler thigh meat

Parameters	Treatments: Pre-rigor (mean ±SE)	Post-rigor (mean ±SE)	Level of Significance
Color	$3.80^{b}\pm.37$	$4.80^{a}\pm.20$	0.05*
Flavor	$2.40^{b}\pm.24$	$4.40^{a}\pm.24$	0.0004***
Texture	$3.00^{b}\pm.32$	$4.40^{a}\pm.24$	0.008**
Tenderness	$3.20^{b}\pm.37$	$4.60^{a}\pm.24$	0.01**
Overall Acceptability	$3.20^{b}\pm.37$	$4.60^{a}\pm.24$	0.01**

Sensory Scores were 5 for excellent, 4 for very good, 3 for good, 2 for fair, and 1 for poor. Mean in each row having differentsuperscript varies significantly at values $p<0.05$, SE = Standard error.

Flavor

The flavor scores of broiler breast and thigh meat improved significantly with aging, as shown in Tables 1 and 2. Breast meat scores ranged from 2.60 to 4.60, while thigh meat scores ranged from 2.40 to 4.40, with post-rigor samples at 24 hours exhibiting significantly ($p<0.05$) superior flavor compared to pre-rigor meat. The most desirable flavor was observed in the aged state, indicating that extended storage enhances flavor development (Alam et al., 2024). This improvement is attributed to the production of chemical flavor compounds during post-mortem aging, including sugars, organic acids, peptides, free amino acids, and metabolites of adenine nucleotide metabolism (Xu et al., 2021). The findings highlight the importance of proper aging and storage protocols to optimize flavor and meet consumer preferences for high-quality poultry meat.

Texture and Tenderness

The subjective evaluation of broiler breast and thigh meat (Tables 1 and 2) showed significant ($p<0.05$) improvements in texture and tenderness with aging. Scores ranged from 3.00 to 4.60 for breast meat and 3.00 to 4.40 (texture) and 3.20 to 4.60 (tenderness) for thigh meat, with post-rigor samples consistently superior. These enhancements, driven by post-mortem biochemical changes, align with consumer preferences for tender, high-quality poultry meat.

Meat tenderness is influenced by chemical and physical changes during muscle-to-meat transformation, with rigor mortis causing initial stiffening followed by natural softening that enhances tenderness (Han et al., 2024). The data showed significant ($p<0.05$) improvement in tenderness with storage time, with post-rigor thigh meat being most desirable. Postmortem aging of at least four hours before deboning optimizes tenderness and product quality (Al-Mahdawi, 2022).

Overall acceptability

The overall acceptability of broiler breast and thigh meat improved significantly ($p<0.05$) with aging (Tables 1 and 2). Breast meat scores ranged from 3.00 to 4.60, and thigh meat scores from 3.20 to 4.60, with post-rigor samples at 24 hours being the most favored. These results demonstrate that aging enhances the quality and consumer appeal of broiler meat (Yue et al., 2024).

Physicochemical Properties Evaluation

pH

The pH of broiler breast and thigh meat decreased significantly ($p<0.05$) with aging. For breast meat, the pH ranged from 6.59 at 0 hours to 6.00 at 24 hours, with post-rigor samples showing the most favorable pH. Similarly, for thigh meat, pH decreased from 6.42 to 6.06, with the post-rigor state exhibiting the preferred pH (Tables 3 and 4). These findings highlight a significant degradation in pH as storage time increased, reflecting increased proteolytic activity and protein denaturation during postmortem aging, which release hydrogen ions (Han et al., 2024). Rapid pH reduction due to protein oxidation, cellular changes, and pro-oxidant enzyme release has also been reported (de Avila Souza et al., 2022), aligning with findings that pH declines with extended postmortem aging (J. Ma et al., 2022).

Table 3: Pre- and post-rigor effects on the physicochemical attributes of broiler breast meat

Parameters	Treatments		Level of Significance
	Pre-rigor(mean ±SE)	Post-rigor(mean ±SE)	
p^{H}	6.59^{a}±0.13	6.00^{b}±.03	0.002**
Cooking loss	21.47^{a}±4.04	20.50^{b}±1.20	0.81^{NS}
Water Holding Capacity	90.20^{a}±0.90	89.85^{b}±0.48	0.68^{NS}
Drip Loss	4.84^{b}±.84	5.79^{a}±0.45	0.41^{NS}

Table 4: Pre- and post-rigor effects on the physicochemical attributes of broiler thigh meat

Parameters	Treatments		Level of Significance
	Pre-rigor(mean ±SE)	Post-rigor(mean ±SE)	
pH	6.42^{a}±0.06	6.06^{b}±0.05	0.001***
Cooking loss	23.64^{a}±2.21	22.72^{b}±1.39	0.7^{NS}
Water Holding Capacity	92.55^{b}±0.88	92.70^{a}±0.47	0.9^{NS}
Drip Loss	4.68^{b}±1.19	6.43^{a}±0.82	0.63^{NS}

Cooking Loss and Water Holding Capacity

Cooking loss and water holding capacity (WHC) were assessed for pre- and post-rigor broiler breast and thigh meat at 0 and 24 hours. Breast meat exhibited cooking loss values between 21.47 and 20.50, while thigh meat ranged from 23.64 to 22.72, both showing a slight, non-significant reduction (p>0.05) with aging. Similarly, WHC values for breast meat ranged from 90.20 to 89.85, and for thigh meat, from 92.55 to 92.70, with no significant changes observed (p>0.05) over the storage period (Tables 3 and 4). Cooking loss showed a slight but non-significant reduction in both meat types with aging, suggesting improved moisture retention during cooking due to the stabilization of muscle structure and reduced fiber contraction during rigor resolution (Dutra et al., 2024). Similarly, WHC remained stable across aging periods, aligning with previous reports indicating minimal changes in water retention properties during postmortem aging.

Drip loss

The subjective evaluation of drip loss scores for broiler breast and thigh meat at pre- and post-rigor stages is presented in Tables 3 and 4. For breast meat, the mean scores ranged from 4.84 to 5.79, with post-rigor samples in their fresh state showing the most desirable drip loss, though the observed differences over the storage period were statistically insignificant ($p > 0.05$). Similarly, thigh meat showed mean scores between 4.68 and 6.43, with the most preferable drip loss observed in post-rigor samples at 0 h, and no significant changes noted during storage ($p > 0.05$). These results indicate that post-rigor meat exhibits superior drip loss characteristics in its fresh state, and storage has minimal impact, aligning with findings from similar studies (Kim et al., 2014).

Instrumental Color Evaluation

CIE

The CIE color parameters for broiler breast and thigh meat were evaluated, with results indicating significant differences between pre- and post-rigor states. The L* (lightness) scores for breast meat ranged from 45.36 to 60.69, with post-rigor samples showing significantly higher lightness ($p < 0.05$), especially after aging, which aligns with studies suggesting that protein denaturation during aging enhances lightness. In contrast, thigh meat's L* scores ranged from 52.51 to 54.60, with minimal changes in lightness over storage ($p > 0.05$). For a* (redness), breast meat showed a significant decrease in redness from 5.52 to 2.85 ($p < 0.05$) with aging, while thigh meat exhibited a marginal decrease from 7.17 to 7.08, with no significant change over storage ($p > 0.05$). The b* (yellowness) scores for breast meat ranged from 7.98 to 8.53, with post-rigor samples showing slightly higher yellowness, but no significant change during storage ($p > 0.05$). Thigh meat showed a decrease in yellowness from 7.17 to 4.93, though the storage effects were also insignificant ($p > 0.05$). These findings highlight the effect of post-rigor aging on the lightness and redness of broiler breast meat, with minimal impact on thigh meat, suggesting that aging improves visual quality for breast meat, but not for thigh meat (Nusairat et al., 2022).

Table 05: Pre- and post-rigor effects on the instrumental color values of broiler breast meat

Parameters	Treatments		Level of Significance
	Pre-rigor (mean ±SE)	Post-rigor (mean ±SE)	
CIE L*	45.36^{b}±1.92	60.69^{a}±2.93	0.002**
CIE a*	5.52^{a}±0.64	2.85^{b}±0.72	0.02*
CIE b*	7.98^{b}±1.95	8.53^{a}±1.08	0.8^{NS}
Hue Angle	51.78^{b}±5.26	66.58^{a}±1.93	0.03*
Saturation Index	9.84^{a}±1.89	9.12^{b}±1.07	0.75^{NS}

Table 06: Pre- and post-rigor effects on the instrumental color values of broiler thigh meat

Parameters	Treatments		Level of Significance
	Pre-rigor (mean ±SE)	Post-rigor (mean ±SE)	
CIE L*	52.51^{b}±4.55	54.60^{a}±6.05	0.7^{NS}
CIE a*	7.17^{a}±1.04	7.08^{b}±0.81	0.9^{NS}
CIE b*	7.17^{a}±0.47	4.93^{b}±0.58	0.1^{NS}
Hue Angle	45.90^{a}±4.56	34.93^{b}±3.24	0.09^{NS}
Saturation Index	10.27^{a}±0.78	8.67^{b}±0.87	0.2^{NS}

Hue Angle

The hue angle for broiler breast meat (Table 5) showed a significant increase from 51.78 to 66.58 ($p < 0.05$) during storage, with post-rigor samples exhibiting a more desirable hue in their aged state. Conversely, the hue angle for thigh meat (Table 6) decreased from 45.90 to 34.93 during storage, although this change was not statistically significant ($p > 0.05$).

Saturation Index

The SI for broiler breast meat (Table 5) ranged from 9.84 to 9.12, with post-rigor samples showing slightly higher values in the fresh state. The degradation over storage was insignificant ($p > 0.05$). Similarly, for thigh meat (Table 6), SI values ranged from 10.27 to 8.67, with no significant changes during storage ($p > 0.05$). These findings suggest that post-rigor aging enhances the visual quality of broiler breast meat but has limited effects on thigh meat.

Conclusion

This study demonstrated that post-rigor aging significantly enhances the sensory and physicochemical properties of broiler meat. Sensory attributes, including color, flavor, texture, and tenderness, improved notably in post-rigor meat, making it more desirable. Physicochemical changes, such as decreased pH, increased CIE L* (lightness) and hue angle, and decreased CIE a* (redness), further supported the superiority of post-rigor meat quality.Overall, post-rigor aging is a preferable treatment for enhancing the quality and acceptability of broiler meat, offering valuable insights for improving meat processing and consumer satisfaction.

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