Effect of Purchasing Time and Market Stall on the Physicochemical Characteristics and Microbiological Quality of Broiler Breast and Thigh Sold in a Public Market within Los Baños, Laguna

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Abstract

In the Philippines, >70% of chicken meat is distributed through wet markets with uncertain quality attributes at point-of-sale. Thus, it is important to determine the effect of purchasing time and market stall on the physicochemical and microbiological qualities of raw chicken breast and thigh. Samples were purchased from two randomly selected stalls at 7:00 AM, 11:00 AM, and 3:00 PM. Aerobic plate count (APC) and enumeration of E. coli and total coliforms were conducted. Temperature, pH, meat color, water-holding capacity (WHC), thiobarbituric acid reactive substances (TBARS), and Warner-Bratzler shear force (WBSF) were measured. For chicken breast, there was a significant interaction between purchasing time and market stall for the microbiological quality, temperature, pH, WBSF, and color. There was a significant interaction between the microbiological quality and temperature for the chicken thigh. For breast, pH negatively correlated with APC, log CFU/g E. coli, and total coliforms ($r = -0.43$, $r = -0.60$, $r = -0.38$, respectively, $n = 36$, $p < 0.05$). For chicken thigh, temperature positively correlated with APC, log CFU/g E. coli, and total coliforms ($r = 0.44$, $r = 0.72$, $r = 0.62$, respectively, $n = 36$, $p < 0.05$). Log CFU/g E. coli positively correlated to pH and TBARS ($r = 0.54$, $r = 0.33$, respectively, $n = 36$, $p < 0.05$). The study revealed that the effects of purchasing time on the quality of chicken meat depend on the market stall conditions.

Keywords: chicken, microbiological quality, physicochemical characteristics, time, wet market

1. Introduction

In the Philippines, chicken is a staple protein source, with a forecasted annual consumption of 1.998 million metric tons (USDA Foreign Agricultural Service [USDA-FAS], 2024). Wet markets remain the primary distribution outlet for fresh chicken meat (USDA-FAS, 2020), and many Filipinos still consider meat from wet markets as fresher and cheaper than that sold frozen in supermarkets (Pascual *et al*., 2019). However, many fresh chicken sold in these wet markets comes from non-accredited dressing plants that supply unbranded chicken. These plants are not accredited by the National Meat Inspection Services (NMIS). They are only required to comply with the Code of Sanitation in the Philippines (PD 856), as enforced by local government units (Gonzales *et al*., 2021). The less stringent regulations for these chicken products pose a concern for food safety and perishability. The wet market environment further increases the risk of microbial contamination due to a high volume of foot traffic, a lack of infrastructure for hygiene (i.e., toilets, handwashing stations), and the open-air display of raw products (Nadimpalli and Pickering, 2020; Gonzales *et al*., 2021).

Given the distribution of chicken meat in the Philippines, it is necessary to monitor its quality to uphold food safety. The microbiological quality and physicochemical characteristics of meat play a crucial role in determining the acceptability of chicken meat. Regarding microbiological quality, it is known that microbial growth can occur in chicken meat under refrigerated and even frozen conditions. However, the rates of growth can vary depending on the initial microbiological load of the meat. In an experiment involving the storage of chicken at ambient conditions for 12 hours, Manalo and Gabriel (2020) found that from an initial aerobic plate count of 5.20 Log CFU/g, the counts increased to 7.55 Log CFU/g after six hours and 8.87 Log CFU/g after twelve hours. Meanwhile, Ab Aziz *et al*. (2020) found that coliform and *Salmonella* populations in refrigerated broiler breast did not significantly differ between 24 and 72 hours in frozen storage. The studies highlight how spoilage rates of chicken meat can vary greatly based on the initial load and storage conditions.

Some of the important physicochemical characteristics for evaluating chicken meat quality include temperature, pH, water holding capacity (WHC), shear force, color, and lipid oxidation (as thiobarbituric acid reactive substances, TBARS). These parameters are used to gauge the freshness of chicken meat and have been relatively well studied with regards to how they change in relation to time and microbial spoilage.

Regarding pH, it is known that the pH of broiler meat decreases from 7.0–7.2 (living muscle) to a value of 5.3–5.7 after 24 hours post-mortem due to the anaerobic breakdown of glycogen into lactic acid, leading to the acidification of the muscle tissue (Mir *et al*., 2017; Zybert *et al*., 2014). However, during extended storage, once available carbohydrates are depleted, meat pH may rise due to the utilization of amino acids by bacteria, which results in the accumulation of alkaline nitrogenous compounds such as ammonia and amines (Allen *et al*., 1997; Zhang *et al*., 2016).

Meanwhile, meat color depends on the myoglobin content in the muscles, the oxidative state of myoglobin, and the meat pH. It is believed that extended storage and repeated freezing and thawing can cause the denaturation of myoglobin, resulting in autoxidation and loss of color presentation. Other studies suggest that the loss of color is due to the reduced enzymatic activity of the system responsible for reducing metmyoglobin back to myoglobin (Hayat *et al*., 2021; Leygonie *et al*., 2012). Hayat *et al*. (2021) found that, for freshly slaughtered chicken breast, longer durations of cold transport (1 h, 5 h) resulted in lighter meat, regardless of temperature (4, 10, 15 °C). In contrast, the study by Ab Aziz *et al*. (2020) found that extended storage (72 h vs. 24 h) resulted in significantly darker meat at various storage temperatures (4, -10, -18, and -40 °C).

For water holding capacity and drip loss, it is generally believed that more extended periods of frozen storage result in reduced water holding capacity, consequently increasing drip loss. The reduction in water holding capacity is attributed to the formation of ice crystals, which rupture tissue membranes, and the movement of water from intracellular to extracellular spaces (Leygonie *et al*., 2012).

Although the effects of storage time and temperature on the quality of chicken meat have been previously studied, very few have examined how chicken meat deteriorates in a wet market setting. To address this gap, this study aimed to determine the effect of purchasing time and market stall on the physicochemical characteristics and microbiological quality of chicken breasts and chicken thighs sold in a wet market within Los Baños, Laguna. The study also aimed to identify potential relationships between changes in microbiological quality and changes in physicochemical characteristics.

The data generated by this study provides empirical data that can supplement efforts to model and predict chicken meat quality. Meanwhile, the implications of this study can be used by policymakers to push for more

consistent practices in the wet market, ensuring that hygienic quality is consistent between and among market stalls. Ultimately, this study contributes to the goal of ensuring that safe and acceptable poultry products are being sold to consumers in the wet market, which for many is the primary avenue for accessing animal protein.

2. Methodology

2.1 Experimental Design

A completely randomized design was employed to test the effects of purchasing time and market stall on broiler breast and thigh quality. Three-factor levels were used for purchasing time: 7:00 AM, 11:00 AM, and 3:00 PM. Two factor levels were used for the market stalls: Stall 1 and Stall 2. The two stalls were randomly selected among the stalls present in a wet market within Los Baños, Laguna, Philippines. Breast and thigh parts were treated as separate populations and analyzed separately.

To determine microbiological quality, two replicate cuts of raw chicken were randomly sampled for each treatment. To measure pH, temperature, color, and water-holding capacity (WHC), another two replicate cuts of raw chicken were sampled for each treatment. For assessing cook loss, Warner-Bratzler shear force (WBSF), and thiobarbituric acid reactive substance (TBARS), an additional three replicate cuts were sampled for each treatment.

2.2 Sample Collection

The raw chicken breast and thigh samples were randomly purchased from two stalls in the public market within Los Baños, Laguna. The samples were packed in clear polyethylene plastic bags (‘*plastic linaw’*) provided by the market vendors and temporarily stored in a clean Styrofoam ice box. The chicken samples used for the determination of microbiological quality and for measuring the pH, temperature, and color were immediately processed upon arrival in the laboratory. Meanwhile, the samples used for the water-holding capacity and shear force parameters were vacuum-sealed and stored in the freezer for at least 24 hours before analysis.

2.3 Determination of Microbiological Quality of Broiler Breast and Thigh

2.3.1 Sample Preparation

Sample preparation was based on the Bacteriological Analytical Manual (BAM), 'Chapter 1: Food Sampling/Preparation of Sample Homogenate' by Andrews and Hammack (2022). Sample preparation was conducted in an isolation room after the working area had been sterilized with an overhead UV light for fifteen minutes. The skin and surface film were removed from each chicken sample using a sterile, stainless steel kitchen knife. Afterwards, 25 grams of meat were sliced off and placed in a sterile sampling bag containing 225 mL of sterilized 0.1% peptone water (TMMedia 1505). This was then homogenized using a stomacher (Stomacher® Lab-Blender 400) for 2 minutes. The homogenate was serially diluted in screwcap tubes containing 0.1% peptone water to obtain 10-3, 10-4, and 10-5 dilutions. Before any transfers, the tubes were shaken using a vortex mixer (Hercuvan TT-2800-VVM) for 10 to 15 seconds. Sterile 0.1% peptone water was employed as the negative control.

2.3.2 Aerobic Plate Count (APC)

The methods for the aerobic plate count were adapted from BAM Chapter 3: Aerobic Plate Count (Maturin and Peeler, 2001; Klaharn *et al*., 2022). Plate Count Agar was prepared according to the manufacturer's instructions (HiMedia M091, 2023) and sterilized using a pressure cooker at 15 psi for 15 min. 10-4 and 10-5 dilutions were plated in triplicate at 1 mL of sample volume. Pour plating was conducted aseptically under a class 2 biological safety cabinet (BIOBASE BSC-1100IIB2-X). After the plates had solidified, they were stacked in an inverted position inside a sterile polyethylene bag closed with loose rubber bands, maintaining an aerobic environment. They were placed inside an incubator (Lab-Line Imperial II) for 24±2 h at 35±1 °C. After incubation, the plates were observed, and the CFU was computed according to the guidelines in BAM Chapter 3: Aerobic Plate Count (Maturin and Peeler, 2001).

2.3.3 Quantification of *E. coli* and Total Coliforms

The methods for the enumeration of *E. coli* and coliforms were adapted from the usage instructions for Condalab's '*E. coli* - Coliforms Chromogenic Medium' (Condalab, 2021). The media was prepared using sterile distilled water, and was heated to dissolution using a microwave. Dilutions of 10^{-3} and 10^{-4} were pour plated in triplicate at 1 mL sample volume. Pour plating was

conducted aseptically under a class 2 biological safety cabinet (BIOBASE BSC-1100IIB2-X). After the plates had solidified, these were stacked in an inverted position inside a clean polyethylene bag, and placed inside an incubator (Lab-Line Imperial II) for 24±2 h at 35±1 °C. After incubation, the plates were observed. Blue to dark violet colonies were counted as *E. coli* colonies. Total coliforms were counted as the sum of *E. coli* colonies plus pink colonies. The CFU was computed according to the guidelines in BAM Chapter 3: Aerobic Plate Count (Maturin and Peeler, 2001).

2.4 Determination of Physicochemical Characteristics of Broiler Breast and Thigh

2.4.1 Temperature

Upon arrival in the laboratory, the temperature of each chicken sample was measured using an insert-type digital thermometer (Rycom MOD110511367) by piercing the probe tip directly into the meat. Three readings were obtained from different locations and then averaged for each sample.

2.4.2 pH

The pH of each raw chicken sample was measured using an insert-type skin pH acidimeter (ATC 6118L) by piercing the probe tip directly into the meat. Three readings were measured from three locations and then averaged for each sample (Noh *et al*., 2023).

2.4.3 Color

Each chicken sample's CIE color values (L*, a*, b*) were measured using a Minolta CR-400 Chroma Meter (Minolta Co., Osaka, Japan). Standardization was performed by calibrating the chroma meter against a white calibration plate (*Y= 84.60*, *x= 0.3155*, *y= 0.3214*) covered with cling wrap. Before measurement, the chicken skin was removed with a knife, and the surface was covered with cling wrap. Three readings were obtained from different locations on the meat surface (Ragab *et al*., 2019).

The chroma (C*) and hue angle (h°) were derived based on Equations 1 and 2 (Konika Minolta Inc., 2007).

$$C^* = \sqrt{((a^*)^2 + (b^*)^2)} \quad (1)$$

$$h^{\circ} = arctan\left(\frac{b^*}{a^*}\right) \quad (2)$$

2.4.4 Water-Holding Capacity

The Carver Press method was used to measure the water-holding capacity (WHC). Three cylindrical portions (1 g) of meat were cut from each raw chicken sample using a 16-mm cork-borer. Each cut portion was sandwiched between two Whatman No. 1 filter papers and then inserted between two Plexiglass plates. The meat was compressed under a Carver hydraulic press at 500 psi for 1 minute. The pressed meat sample and the total area were traced from the filter paper. The meat area and total area were measured using an image processing software, ImageJ.

The water-holding capacity, expressed as *%Free Water (%FW)*, was calculated based on Equation 3.

$$\%FW = \frac{Area_{outer} - Area_{inner}}{Area_{outer}} \times 100 \quad (3)$$

where $Area_{outer}$ = the total area of the water stain; $Area_{inner}$ = the total area of the pressed meat sample (Warner, 2014; Wierbicki and Deatherage, 1958).

2.4.5 Shear Force Test

First, the samples were packaged individually using a vacuum sealer and cooked in a circulating hot water bath set at 82 °C. The internal temperature of the meat was monitored using an insert-type digital thermometer inserted into one of the samples. The samples were removed from the water bath when the internal temperature reached 75 °C and were cooled to room temperature under running tap water. The cooked samples were then patted dry with a paper towel. Afterwards, the cooked chicken samples were cooled to 4–6 °C. The shear force measurement was performed using the Warner-Bratzler protocol with slight modifications. Two rectangular-shaped meat pieces were obtained from each cooked chicken sample, with the geometrical dimensions of *2.0 cm x 1.0 cm x 1.0 cm*, with the length cut out of the meat along the muscle fibers. The shear force of the samples was measured using a texture analyzer (Shimadzu EZ-SX) fitted with a V-shape shear force blade. The analyzer operating parameters were set as follows: 200 mm/min crosshead speed and 500 N load cell. Individually, the samples were sheared perpendicular to the muscle fiber orientation. The average shear force values were obtained, and the results were expressed as the maximum shear force in newtons (N) (Noh *et al*., 2023).

2.4.6 TBARS

The lipid oxidation of the chicken samples was determined through the thiobarbituric acid reactive substance (TBARS) for oxidative rancidity—a rapid, wet method described by Buege and Aust (1978) with slight modifications. Briefly, 0.5g of minced meat was obtained from each chicken sample, and 2.5 mL of freshly prepared TBA stock solution (0.375% thiobarbituric acid, 15% trichloroacetic acid, and 0.25 N hydrochloric acid) was added to each in a polypropylene falcon tube. The tubes were vortexed thoroughly and heated in a boiling water bath for 10 minutes, with the caps loosened before heating. The tubes were cooled under running tap water and centrifuged at 5000 rpm at 4 °C for 10 min. The supernatant (200 mL) from each sample tube was pipetted to a microtiter plate in triplicate. The absorbance was measured using a spectrophotometer at $l=532$ nm against a blank containing 200 mL of centrifuged TBA stock solution. The TBA values were expressed as ppm malonaldehyde: *TBARS value (ppm) = sample A532 x 2.77*. The TBARS ppm values were averaged for each sample (Noh *et al*., 2023).

3. Results and Discussion

3.1 Effect of Purchasing Time and Market Stall on the Microbiological Quality of Broiler Meat

Purchasing time and market stall had a significant interaction effect on the APC Log CFU/g values of broiler breast, $F\ (2, 30) = 23.98, p < 0.05$, and broiler thigh, $F\ (2, 30) = 32.29, p < 0.05$. The mean values obtained at 7:00 AM were significantly lower for broiler breast than those at other sampling times for both stalls, $p < 0.05$. Similarly, for broiler thigh, the mean values obtained at 7:00 AM were statistically similar to the lowest values among sampling times, regardless of stall. This suggests that the APC Log CFU/g values are lowest at 7:00 AM and generally increase as the day progresses. However, the rate of increase varies between market stalls. The means and standard deviations of the Log CFU/g values are summarized in Table 1.

The mean APC Log CFU/g values, presented in Table 1, range from 5.626 to 7.001 Log CFU/g for breast and 6.124 to 6.899 Log CFU/g for thigh. Most of the mean values fall below the limit of 10^7 CFU/mL set by the Philippine National Meat Inspection Services (2008), which differentiates marginally acceptable from unacceptable quality meat. Only the broiler breast samples obtained at 3:00 PM from Stall 2 ($M=7.001$) exceeded the limit.

Purchasing time and market stall also had a significant interaction effect on the Log CFU/g values of *E. coli* for broiler breast, $F\ (2, 30) = 46.92, p < 0.05$, and broiler thigh, $F\ (2, 30) = 56.65, p < 0.05$. For broiler breast, the mean values were highest at 3:00 PM for both stalls. Meanwhile, the mean values for broiler thigh were lowest at 3:00 PM for Stall 1 and 11:00 AM for Stall 2.

The mean Log CFU/g values of *E. coli,* presented in Table 1, range from 3.923 to 5.235 Log CFU/g for breast and 4.018 to 5.270 Log CFU/g for thigh. The results suggest that the differences in the *E. coli* counts throughout the day are more likely due to changes in the wet market environment, rather than growth during storage. This is because, compared to previous studies (Ab Aziz *et al*., 2020; Barrera *et al*., 2007; Ciftcioglu *et al*., 2008), the differences of mean Log CFU/g values between sampling times are quite large for only four-hour intervals. An increase in Log CFU/g greater than 0.5 usually occurs after more than one day of refrigerated storage (4 °C) in controlled environments.

Regarding the Log CFU/g values of total coliforms, purchasing time and market stall also had a significant interaction effect for broiler breast, $F\ (2, 30) = 14.61, p < 0.05,$ and broiler thigh, $F\ (2, 30) = 110.9, p < 0.05$. For broiler breast, the mean values obtained at 7:00 AM were significantly lower than other sampling times for both stalls, $p < 0.05$. For broiler thigh, mean values were highest at 11:00 AM in Stall 1. Meanwhile, for Stall 2, the values were highest at 3:00 PM and lowest at 11:00 AM.

Table 1. Log CFU/g values (Mean±SD) of APC, *E. coli,* and Total Coliforms

Location and Purchasing Time		APC	*E. coli*	Total Coliforms
Broiler Breast				
Stall 1	7:00 AM	$5.782 \pm 0.302^{b,x}$	$4.749 \pm 0.265^{a,x}$	$4.835 \pm 0.285^{b,x}$
	11:00 AM	$6.258 \pm 0.075^{a,x}$	$4.238 \pm 0.200^{b,y}$	$5.131 \pm 0.236^{ab,y}$
	3:00 PM	$6.206 \pm 0.211^{a,y}$	$4.970 \pm 0.315^{a,x}$	$5.292 \pm 0.377^{a,y}$
Stall 2	7:00 AM	$5.626 \pm 0.079^{f,x}$	$3.923 \pm 0.131^{f,y}$	$4.439 \pm 0.297^{e,y}$
	11:00 AM	$6.297 \pm 0.145^{e,x}$	$4.932 \pm 0.090^{e,x}$	$5.731 \pm 0.227^{d,x}$
	3:00 PM	$7.001 \pm 0.147^{d,x}$	$5.235 \pm 0.027^{d,x}$	$5.938 \pm 0.086^{d,x}$
Broiler Thigh				
Stall 1	7:00 AM	$6.159 \pm 0.134^{b,x}$	$4.752 \pm 0.097^{a,}$y	$5.264 \pm 0.157^{b,y}$
	11:00 AM	$6.564 \pm 0.165^{a,x}$	$4.872 \pm 0.309^{a,x}$	$6.104 \pm 0.179^{a,x}$
	3:00 PM	$6.119 \pm 0.133^{b,y}$	$4.018 \pm 0.171^{b,y}$	$5.085 \pm 0.239^{b,y}$
Stall 2	7:00 AM	$6.212 \pm 0.168^{e,x}$	$5.061 \pm 0.097^{d,x}$	$5.564 \pm 0.079^{e,x}$
	11:00 AM	$6.124 \pm 0.150^{e,y}$	$4.581 \pm 0.153^{e,y}$	$4.890 \pm 0.221^{f,y}$
	3:00 PM	$6.899 \pm 0.311^{d,x}$	$5.270 \pm 0.158^{d,x}$	$5.840 \pm 0.059^{d,x}$

a–c means from Stall 1 with different superscripts differ significantly ($p < 0.05$) between purchasing times.
d–f means from Stall 2 with different superscripts differ significantly ($p < 0.05$) between purchasing times.
x-y means from the same purchasing time with different superscripts differ significantly ($p < 0.05$) between stalls.

Coliforms and *Salmonella* are known for their ability to grow in meat stored in refrigerated conditions, even within a matter of hours (Hayat *et al*., 2021). However, in this study, the differences in the mean Log CFU/g values are larger than what could be explained by typical bacterial growth rates.

The relatively large differences between 4-hour sampling intervals and the significant interaction between purchasing time and market stall suggest that increasing Log CFU/g values may also result from the buildup of environmental contaminants throughout the day. Wet markets present a high likelihood of microbial contamination due to poor and unregulated hygiene conditions (Gonzales *et al*., 2021). Many markets lack accessible toilets and handwashing stations, elevating the risk of transmitting fecal microbes such as *E. coli* (Nadimpalli and Pickering, 2020). For instance, studies in Hong Kong found that hygiene practices were largely insufficient, regardless of whether the wet market had access to modern infrastructure (Ngan *et al*., 2020; Sekoai *et al*., 2020).

Notably, compared to the trend observed for the APC Log CFU/g values, the effects of purchasing time on the Log CFU/g values of *E. coli* and total coliforms vary more between the stalls. Although certain *E. coli* strains can grow in refrigerated conditions (Arias *et al*., 2001; Djenane *et al*., 2012; Palumbo, 1986), and contamination from the market environment throughout the day is what affects the microbiological quality of chicken meat. Coliforms and *E. coli* are widespread in stool and the environment, and are naturally present in the lower digestive tract of poultry. These can be spread through contaminated surfaces, food, and water (Ekici and Dümen, 2019). Fecal contamination and the presence of *E. coli* in meat may occur if the bowels rupture during evisceration, if there is indirect contamination with polluted water, and from handlers during various steps along the food chain, including production, processing, distribution, retail marketing, and handling or preparation (Eyi and Arslan, 2012). Other studies have observed a similarly high prevalence of *E. coli* in raw meat products. A study by Eyi and Arslan (2012) found that 49 out of 56 poultry samples (87.5%) purchased from selected butcher shops and delicatessens in the city of Bolu, Turkey, tested positive for *E. coli*. A separate study by Elumba *et al*. (2018), with a sample size of 50, found that 68% of drumsticks and 96% of chicken wings sampled from a wet market in Valencia City, Bukidnon, Philippines, were contaminated with *E. coli.*

3.2 Effect of Purchasing Time and Market Stall on the Physicochemical Characteristics

3.2.1 Temperature

Purchasing time and market stall had a significant interaction effect on the temperatures of broiler breast, $F\ (2, 60) = 13.18,\ p < 0.05$, and broiler thigh, $F\ (2, 30) = 35.32,\ p < 0.05$. For broiler breast, temperature decreased significantly with increasing sampling time in Stall 1, but no significant differences between sampling times were observed in Stall 2. For broiler thigh, in Stall 1, values were highest at 11:00 AM and lowest at 3:00 PM. Meanwhile, for Stall 2, there were no significant differences between sampling times. The variation in temperature between storage times can be attributed to differences in storage practices between market stalls, and the fluctuating traffic conditions throughout the day. Based on observation, chickens at 7:00 AM were new. Some were left on display until they were bought at 11:00 AM. When most chickens on display had already been sold, the vendors would replace them with new ones from their chiller. This is why the chicken brought at 3:00 PM has a lower temperature. However, the exact variations of these conditions are beyond the scope of this study.

The mean temperature values, presented in Table 2, range from 21.17 to 27.48 °C for breast, and 25.83 to 28.17 °C for thigh. These temperatures are above the recommended temperatures (<4 °C) to maintain desirable physicochemical properties and minimize spoilage (United States Department of Agriculture [USDA], 2009). The temperature values fell within the range that support the growth of mesophilic bacteria – 20 to 45 °C – among which include *E. coli* and *Salmonella* (Schiraldi and De Rosa, 2014). The temperatures of the samples reflect the practices in the wet market, wherein vendors display meat outside of the chiller unit.

3.2.2 Water Holding Capacity (WHC), expressed as *%FW*

For both broiler breast and thigh, the *%FW* values were not significantly different between sampling times and between stalls. There was also no significant interaction effect on the %FW of the samples. This implies that the fixed factors did not significantly influence variation in meat WHC. Similar findings were observed by Hayat *et al*. (2021), wherein drip loss and cook loss did not significantly differ within 4-hour intervals of cold transport at 4 °C.

3.2.3 Shear Force

Purchasing time and market stall had a significant interaction effect on the shear force of broiler breast, $F\ (2, 60) = 13.18,\ p < 0.05$, but not on broiler thigh. For broiler breast, for Stall 1, shear force was significantly lower at 11:00 AM compared to 7:00 AM. Meanwhile, Stall 2 had no significant differences between sampling times. In addition, Stall 1 had significantly higher shear force values than Stall 2, regardless of sampling time. For broiler thigh, the values were highest at 7:00 AM and lowest at 11:00 AM for both stalls.

The variations in the shear force values observed are most likely due to the differences in the muscle characteristics of the samples, particularly the contractile state of the myofibrillar proteins (Mir *et al*., 2017), which is significantly determined by the extent of the development of rigor mortis. This is affected by the pre-slaughter and post-slaughter processing conditions of the meat. The degradation of the myofibrillar proteins impacts meat tenderness (Augustyńska-Prejsnar *et al*., 2023). Furthermore, other sources of variation may be attributed to the differences in storage conditions before thermal processing, the internal temperature of the meat during analysis, variations in the geometric dimensions of meat pieces, and the location of the sample from which the meat pieces were cut (Sofyan *et al*., 2020).

However, the variation in the shear force values observed is most likely due to differences in storage conditions, geometric dimensions of meat pieces, and the sampling location in the muscles. Sofyan *et al*. (2020) emphasize that muscle characteristics, particularly the location of samples where the meat pieces were cut, largely influence the shear force variations in meat.

3.2.4 pH

Purchasing time and market stall had a significant interaction effect on the pH values of broiler breast only, $F\ (2, 60) = 13.18,\ p < 0.05$. For broiler breast, there were no significant differences in the pH values in Stall 1, but in Stall 2, the mean pH value at 3:00 PM was significantly lower compared to 7:00 AM and 11:00 AM, $p < 0.05$. Meanwhile, for broiler thigh, there were no significant differences in the pH values between sampling times and between stalls.

The mean pH values, presented in Table 2, range from 6.11 to 6.49 for the breast, and 6.40 to 6.85 for the thigh. The mean pH values of the breast samples lie beyond the normal pH range for chicken breasts, which is 5.70 to

6.10 (Beauclercq *et al*., 2022; Kralik *et al*., 2018). Similarly, the pH values of the thigh samples also lie beyond the normal pH range for chicken thighs, which is 5.70 to 5.90 (Fernandes *et al*., 2016). High pH values can be caused by a reduced glycogen reserve, which indicates that the animals may have been exposed to longer stress before slaughtering (Kralik *et al*., 2018). Meat pH is also known to increase during extended periods of storage due to the accumulation of alkaline nitrogenous compounds such as ammonia and amines (Katiyo *et al*., 2020).

3.2.5 TBARS

Purchasing time and market stall did not have a significant interaction effect on the TBARS values of broiler breast and broiler thigh. For broiler breasts from Stall 1, the values at 3:00 PM were significantly higher than 7:00 AM, $p < 0.05$. However, for Stall 2, the values did not significantly differ between sampling times. Regarding broiler thigh, for Stall 1, the values obtained at 11:00 AM were significantly higher than other sampling times, $p < 0.05$. Stall 2 did not have significantly different values between sampling times, but Stall 2 had greater mean TBARS values compared to Stall 1 across all sampling times.

The mean temperature values, presented in Table 2, range from 0.0422 to 0.1460 mg MDA/kg for breast, and 0.0435 to 0.978 mg MDA/kg for thigh. The values suggest that the degree of lipid oxidation is low since values of less than 0.2 mg MDA/kg are associated with freshness in meat. Poor quality meat is shown to have TBARS values of 0.6 to 2.0 mg MDA/kg (Brewer *et al*., 1992; Mohan *et al*., 2017).

3.2.6 Color

For broiler breast, the lightness (L*) values were not significantly different between sampling times and between stalls. There was also no significant interaction effect on the lightness (L*) of the samples.

Purchasing time and market stall had a significant interaction effect, $F(2, 60) = 6.469, p < 0.05$, on the redness (a*) of the chicken breast samples. For Stall 1, the values did not significantly differ between sampling times. However, for Stall 2, the a* value obtained at 3:00 PM was significantly higher compared to 7:00 AM and 11:00 AM.

Purchasing time and market stall had a significant interaction effect, $F(2, 60) = 11.11, p < 0.05$, on the yellowness (b*) of the chicken breast samples. For Stall 1, the values did not significantly differ between sampling times.

However, for Stall 2, the b* value obtained at 3:00 PM was significantly higher compared to 7:00 AM and 11:00 AM.

Purchasing time and market stall had a significant interaction effect, *F (2, 60) = 13.63, p <0.05,* on the chroma (c*) of the chicken breast samples. For Stall 1, the values did not significantly differ between sampling times. However, for Stall 2, the c* value obtained at 3:00 PM was significantly higher compared to 7:00 AM and 11:00 AM.
There was also no significant interaction effect for the hue angle (h°) of the chicken breast samples. For both stalls, the values did not significantly differ between sampling times. However, Stall 1 had significantly higher hue angle values compared to Stall 2, regardless of sampling time.

For broiler thigh, the color parameters were not significantly different between sampling times and between stalls. In addition, there was also a significant interaction effect for all color parameters.

Table 2. Descriptive statistics (Mean±SD) for physicochemical parameters

Location and Purchasing Time		Temperature (°C)	WHC	WBSF	pH	TBARS
Broiler Breast						
Stall 1	7:00 AM	27.48 ± 1.210 ^{a,x}	59.81 ± 11.031 ^{a,x}	25.53 ± 4.055 ^{a,x}	6.45 ± 0.172 ^{a,x}	0.0697 ± 0.072 ^{b,x}
	11:00 AM	24.89 ± 1.711 ^{b,x}	54.91 ± 13.019 ^{a,x}	17.92 ± 3.102 ^{b,x}	6.45 ± 0.157 ^{a,x}	0.0884 ± 0.090 ^{ab,x}
	3:00 PM	21.17 ± 4.569 ^{c,y}	53.62 ± 13.833 ^{a,x}	21.51 ± 6.547 ^{ab,x}	6.49 ± 0.170 ^{a,x}	0.1460 ± 0.094 ^{a,x}
Stall 2	7:00 AM	25.50 ± 0.548 ^{d,x}	46.35 ± 3.810 ^{d,x}	9.97 ± 1.595 ^{d,y}	6.43 ± 0.124 ^{d,x}	0.0422 ± 0.005 ^{d,x}
	11:00 AM	26.33 ± 0.516 ^{d,x}	51.42 ± 7.713 ^{d,x}	11.79 ± 0.793 ^{d,y}	6.40 ± 0.094 ^{d,x}	0.0465 ± 0.001 ^{d,x}
	3:00 PM	27.17 ± 0.408 ^{d,x}	59.07 ± 12.515 ^{d,x}	14.78 ± 1.542 ^{d,y}	6.11 ± 0.125 ^{e,y}	0.0898 ± 0.056 ^{d,x}
Broiler Thigh						
Stall 1	7:00 AM	27.33 ± 0.516 ^{b,y}	63.08 ± 6.724 ^{a,x}	24.47 ± 1.664 ^{a,x}	6.68 ± 0.295 ^{a,x}	0.0529 ± 0.009 ^{b,y}
	11:00 AM	28.17 ±0.408 ^{a,x}	64.05 ± 5.710 ^{a,x}	9.58 ± 2.274 ^{c,x}	6.69 ± 0.182 ^{a,x}	0.0755 ± 0.011 ^{a,y}
	3:00 PM	25.83 ± 0.408 ^{c,y}	64.18 ± 7.042 ^{a,x}	14.61 ± 2.259 ^{b,y}	6.40 ± 0.307 ^{a,x}	0.0435 ± 0.002 ^{b,y}
Stall 2	7:00 AM	28.00 ± 0.000 ^{d,x}	53.59 ± 11.280 ^{d,x}	25.87 ± 1.349 ^{d,x}	6.85 ± 0.121 ^{d,x}	0.0907 ± 0.005 ^{d,x}
	11:00 AM	27.17 ± 0.408 ^{d,y}	61.00 ± 9.186 ^{d,x}	13.61 ± 2.741 ^{f,x}	6.48 ± 0.233 ^{d,x}	0.0978 ± 0.021 ^{d,x}
	3:00 PM	27.67 ± 0.516 ^{d,x}	56.67 ± 5.854 ^{d,x}	20.20 ± 2.777 ^{e,x}	6.64 ± 0.282 ^{d,x}	0.0931 ± 0.020 ^{d,x}

a–c means from Stall 1 with different superscripts differ significantly (p < 0.05) between purchasing times.
d–f means from Stall 2 with different superscripts differ significantly (p < 0.05) between purchasing times.
x-y means from the same purchasing time with different superscripts differ significantly (p < 0.05) between stalls.

Table 3. Descriptive statistics (Mean±SD) for color parameters

Location and Purchasing Time		Lightness (L*)	Redness (a*)	Yellowness (b*)	Chroma (C*)	Hue Angle (h°)
Broiler Breast						
Stall 1	7:00 AM	54.98 ± 5.967 ^{a,x}	2.34 ± 1.237 ^{a,x}	5.81 ± 1.279 ^{a,x}	6.35 ± 1.424 ^{a,x}	1.20 ± 0.166 ^{a,x}
	11:00 AM	57.72 ± 6.357 ^{a,x}	1.49 ± 0.627 ^{b,y}	5.01 ± 2.668 ^{a,x}	5.40 ± 2.356 ^{a,x}	1.16 ± 0.384 ^{a,x}
	3:00 PM	54.56 ± 6.802 ^{a,x}	2.53 ± 1.063 ^{a,y}	4.75 ± 1.405 ^{a,y}	5.46 ± 1.469 a,y	1.07 ± 0.181 a,x
Stall 2	7:00 AM	53.15 ± 4.902 ^{d,x}	3.26 ± 1.248 ^{e,x}	2.82 ± 1.024 ^{e,y}	4.46 ± 0.993 ^{e,x}	0.72 ± 0.281 ^{d,y}
	11:00 AM	54.53 ± 3.735 ^{d,x}	3.81 ± 0.863 ^{e,x}	2.43 ± 1.574 ^{e,y}	4.67 ± 1.211 ^{e,x}	0.54 ± 0.291 ^{d,y}
	3:00 PM	60.01 ± 5.924 ^{d,x}	5.87 ± 0.621 ^{d,x}	7.39 ± 2.579 ^{d,x}	9.57 ± 2.027 ^{d,x}	0.87 ± 0.190 ^{d,x}
Broiler Thigh						
Stall 1	7:00 AM	56.08 ± 5.446 ^{a,x}	3.98 ± 2.212 ^{a,x}	2.55 ± 1.556 ^{a,x}	5.14 ± 1.584 ^{a,x}	0.62 ± 0.436 ^{a,x}
	11:00 AM	57.71 ± 5.290 ^{a,x}	4.68 ± 3.043 ^{a,x}	2.46 ± 1.835 ^{a,x}	5.76 ± 2.528 ^{a,x}	0.58 ± 0.477 ^{a,x}
	3:00 PM	62.61 ± 3.195 ^{a,x}	4.13 ± 1.954 ^{a,x}	4.73 ± 2.365 ^{a,x}	6.77 ± 1.325 ^{a,x}	0.85 ± 0.433 ^{a,x}
Stall 2	7:00 AM	53.74 ± 3.365 ^{d,x}	2.86 ± 2.807 ^{d,x}	0.98 ± 1.716 ^{d,x}	3.79 ± 2.138 ^{d,x}	0.62 ± 0.695 ^{d,x}
	11:00 AM	58.47 ± 4.751 ^{d,x}	3.96 ± 1.805 ^{d,x}	1.93 ± 1.539 ^{d,x}	4.81 ± 1.049 ^{d,x}	0.49 ± 0.465 ^{d,x}
	3:00 PM	56.73 ± 5.631 ^{d,x}	3.45 ± 2.228 ^{d,x}	3.73 ± 2.433 ^{d,x}	5.67 ± 1.843 ^{d,x}	0.81 ± 0.474 ^{d,x}

a–c means from Stall 1 with different superscripts differ significantly ($p < 0.05$) between purchasing times.
d–f means from Stall 2 with different superscripts differ significantly ($p < 0.05$) between purchasing times.
x-y means from the same purchasing time with different superscripts differ significantly ($p < 0.05$) between stalls.

3.3 Correlation of Physicochemical Characteristics and Microbiological Quality of Broiler Breast

The Pearson correlation revealed significant negative correlations between the pH and the APC the Log CFU/g *E. coli,* and the total coliforms *($r = -0.43$*, r = -0.60, r = -0.38 respectively, *$n = 36$, $p < 0.05$*). This finding is inconsistent with other studies that suggest that higher pH values, such as in DFD meat, have greater susceptibility to microbial growth and spoilage (Allen *et al*., 1997; Dave and Ghaly, 2011; Katiyo *et al*., 2020). However, during the early stages post-slaughter, it is possible that microbiological growth occurs while glycogen is still available in the meat, which can contribute to a drop in pH by fermenting glycogen into lactic acid (Manalo and Gabriel, 2020). Similar studies that utilized freshly slaughtered chicken and relatively short storage intervals found that, during the early stages after slaughter, the pH of meat decreases while the microbial load increases (Ab Aziz *et al*., 2020; Hayat *et*

al., 2021). Since the time between slaughtering and purchasing the samples from the wet market was not known, it is possible that the samples were still undergoing post-mortem acidification (Mir *et al*., 2017) alongside bacterial growth.

A significant positive correlation was found between the meat lightness L* and APC and total coliforms *(r = 0.42*, r = 0.40 respectively, *n = 36, p < 0.05*), A significant positive correlation was also found between the meat redness a* and APC, Log CFU/g *E. coli,* and total coliforms *(r = 0.55*, r = 0.35, r = 0.44 respectively, *n = 36, p < 0.05*). A significant positive correlation was also found between the meat yellowness b* and APC and Log CFU/g *E. coli (r = 0.43*, r = 0.48 respectively, *n = 36, p < 0.05*).

This suggests that lighter, redder, and more yellow chicken breasts indicate higher microbial loads, which is inconsistent with prior studies that suggest that DFD meat, which exhibits darker color values, is more prone to bacterial spoilage (Allen *et al*., 1997; Dave and Ghaly, 2011). It is more likely that this correlation occurs due to the observed pH values, since decreasing pH values are associated with lighter-colored meat (Kralik *et al*., 2018).

A significant positive correlation was found between the Log CFU/g *E. coli* and the WBSF (r = 0.35, n = 36, p < 0.05). This may merely be a consequence of the effects of pH, as prior studies suggest that low pH meat is less tender with a higher shear force value (Faria *et al*., 2010; da Silva *et al*., 2017). However, since pH and WBSF did not exhibit a significant correlation in this study, further investigation is recommended before conclusions can be drawn since current literature on the relationship of meat firmness and microbial spoilage is limited.

3.4 Correlation of Physicochemical Characteristics and Microbiological Quality of Broiler Thigh

Pearson correlation revealed significant positive correlations between temperature and the APC the Log CFU/g *E. coli,* and the total coliforms *(r = 0.44*, r = 0.72, r = 0.61 respectively, *n = 36, p < 0.05*). This finding is consistent with the theory that the metabolic activity and growth rate of mesophiles increase as temperatures approach an optimum of around 30-39 °C (Schiraldi and De Rosa, 2014; Jay *et al*., 2008).

Contrary to the findings for chicken breast, a significant positive correlation was found between the pH and Log CFU/g *E. coli* and total coliforms. *(r =*

0.54, r = 0.49, respectively, $n = 36$, $p < 0.05$). This can be linked to how *E. coli* have an optimum pH close to neutral, as *E. coli* maintain a cytoplasmic pH in the range from pH 7.2 to 7.8 (Wilks and Slonczewski, 2007). Other studies have also previously found that meat with higher pH values are more prone to bacterial spoilage (Allen *et al*., 1997; Knox *et al*., 2008).

A significant negative correlation was found between the meat lightness L* and Log CFU/g *E. coli* ($r = -0.40$, $n = 36$, $p < 0.05$), and also between the meat yellowness b* and Log CFU/g *E. coli* ($r = -0.41$, $n = 36$, $p < 0.05$). The correlation between meat lightness and microbial load can be explained by how higher meat pH values make the meat more susceptible to microbial growth, and also results in darker and duller meat colors (Allen *et al*., 1997; Katiyo *et al*., 2020; Jankowiak *et al*., 2021).

A significant positive correlation was found between the TBARS and APC and Log CFU/g *E. coli* ($r = 0.33$, r = 0.51 respectively, $n = 36$, $p < 0.05$). Similar results were reported in other studies, wherein TBARS and microbial counts were found to increase in meat products over increasing lengths of storage time (Djenane *et al*., 2012; Byun *et al*., 2003).

4. Conclusion and Recommendation

Purchasing time and market stall had a significant interaction effect on the microbiological quality of broiler breast and thigh. The differences of the Log CFU/g values between 4-hour intervals were larger than previous studies, suggesting that microbiological quality is not a function of storage time alone in the wet market environment. Regarding the physicochemical characteristics, a significant interaction effect was found for the temperature, pH, shear force, redness a*, yellowness b*, and chroma C* for broiler breasts. For broiler thighs, a significant interaction effect was only found for temperature. However, market stalls exerted a significant simple effect on the hue angle of broiler breasts and the shear force and TBARS values of broiler thighs.

The findings of this study can be used to supplement research on the predictive microbiology of broiler meat. Automating the quality assessment of broiler meat would greatly reduce the time and resources involved in testing, potentially improving the ease and accessibility of monitoring. For policymakers, given the significant interaction between purchasing time and

market stalls on broiler meat quality, further investigation on the levels of environmental contamination, hygiene practices, and sanitation infrastructure in the Los Baños Public Market is recommended. Doing so can provide further insight on why the quality of chicken meat sold changes rapidly over the course of a day, despite refrigeration.

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