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Early post-mortem quality characteristics of commercially available broiler chicken meat from retail poultry outlets

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Abstract

Commercially available broiler chicken meat marketed through retail poultry outlets undergoes rapid post-mortem physicochemical and biochemical changes that influence freshness, quality and consumer acceptability. The present study evaluated the early post-mortem quality characteristics of commercially available broiler chicken meat under ambient retail conditions. A total of 300 broiler chicken meat samples were analysed, comprising breast and leg muscles collected during 0–2, 2–4 and 4–6 h post-mortem intervals. The samples were evaluated for carcass temperature, pH, R-value, lactic acid concentration, instrumental colour values, thiobarbituric acid reactive substances (TBARS) and bleeding efficiency using the malachite green test. Carcass temperature declined significantly ($P<0.001$) in both breast and leg muscles during the first 6 h post-mortem. Muscle pH decreased progressively, whereas R-value and lactic acid concentration increased significantly, indicating normal progression of post-mortem glycolysis and ATP degradation. Breast muscle showed a gradual increase in lightness (L*) and a significant decline in redness (a*), while colour changes in leg muscle were comparatively less pronounced. Lipid oxidation increased significantly with post-mortem time, with TBARS values reaching 0.40 and 0.47 mg malondialdehyde/kg in breast and leg muscles, respectively, at 4–6 h. The malachite green test detected imperfect bleeding in 8% of breast and 6% of leg muscle samples. These findings provide baseline information on early post-mortem quality changes in commercially available broiler chicken meat and highlight the importance of proper slaughter, handling and timely chilling to preserve freshness and quality under retail conditions.

Keywords: Broiler chicken meat, commercial poultry meat, retail outlets, post-mortem changes, pH, TBARS, lactic acid, colour

Introduction

Poultry meat is one of the most widely consumed animal protein sources worldwide due to its high nutritional value, affordability, ease of preparation and consumer acceptability (Hafez and Attia, 2020) [18]. In India, the rapid growth of the poultry sector has been accompanied by an expansion of retail poultry outlets, where freshly slaughtered broiler chicken meat is commonly marketed under ambient conditions, often without adequate refrigerated storage (Persaud and Landes, 2012; Biswal *et al*., 2020) [9, 41].

During the interval between slaughter and consumer purchase, broiler chicken meat undergoes several post-mortem biochemical and physicochemical changes that directly influence its quality, safety and shelf life. The early post-mortem period is characterised by depletion of glycogen reserves, anaerobic glycolysis, accumulation of lactic acid, decline in muscle pH, ATP degradation and development of rigor mortis (Matayompong, 1991; Onopiuk *et al*., 2016) [34, 39]. These changes subsequently affect important meat quality attributes such as colour, water-holding capacity, tenderness, lipid oxidation and overall freshness (Mir *et al*., 2017) [36].

Retail handling conditions play an important role in determining the rate and extent of post-mortem changes in

poultry meat. Factors such as ambient temperature, delay in chilling, slaughter and dressing practices, hygienic handling and duration of display can influence biochemical reactions, oxidative changes and microbial quality of meat (Hayat *et al*., 2021) [19]. Since commercially available broiler chicken meat is often sold within a few hours after slaughter, assessment of early post-mortem quality characteristics is important for understanding the freshness and acceptability of meat reaching consumers.

Although several studies have evaluated quality changes in poultry meat during refrigerated storage, limited information is available on the early post-mortem physicochemical and biochemical changes occurring in commercially available broiler chicken meat under retail conditions. Such information is essential for generating baseline data on retail poultry meat quality and for improving handling and quality control practices. Therefore, the present study was undertaken to assess the early post-mortem quality characteristics of commercially available broiler chicken meat obtained from retail poultry outlets.

Materials and Methods

Sample collection

A total of 300 commercially available broiler chicken meat samples were collected from retail poultry outlets in and around Thrissur district, Kerala, India. The samples comprised breast and leg muscles collected during three early post-mortem intervals, namely 0–2, 2–4 and 4–6 h. The birds had been slaughtered by the conventional method of severing the major blood vessels without prior electrical stunning. Following slaughter and dressing, the carcasses were maintained under ambient retail conditions until sampling.

Breast and leg muscle samples were collected at 0–2, 2–4 and 4–6 h post-mortem for physicochemical and biochemical analyses. Core temperature was recorded hourly from 1 to 6 h post-mortem.

Core temperature

Core temperature of breast and leg muscles was measured using a digital thermometer (HM Digital TM-1, USA). The probe was inserted into the centre of each muscle until a stable reading was obtained, and the temperature was recorded in degrees Celsius.

pH

Muscle pH was determined using a calibrated digital pH meter (µ pH System, Systronics, India) following the method of O'Halloran *et al*. (1997) [38]. Measurements were recorded by inserting the electrode directly into four different locations of each muscle, and the average value was used for analysis. The pH meter was calibrated using pH 4.0 and 7.0 buffer solutions before measurement.

Instrumental colour values

Instrumental colour values, including lightness (L*), redness (a*) and yellowness (b*), were measured using a calibrated spectrocolorimeter (Lovibond LC 100, Germany) as described by Kannatti *et al*. (2024) [24], with minor modifications. The instrument was calibrated using standard black and white tiles before use. Three readings were taken from different locations on each sample, and the mean value was used for statistical analysis.

R-value

R-value was determined according to Honikel and Fischer (1977) [20]. Briefly, 2 g of muscle sample was homogenised with 0.1 M perchloric acid, filtered and diluted with phosphate buffer of pH 7.0. Absorbance was measured at 250 and 260 nm using a UV-visible spectrophotometer (Systronics, India). The R-value was calculated as the ratio of absorbance at 250 nm to absorbance at 260 nm.

Malachite green test

Bleeding efficiency was assessed qualitatively using the malachite green test following Sasidharan *et al*. (2022) [49]. Muscle extracts were treated with acid malachite green reagent followed by 3% hydrogen peroxide. Samples producing a clear blue colour were considered adequately bled, whereas cloudy green or olive-green reactions were considered indicative of imperfect or unsatisfactory bleeding.

Thiobarbituric acid reactive substances

Lipid oxidation was determined by estimating thiobarbituric acid reactive substances (TBARS) using the modified method of Witte *et al*. (1970) [58]. Muscle samples were homogenised with 20% trichloroacetic acid, filtered and reacted with thiobarbituric acid reagent. After heating in a boiling water bath, absorbance was measured at 532 nm using a UV-visible spectrophotometer (Systronics, India). Results were expressed as mg malondialdehyde/kg meat using a tetraethoxypropane standard curve.

Lactic acid content

Lactic acid concentration was determined using the modified Barker–Summerson method described by Pryce (1969) [46], with minor modifications. Muscle extracts prepared with 20% trichloroacetic acid were reacted with p-hydroxybiphenyl reagent, and absorbance was measured at 565 nm using a UV-visible spectrophotometer (Systronics, India). Results were expressed as mg/g muscle.

Statistical analysis

Data were analysed using SPSS software version 24.0. Changes in physicochemical and biochemical parameters during the post-mortem period were analysed separately for breast and leg muscles using repeated-measures analysis of variance followed by least significant difference test for pairwise comparison. Differences between breast and leg muscles at corresponding post-mortem intervals were analysed using paired t-test. The proportion of samples showing imperfect bleeding in the malachite green test was expressed as percentage. Statistical significance was set at $P < 0.05$.

Results and Discussion

Temperature

Carcass temperature decreased significantly ($P < 0.001$) in both breast and leg muscles during the 6 h post-mortem period (Table 1). Breast muscle temperature declined from 32.11 ± 0.34°C at 1 h to 26.73 ± 0.51°C at 6 h, while leg muscle temperature decreased from 30.17 ± 0.24°C to 27.08 ± 0.15°C during the same period. Breast muscle recorded significantly higher temperature than leg muscle during the initial post-mortem period, whereas no significant difference was observed between the muscles at 5 and 6 h.

Table 1: Temperature (°C) of breast and leg muscles of commercially available (CA) broiler chicken meat during the early post-mortem period.

Muscle	Time interval after death	CA
Breast	1 h	$32.11^{A\alpha} \pm 0.34$
	2 h	$28.92^{B\alpha} \pm 0.13$
	3 h	$28.04^{C\alpha} \pm 0.10$
	4 h	$27.68^{D\alpha} \pm 0.13$
	5 h	$27.32^{E\alpha} \pm 0.15$
	6 h	$26.73^{E\alpha} \pm 0.51$
	F-value(P-value)	67.18** (<0.001)
Leg	1 h	$30.17^{A\beta} \pm 0.24$
	2 h	$28.24^{B\beta} \pm 0.10$
	3 h	$27.70^{C\beta} \pm 0.10$
	4 h	$27.47^{D\beta} \pm 0.12$
	5 h	$27.22^{E\alpha} \pm 0.15$
	6 h	$27.08^{F\alpha} \pm 0.15$
	F-value(P-value)	95.15** (<0.001)

** Significant at 0.01 level

CA- Commercially available

Means having different capital letter as superscript differ significantly within a column for each muscle

Means having different Greek letter as superscript differ significantly between muscles within each group and time interval

The progressive decline in temperature observed in both muscles reflects normal post-mortem heat dissipation following slaughter. After cessation of circulation and metabolic activity, body heat is gradually lost from the carcass until equilibrium with the surrounding environment is reached. Under ambient retail conditions, carcass cooling occurs more slowly than under refrigerated storage, allowing biochemical reactions such as glycolysis, ATP degradation and rigor development to continue during the early post-mortem period.

The initially higher temperature recorded in breast muscle may be related to differences in muscle size, anatomical location, fibre composition and metabolic activity. Broiler breast muscle is predominantly glycolytic and may undergo faster post-mortem biochemical activity than leg muscle, which contains a higher proportion of oxidative fibres. Differences in muscle structure and metabolic characteristics can therefore influence the rate of heat loss and post-mortem temperature decline.

Ambient temperature is an important factor influencing post-mortem carcass cooling and subsequent meat quality (Sauer *et al*., 2024). Listos *et al*. (2021) [31, 50] also reported that carcass temperature gradually declines after death until it reaches equilibrium with the surrounding environment. The declining temperature pattern observed in the present study is consistent with the normal process of algor mortis described during early post-mortem changes.

Temperature decline plays a critical role in determining the rate of post-mortem biochemical changes. The gradual reduction observed in the present study would have permitted continuation of glycolysis and associated pH decline during the early post-mortem period. Monitoring carcass temperature during the first few hours after slaughter is therefore important for maintaining freshness, controlling biochemical deterioration and improving the quality of broiler chicken meat marketed through retail poultry outlets.

pH

Muscle pH decreased significantly with increasing post-mortem time in both breast and leg muscles. In breast muscle, pH declined from 6.06 ± 0.02 during 0–2 h to 5.79 ± 0.02 during 4–6 h, whereas in leg muscle it decreased from 6.25 ± 0.02 to 6.04 ± 0.03 during the same period. At all sampling intervals, leg muscle maintained significantly higher pH values than breast muscle.

The post-mortem decline in pH is a characteristic biochemical change occurring during the conversion of muscle to meat. After slaughter, cessation of blood circulation limits oxygen supply to the muscle, and energy production shifts from aerobic metabolism to anaerobic glycolysis. During this process, muscle glycogen is converted into lactic acid, resulting in progressive acidification of the muscle tissue (Berri *et al*., 2005; Kuźniacka *et al*., 2020) [5, 7]. The decline in pH continues until glycogen reserves are depleted or glycolytic enzyme activity is inhibited by the acidic environment (Kowalska *et al*., 2020 [28]; Połtowicz, 2012).

The progressive reduction in pH observed in the present study indicates normal post-mortem glycolysis in commercially available broiler chicken meat. Similar post-mortem acidification patterns in poultry meat have been reported by Mir *et al*. (2017) [36], Gerônimo *et al*. (2018) and Ramanathan *et al*. (2020) [5], who related pH decline to glycogen degradation, lactic acid accumulation and post-mortem energy metabolism.

The greater pH decline observed in breast muscle may be attributed to its predominantly glycolytic fibre composition and higher glycogen content. Breast muscle contains a higher proportion of fast-twitch glycolytic fibres, which favour rapid glycogen breakdown and faster lactic acid accumulation after slaughter. In contrast, leg muscle contains a greater proportion of oxidative fibres and therefore shows comparatively slower acidification and higher pH during the early post-mortem period (Awad *et al*., 2019; Baldi *et al*., 2020; Brothers *et al*., 2019; Portillo-Salgado *et al*., 2023) [4, 5, 11, 45].

Muscle pH is an important determinant of meat quality because it influences protein denaturation, water-holding capacity, colour development, tenderness, lipid oxidation and microbial stability (Chaijan, 2008) [12]. The pH values recorded in the present study were within the expected range for normally progressing post-mortem metabolism in broiler chicken meat. Therefore, the gradual pH decline observed in both breast and leg muscles indicates normal biochemical conversion of muscle to meat and provides useful baseline information on the freshness and quality of commercially available broiler chicken meat marketed through retail outlets.

Table 2: pH, R value, of breast and leg muscles of commercially available broiler (CA) chicken meat during the early post-mortem period.

Muscle	Time interval after death (h)	pH	R Value
Breast	0-2	$6.06^{A\beta} \pm 0.02$	$1.27^{B\alpha} \pm 0.01$
	2-4	$5.90^{B\beta} \pm 0.02$	$1.28^{B\alpha} \pm 0.01$
	4-6	$5.79^{C\beta} \pm 0.02$	$1.33^{A\alpha} \pm 0.01$
	F-value (P-value)	87.579** (<0.001)	26.070** (<0.001)
Leg	0-2	$6.25^{A\alpha} \pm 0.02$	$1.15^{C\beta} \pm 0.01$
	2-4	$6.10^{B\alpha} \pm 0.03$	$1.19^{B\beta} \pm 0.01$
	4-6	$6.04^{C\alpha} \pm 0.03$	$1.26^{A\beta} \pm 0.01$
	F-value(P-value)	40.333** (<0.001)	68.354** (<0.001)

** Significant at 0.01 level

CA- Commercially available

Means having different capital letter as superscript differ significantly within a column for each muscle

Means having different Greek letter as superscript differ significantly between muscles within each group and time interval

R-value

R-value, expressed as the absorbance ratio at 250 nm to 260 nm, is an important biochemical indicator of post-mortem ATP degradation and rigor mortis development. In the present study, R-value increased significantly with increasing post-mortem time in both breast and leg muscles of commercially available broiler chicken meat. Breast muscle R-value increased from 1.27 ± 0.01 during 0–2 h to 1.33 ± 0.01 during 4–6 h, whereas leg muscle R-value increased from 1.15 ± 0.01 to 1.26 ± 0.01 during the same period. Breast muscle consistently recorded higher R-values than leg muscle throughout the early post-mortem period.

The progressive increase in R-value indicates normal post-mortem ATP depletion and advancement of rigor mortis. Following slaughter, oxygen supply to the muscle is interrupted and ATP regeneration becomes limited. As post-mortem metabolism progresses, ATP is degraded into nucleotide breakdown products such as inosine monophosphate, inosine and hypoxanthine, leading to an increase in R-value. Similar observations were reported by Honikel and Fischer (1977) and Honikel and Hamm (1978) [20, 21], who described R-value as a useful indicator of post-mortem energy metabolism and ATP degradation.

The higher R-values observed in breast muscle may be attributed to its predominantly glycolytic fibre composition. Glycolytic muscles generally undergo faster ATP depletion and post-mortem biochemical changes than oxidative muscles. In contrast, leg muscle contains a higher proportion of oxidative fibres and therefore may show comparatively slower ATP degradation during the early post-mortem period. The concurrent increase in R-value, decline in pH and increase in lactic acid concentration observed in the present study confirms the coordinated progression of post-mortem glycolysis, ATP degradation and rigor development in commercially available broiler chicken meat. McKee and Sams (1998) [35] also reported that carcass temperature and post-mortem glycolytic rate can influence ATP breakdown and rigor mortis development. Therefore, R-value provides useful supportive information for assessing freshness and post-mortem biochemical progression in broiler chicken meat under retail conditions.

Malachite Green Test

The malachite green test revealed imperfect bleeding in 8.0% of breast muscle samples and 6.0% of leg muscle samples collected from retail poultry outlets. The majority of the samples showed a clear blue reaction, indicating adequate bleeding following slaughter. Only a small proportion of samples produced cloudy green or olive-green reactions, suggesting residual blood retention and imperfect bleeding.

The malachite green test is a rapid qualitative screening method used to detect residual haemoglobin in meat and assess bleeding efficiency. Efficient exsanguination is important for maintaining meat quality because residual blood can affect meat appearance, promote oxidative deterioration and support microbial growth. Shylaja *et al*. (2001) [51] reported that the malachite green test is useful for identifying meat with poor bleeding efficiency. Similarly, Sohaib *et al*. (2020) [54] observed that meat from improperly bled or dead birds showed quality and safety differences compared with properly slaughtered poultry meat.

The low proportion of positive samples observed in the present study indicates that most commercially available broiler chicken meat samples from retail poultry outlets were adequately bled before marketing. However, the presence of imperfect bleeding in a small percentage of samples suggests variation in slaughtering and bleeding practices among retail outlets. Such variation may be due to differences in slaughter technique, bleeding time, bird condition before slaughter and handling practices. Residual blood may also accelerate oxidative deterioration because haem pigments can act as pro-oxidants, thereby affecting colour stability and shelf life of meat. Noraldin and Sabow (2022) [37] also emphasised the importance of bleeding efficiency in determining carcass quality and meat characteristics.

Overall, the malachite green test served as a simple and practical screening tool for assessing bleeding efficiency in commercially available broiler chicken meat. Although most samples showed satisfactory bleeding, routine monitoring of bleeding efficiency may help improve quality control and ensure better freshness and acceptability of poultry meat marketed through retail outlets

Table 3: Incidence of imperfect bleeding in commercially available broiler chicken meat as determined by the malachite green test.

Group	Number of samples showing imperfect bleeding			
	Breast, n=50		Leg, n=50	
	Number	Per cent	Number	Per cent
CA	4	8.0	3	6.0

Thiobarbituric Acid Reactive Substances (TBARS)

TBARS values increased significantly ($P < 0.001$) with increasing post-mortem time in both breast and leg muscles. In breast muscle, TBARS values increased from 0.19 ± 0.01 mg malondialdehyde/kg during 0–2 h to 0.40 ± 0.01 mg malondialdehyde/kg during 4–6 h. Similarly, in leg muscle, the values increased from 0.18 ± 0.01 to 0.47 ± 0.01 mg malondialdehyde/kg during the same period. Lipid oxidation was significantly higher in leg muscle than in breast muscle at 2–4 h and 4–6 h post-mortem.

Table 4: TBARS values (mg malondialdehyde/kg meat) and Lactic acid concentration (mg/g) of breast and leg muscles of commercially available broiler chicken meat during the early post-mortem period.

Muscle	Time interval after death (h)	TBARS values (mg malondialdehyde/kg meat)	Lactic acid concentration (mg/g)
Breast	0-2	$0.19^{C\alpha} \pm 0.01$	$2.10^{C\alpha} \pm 0.09$
	2-4	$0.28^{B\beta} \pm 0.01$	$3.37^{B\alpha} \pm 0.17$
	4-6	$0.40^{A\beta} \pm 0.01$	$4.38^{A\alpha} \pm 0.2$
	F-value (P-value)	201.059** (<0.001)	54.783** (<0.001)

Leg	0-2	$0.18^{C\alpha} \pm 0.01$	$1.96^{C\alpha} \pm 0.08$
	2-4	$0.34^{B\alpha} \pm 0.01$	$2.46^{B\beta} \pm 0.1$
	4-6	$0.47^{A\alpha} \pm 0.01$	$3.15^{A\beta} \pm 0.12$
	F-value (P-value)	389.65** (<0.001)	45.483** (<0.001)

** Significant at 0.01 level

CA- Commercially available

Means having different capital letter as superscript differ significantly within a column for each muscle

Means having different Greek letter as superscript differ significantly between muscles within each group and time interval

The progressive increase in TBARS values indicates the formation of secondary lipid oxidation products during the early post-mortem period. After slaughter, disruption of cellular membranes, depletion of endogenous antioxidant systems and exposure of membrane phospholipids to pro-oxidant factors promote oxidative reactions, leading to the formation of malondialdehyde and other aldehydic compounds (Chaijan, 2008) [12]. The higher TBARS values observed in leg muscle may be attributed to its greater myoglobin concentration, oxidative fibre composition and phospholipid content, which increase its susceptibility to oxidative deterioration.

Residual blood components, particularly haemoglobin and other haem pigments, may further contribute to lipid oxidation by acting as pro-oxidants. Free iron released from haem proteins can catalyse oxidative reactions and accelerate the formation of peroxides, carbonyl compounds and malondialdehyde (Alvarado *et al*., 2007; El-Tarabany *et al*., 2022 [3, 14]; Xu *et al*., 2018). Therefore, even minor differences in bleeding efficiency and residual blood content may influence oxidative stability in retail poultry meat.

Similar increases in TBARS values during post-mortem storage of poultry meat have been reported by Sohaib *et al*. (2020), Noraldin and Sabow (2022) and Belore *et al*. (2023) [6, 37, 54]. Although lipid oxidation increased significantly during the 6 h observation period, the recorded TBARS values remained below the level generally associated with perceptible rancidity, indicating acceptable oxidative stability during the early post-mortem period (Esposito *et al*., 2022) [15]. However, the increasing trend highlights the need for prompt chilling, hygienic handling and proper retail storage to minimise oxidative deterioration and preserve the freshness, sensory quality and nutritional value of commercially available broiler chicken meat.

Lactic acid

Lactic acid concentration increased significantly ($P < 0.001$) in both breast and leg muscles during the early post-mortem period. In breast muscle, lactic acid concentration increased from 2.10 ± 0.09 mg/g during 0–2 h to 4.38 ± 0.20 mg/g during 4–6 h. In leg muscle, the values increased from 1.96 ± 0.08 to 3.15 ± 0.12 mg/g during the same period. Breast muscle recorded consistently higher lactic acid concentration than leg muscle at all post-mortem intervals.

The progressive increase in lactic acid reflects the continuation of anaerobic glycolysis after slaughter. Following cessation of blood circulation and oxygen supply, muscle glycogen is converted into lactic acid, which accumulates within the muscle tissue and contributes to the decline in pH and development of rigor mortis (Lawrie and Ledward, 2006) [30]. In the present study, an inverse relationship between lactic acid concentration and pH was clearly observed. As lactic acid concentration increased from 0–2 h to 4–6 h, pH values declined correspondingly in both breast and leg muscles. This indicates that post-mortem acidification in commercially available broiler chicken meat was mainly associated with lactate accumulation.

Similar observations were reported by Bodwell *et al*. (1965) [10], who observed an increase in lactic acid concentration along with a decline in muscle pH during the early post-mortem period. Šimek *et al*. (2003) also reported progressive increases in lactic acid concentration after slaughter and observed a negative association between lactic acid level and pH. The higher lactic acid concentration recorded in breast muscle may be attributed to its predominantly glycolytic fibre composition and greater glycogen reserves, resulting in faster post-mortem glycolysis than in leg muscle. Similar muscle-specific differences have been reported by Petracci *et al*. (2015), Suman and Joseph (2012) and Zhang *et al*. (2012) [43, 55, 61].

Variations in pre-slaughter handling, stress, fasting and transport conditions may also influence muscle glycogen reserves and alter post-mortem glycolytic rate, lactic acid accumulation and ultimate pH (Alam *et al*., 2023; Irfan *et al*., 2023; Wu *et al*., 2023) [2, 22]. However, the progressive increase in lactic acid observed in the present study, together with the decline in pH and increase in R-value, confirms the normal progression of post-mortem metabolism in commercially available broiler chicken meat under retail conditions.

Instrumental colour

Lightness (L* value)

Lightness (L*) increased significantly in breast muscle during the post-mortem period, whereas no significant change was observed in leg muscle. Breast muscle showed a gradual increase in L* value from 0–2 h to 4–6 h post-mortem, while leg muscle values remained relatively stable throughout the observation period.

The increase in breast muscle lightness may be associated with post-mortem pH decline, protein denaturation and changes in intracellular water distribution, which increase light scattering from the muscle surface (Ahmad *et al*., 2015) [1]. Breast muscle is predominantly composed of glycolytic fibres and undergoes faster post-mortem acidification than leg muscle. This rapid pH decline may promote structural changes in muscle proteins and contribute to increased surface reflectance. Similar observations were reported by Petracci and Fletcher (2002) [42], who described the relationship between post-mortem pH decline and changes in poultry meat colour.

The relatively stable L* values observed in leg muscle may be due to its higher myoglobin concentration and oxidative fibre composition, which influence light absorption and

reduce visible changes in surface lightness during the early post-mortem period. The modest increase in breast muscle lightness observed in the present study is therefore consistent with its greater pH decline and glycolytic nature.

Redness (a* value)

Redness (a*) decreased significantly in breast muscle during the study period, whereas no significant change was observed in leg muscle. Leg muscle consistently recorded higher a* values than breast muscle at all post-mortem intervals.

The reduction in redness of breast muscle during the early post-mortem period may be attributed to changes in haem pigment chemistry and gradual oxidation of myoglobin. The faster pH decline in breast muscle may also influence pigment stability and surface colour expression. In contrast, the higher redness of leg muscle is mainly due to its greater myoglobin concentration and higher proportion of oxidative fibres compared with breast muscle (Suman and Joseph, 2012) [55]. These characteristics contribute to darker colour and greater pigment stability in leg muscle.

Similar reductions in redness during post-mortem storage have been reported by Fletcher (2002) and Qiao *et al.* (2002) [16, 47]. The present findings indicate that muscle type has a stronger influence on redness than post-mortem interval during the early period under ambient retail conditions. The higher a* values in leg muscle reflect its oxidative metabolic profile, greater haem pigment content and comparatively higher pH, which together help maintain redness during early post-mortem changes.

Yellowness (b* value)

Yellowness (b*) did not differ significantly among post-mortem intervals in either breast or leg muscle. Although minor numerical variations were observed, b* values remained relatively stable throughout the 6 h observation period.

The absence of significant change in b* values suggests that yellowness is comparatively stable during the early post-mortem period and is less affected by immediate biochemical changes after slaughter than lightness and redness. Similar findings were reported by Alvarado *et al.* (2007) [3], who observed minimal changes in yellowness during early post-mortem storage of broiler meat.

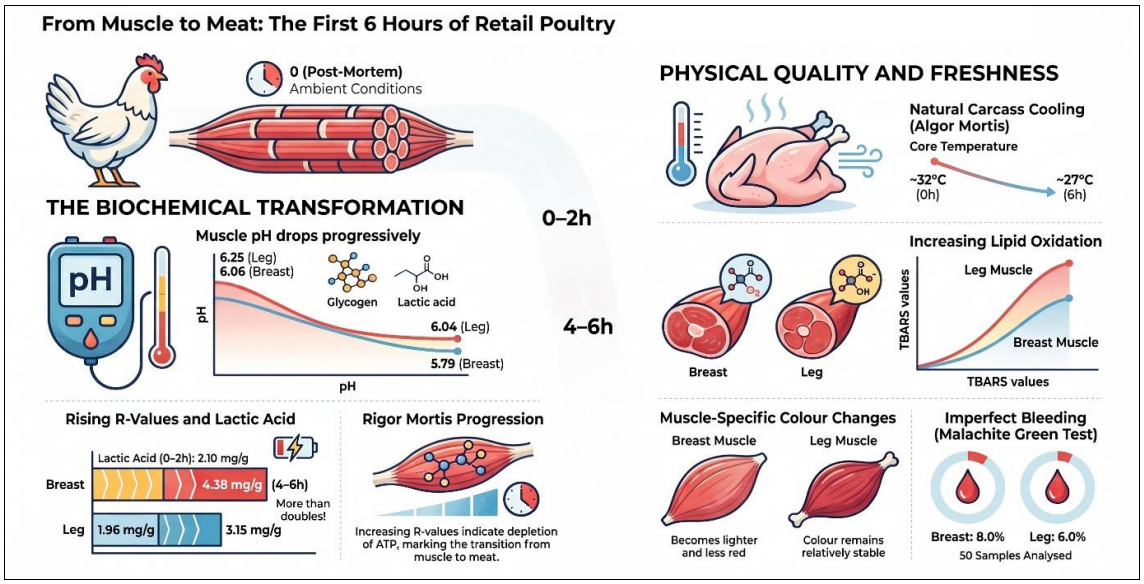
Yellowness in poultry meat may be influenced by pigment composition, lipid content, oxidation status and dietary carotenoid deposition. In the present study, the relatively low level of oxidative deterioration during the early post-mortem period may have contributed to the stability of b* values. Therefore, while L* and a* showed muscle-specific changes, yellowness remained comparatively stable in both breast and leg muscles of commercially available broiler chicken meat.

Table 5: L*, a* and b* values of breast and leg muscles of commercially available broiler chicken meat during the early post-mortem period.

Muscle	Time interval after death (h)	L* value	a* value	b* value
Breast	0-2	$34.10^{B\beta} \pm 0.6$	$3.94^{A\beta} \pm 0.47$	$10.34^{b\beta} \pm 0.56$
	2-4	$35.31^{AB\alpha} \pm 0.67$	$2.67^{B\beta} \pm 0.22$	$10.82^{b\alpha} \pm 0.41$
	4-6	$36.05^{A\alpha} \pm 0.72$	$2.04^{C\beta} \pm 0.18$	$10.89^{b\alpha} \pm 0.45$
	F-value (P-value)	3.387* (0.045)	9.282** (0.001)	0.398^{ns} (0.673)
Leg	0-2	$36.78^{\alpha} \pm 0.77$	$8.16^{\alpha} \pm 0.55$	$11.76^{a\alpha} \pm 0.68$
	2-4	$36.55^{\alpha} \pm 0.62$	$7.81^{\alpha} \pm 0.48$	$11.38^{a\alpha} \pm 0.52$
	4-6	$35.8^{\alpha} \pm 0.74$	$7.98^{\alpha} \pm 0.47$	$10.96^{a\alpha} \pm 0.5$
	F-value(P-value)	0.564^{ns} (0.571)	0.177^{ns} (0.818)	0.501^{ns} (0.608)

** Significant at 0.01 level; * Significant at 0.05 level; ns non-significant

Graphical Abstract



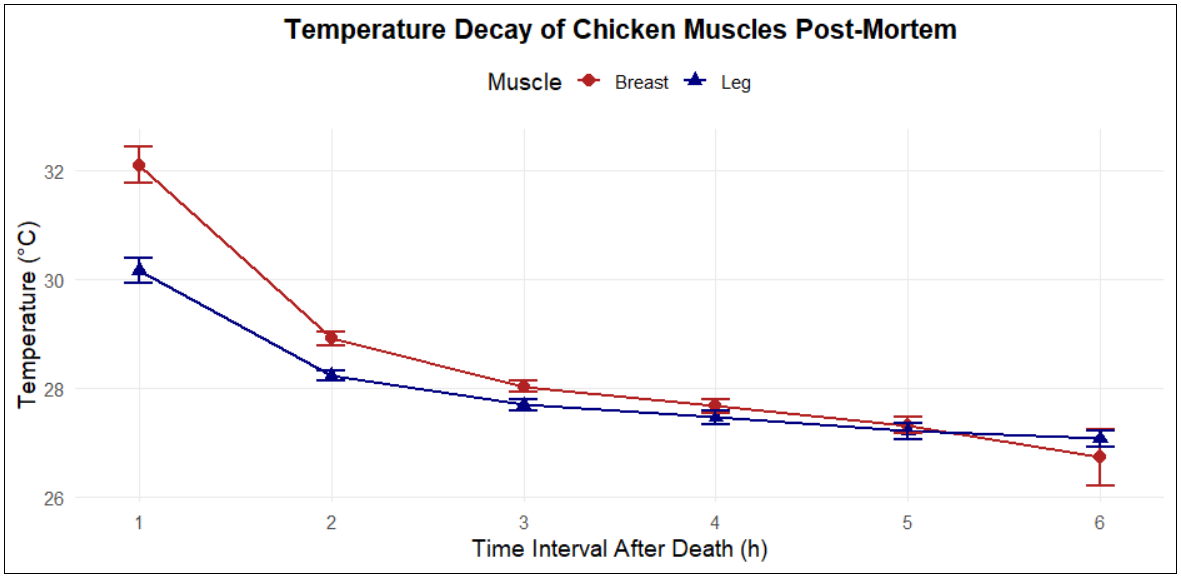


Fig 1: Temperature changes in breast and leg muscles during early post-mortem period

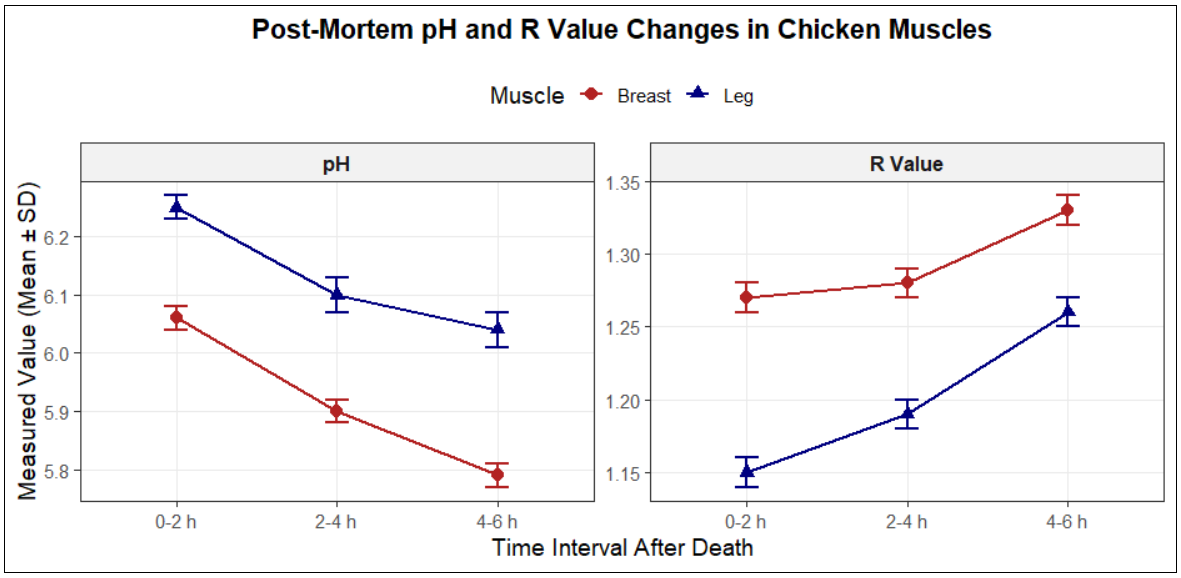


Fig 2: pH and R-value changes in breast and leg muscles

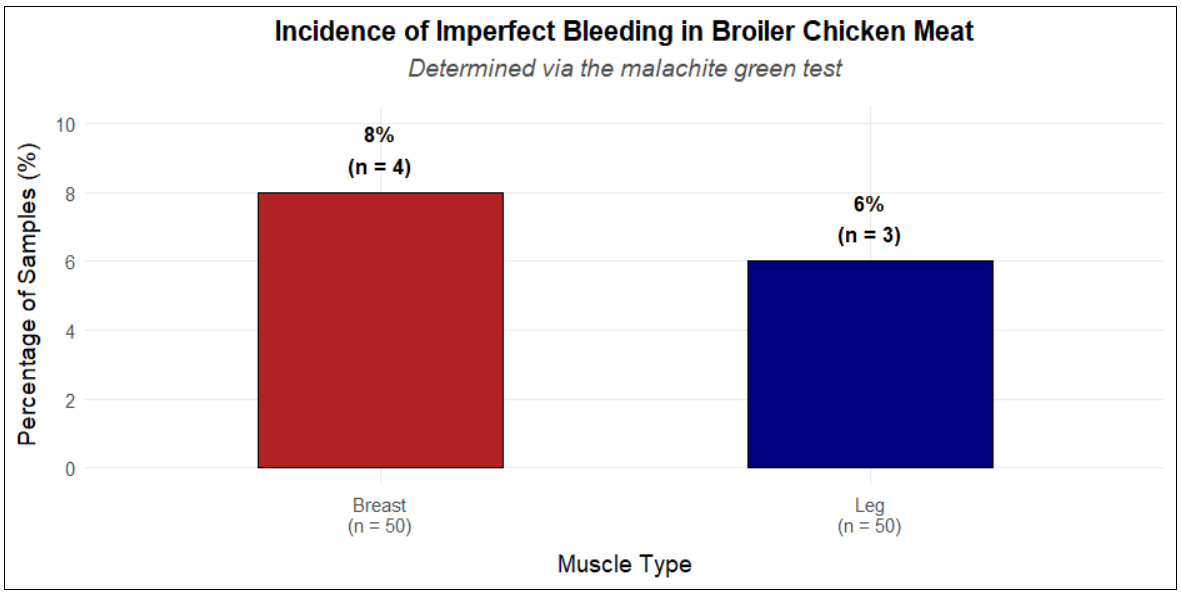


Fig 3: Incidence of imperfect bleeding in commercially available broiler chicken meat as determined by the malachite green test

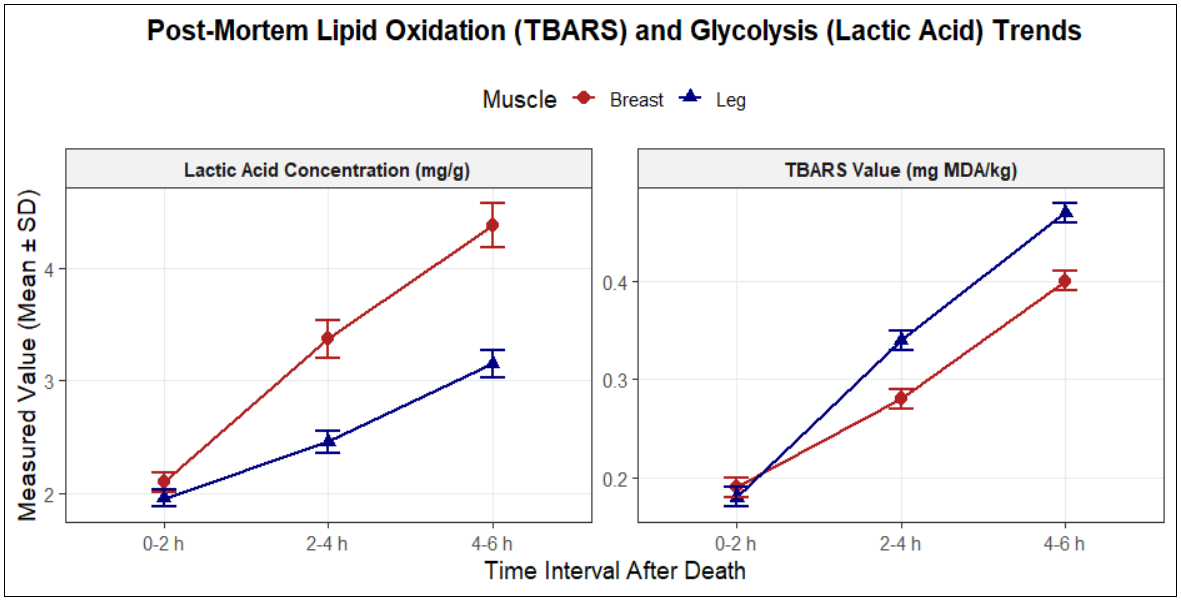


Fig 4: TBARS and lactic acid changes during early post-mortem period

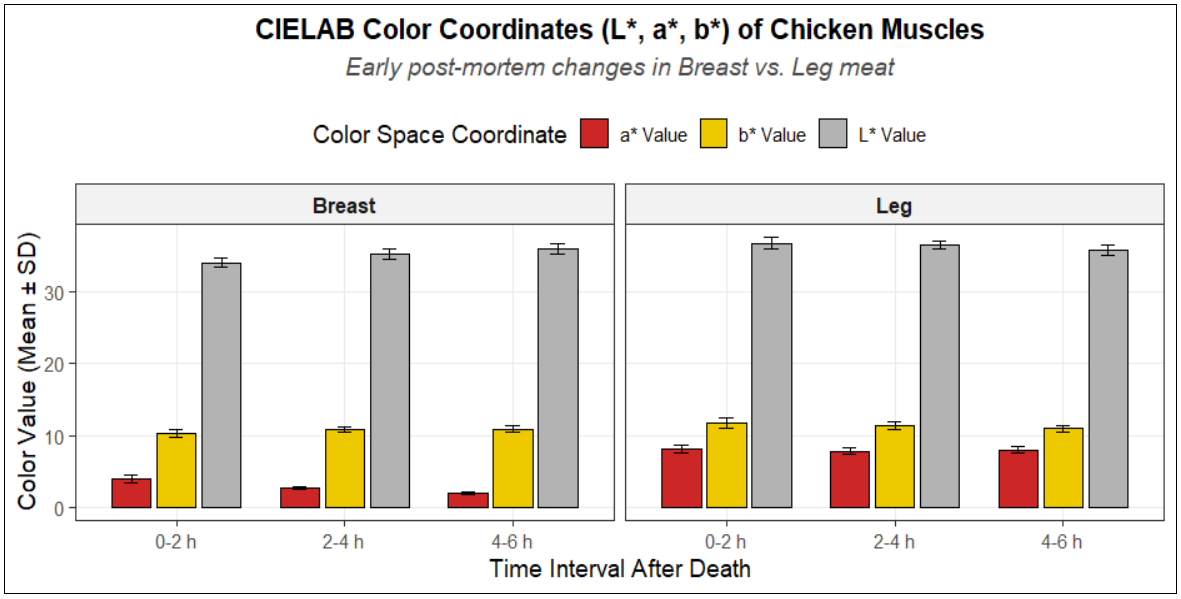


Fig 5: Instrumental colour values of breast and leg muscles

CA- Commercially available

Means having different capital letter as superscript differ significantly within a column for each muscle

Means having different Greek letter as superscript differ significantly between muscles within each group and time interval

Conclusion

The present study demonstrated progressive physicochemical and biochemical changes in commercially available broiler chicken meat during the early post-mortem period under retail conditions. Significant reductions in carcass temperature and muscle pH, along with increases in R-value and lactic acid concentration, confirmed the normal progression of post-mortem glycolysis, ATP degradation and rigor development. TBARS values also increased with time, indicating gradual lipid oxidation, although the values remained within acceptable limits during the 6 h observation period. Instrumental colour changes were more evident in breast muscle, which showed increased lightness and reduced redness, while yellowness remained relatively stable in both breast and leg muscles. The malachite green test revealed imperfect bleeding in a small proportion of samples, indicating variation in bleeding efficiency among retail poultry outlets. Overall, the findings provide useful baseline information on the early post-mortem quality characteristics of 300 commercially available broiler chicken meat samples and emphasise the importance of proper slaughter, hygienic handling, prompt chilling and improved retail storage practices to preserve freshness, quality and consumer acceptability.

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Conflict of interest

The authors declare that they have no conflict of interest.

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Ethical statement
The study was conducted using commercially available broiler chicken meat samples collected from retail poultry outlets. No live-animal experiment was conducted as part of this study.

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