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Physicochemical characteristics, microbiological quality, and *Salmonella* spp. detection of commercial broilers sold in Batong Malake public market, Los Baños, Philippines

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Abstract

The increasing incidence of foodborne illnesses worldwide is a significant health concern that affects millions of people. Certain foodborne pathogens may be present and can contaminate chicken meat if not properly handled and stored. This study was conducted to evaluate the physicochemical characteristics, microbiological quality, and safety of commercial broilers sold in Batong Malake public market, Los Baños, Laguna, Philippines. Chicken breasts and thighs were purchased from three randomly selected stalls, with sample collection conducted at 7 AM, 11 AM, and 3 PM. The aerobic plate count (APC), temperature, pH, meat color (L*, a*, and b*), water-holding capacity (WHC), and thiobarbituric acid reactive substances (TBARS) of all samples were evaluated, as were how stalls and purchasing times affected these characteristics. Results showed that the effect of purchasing times on the L* of chicken breasts, the WHC of chicken thighs, and the recorded temperatures, b*, and a* values of both chicken breasts and thighs differ significantly across stalls. No *Salmonella* spp. was detected using polymerase chain reaction (PCR). Moderate significant positive correlations were observed between temperature and APC ($r = 0.40$, $n = 27$, $p<0.05$) and between a* and b* values ($r = 0.43$, $n = 27$, $p<0.05$) for chicken breasts, as well as between temperature and a* ($r = 0.46$, $n = 27$, $p<0.05$) and between TBARS and b* ($r = 0.40$, $n = 27$, $p<0.05$) for chicken thighs. On the other hand, moderate significant negative correlations were observed between pH and L* for chicken breasts and thighs ($r = -0.48$ and $r = -0.42$, $n = 27$, $p<0.05$, respectively), between pH and b* ($r = -0.54$, $n = 27$, $p<0.05$), and between L* and a* ($r = -0.45$, $n = 27$, $p<0.05$) for chicken thighs. This study revealed that the majority of the recorded physicochemical properties for meat quality and safety could indicate the freshness of the purchased chicken broilers at the Batong Malake public market.

1. Introduction

The poultry industry is one of the growing animal industries in the Philippines, which includes the production of livestock such as ducks, geese, and chickens − the most common type of poultry in the country. According to the Philippine Statistics Authority (PSA) (2023), the total chicken production amounted to 477.76 thousand metric tons in the second quarter of 2023, showing a 3.2% increase in comparison to the same quarter of 2022. The broiler sector of the industry has shown significant progress over the years, driven by the increasing demand for its consumption. Broilers are chickens that are raised and bred to achieve the optimum size for their meat (Maurer, 2003). Due to its affordability, which the African Swine Fever (ASF) outbreak inadvertently caused, cultural and religious acceptability, and lower fat content, most consumers preferred chicken meat over pork (Acosta, 2022; Department of Agriculture - Bureau of Agricultural Research, 2022). According to Halili (2023), 1.53 million metric tons of chicken broilers were estimated to be produced in 2024 in the Philippines, as stated by the US Department of Agriculture (USDA).

The volume of chicken meat consumption in 2023 was forecast to be 2.0 million metric tons (Statista Research Department, 2023). Breasts and thighs are the usual chicken cuts that Filipinos prefer to cook and consume. These cuts are commonly bought either in supermarkets or public markets. Although public markets are generally considered dirty compared to

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supermarkets, a study by Pascual *et al*. (2020) found that most consumers prefer to buy highly perishable foods like fish and meat from public markets since they are perceived to be more affordable, and fresher compared to other retail outlets. Other reasons include the desire of the consumers to support local farmers and small retailers. Commercial broilers sold in public markets are usually kept chilled and frozen to preserve raw meat quality. The study by Manalo and Gabriel (2020) indicated that the storage condition of chicken meat, including the storage temperature and initial microbial level, is one of the contributing factors to its shelf-life, safety, and suitability. Determinants are used to assess the quality of raw chicken meat, which is associated with spoilage, inclusive of the evaluation of its physical and chemical characteristics.

Physical determinants, such as sensory attributes (color, odor, and texture), temperature, and water-holding capacity (WHC), are essential factors that influence the freshness and overall quality of chicken meat. Color is a particularly important attribute, as it is often the first property that consumers notice and evaluate when purchasing chicken meat. A pale pink color is generally associated with fresh raw chicken breast, while a dark red color indicates freshness in the raw thigh and leg meat (Mir *et al*., 2017). The measurement of color characteristics, including lightness, redness, and yellowness, is crucial for assessing the appearance of chicken meat (Fernandes *et al*., 2016; Hayat *et al*., 2021). Temperature control is also vital for preserving the quality of chicken meat. A study by Hayat et al. (2021) found that the storage temperature of broiler chicken breast muscle significantly impacted its quality traits. Another critical factor is the WHC which affects the overall quality of chicken meat. It is described as the meat's ability to retain water in its tissue, and it is associated with the nutritional quality of the meat, particularly its protein quality. Higher cooking loss is indicative of lower meat quality (Watanabe *et al*., 2018).

The pH and thiobarbituric acid reactive substances (TBARS) are the chemical properties that significantly influence the overall meat quality and other physicochemical properties of chicken meat. Mir *et al*. (2017) defined meat pH as the amount of glycogen in the muscle before slaughter and the rate of glycogen conversion into lactic acid after slaughter. The pH level directly correlates with water-binding capacity, indicating that a higher pH corresponds to a higher water-binding capacity. The thiobarbituric acid reactive substances (TBARS) are a useful tool for detecting lipid oxidation, which is associated with meat quality deterioration. TBARS measures malondialdehyde (MDA), a degradation product of lipid oxidation (Sujiwo *et al*., 2018; Kumar *et al*., 2018). Understanding the physicochemical properties of chicken meat and their impact on spoilage and quality is essential for ensuring the safety and nutritional value of this popular protein source.

Several microorganisms can be present in raw poultry meats, but this study predominantly focuses on the presence of *Salmonella* spp. These microorganisms can cause food-borne infections that affect millions of people and can be associated with significant mortality. *Salmonella* spp. can cause salmonellosis, which is one of the most common foodborne infections worldwide. In the Philippines, the Department of Health (DOH) (2019) noted in their Food and Water Borne Disease Prevention and Control Program (FWBDPCP) Strategic Plan that a total of 1,427 cases due to *Salmonella* spp. were reported from 2012-2016. The prevalence of foodborne illnesses worldwide serves as a stark reminder of the significance of food safety and the necessity of correctly handling, preparing, and storing food products to reduce the risk of infection. Following this, polymerase chain reaction (PCR), including multiplex PCR (mPCR) and real-time or quantitative PCR (qPCR), is one of the molecular techniques used to detect pathogens present in raw food, including *Salmonella* spp. This method allows the rapid detection and identification of foodborne pathogens with its high sensitivity and specificity, which is vital to the prevention and control of the spread of foodborne diseases (Law *et al*., 2015).

This study focused on analyzing the physicochemical properties and microbiological quality of commercial broilers sold in the Batong Malake public market. The detection of the presence of *Salmonella* spp. through PCR was also conducted to evaluate the safety of these commercial broilers. This is relevant since limited studies have been done regarding PCR-based detection of *Salmonella* spp. in this particular location. The results of this study could be used by the food industry and retail markets to develop and implement preventive and control measures for the spread of foodborne diseases, as well as promote food safety. Aside from this, the objectives included establishing the effect of stalls and purchasing times on the physicochemical characteristics and microbiological quality of the commercial broilers and whether there was a correlation between the mentioned characteristics.

2. Materials and methods

2.1 Sample collection and preparation

Raw chicken breast and thigh samples were randomly purchased from three stalls in the Batong

Malake public market. This wet market serves half of the population of Los Baños despite having only 6 stalls selling dressed chicken. Out of 6 stalls, 3 random stalls (50%) were sampled at three different sampling times (7 AM, 11 AM, and 3 PM) in triplicate per day. Based on our preliminary evaluation, this experimental design allowed for sampling for the entire day. Three breasts and three thighs were purchased per stall, with sample collection conducted at 7 AM, 11 AM, and 3 PM. All samples underwent physicochemical and microbiological analyses in triplicate on the day of sample collection. PCR-based detection of *Salmonella* spp. was performed on pooled samples per stall for each breast and thigh.

2.2 Physicochemical analysis

2.2.1 Temperature and pH determination

The temperature and pH of each sample right after collection were measured using a calibrated food thermometer and a spear-type digital pH meter (Choe and Kim, 2020), respectively.

2.2.3 Color determination

Meat color was determined using the CIE LAB colorimetric system with three meat color values: L^* for lightness, a^* for redness, and b^* for yellowness on the surface of chicken meat samples (Choe and Kim, 2020). A Chroma Meter colorimeter (Konica Minolta CR-400) was used in the color assessment.

2.2.4 Water-holding capacity measurement

The WHC was measured using the Carver Press Method (Kauffman *et al*., 1986; García-Márquez *et al*., 2012) with modifications. A total of 1 g of chicken meat was cut was cut using a 16 mm cork borer and weighed. Subsequently, it was placed between the centers of two Whatman No. 1 filter papers, each with a 9.1 cm diameter. The filter papers were then pressed at 500 psi for 1 min. The WHC was calculated using the ImageJ software by determining the area of the inner region (pressed meat) and the outer region (surrounding dried water). The formula is as follows:

$$\text{WHC (\%)} = (A_o - A_i)/A_o \times 100$$

where A_o = area of the outer region (cm) and A_i = area of the inner region (cm).

2.2.5 Thiobarbituric acid reactive substances determination

The TBARS for oxidative rancidity was determined using the rapid and wet method based on King *et al*. (2023), adapted from Buege and Aust (1978). Each minced sample weighed 1 g and mixed with 5 mL thiobarbituric acid (TBA) stock solution. The samples were heated in boiling water for 10 mins and cooled in running water. The samples were centrifuged at 5,000×*g* for 10 mins at 4°C to obtain the supernatant, followed by pipetting 200 µL of the supernatants to a 96-well plate (Biologix Europe GmbH). The supernatant absorbance at λ = 532 nm against a blank that contained only the reagents was measured using a spectrophotometer (BioTek Epoch 2 Microplate Spectrophotometer). The TBA value was then calculated using 1.56 × 105/M/cm as the extinction coefficient of the pink TBA chromogen through the following formula:

$$\text{TBARS value (mg MDA/kg)} = \text{sample } A_{532} \times 2.77$$

2.3 Microbiological analysis

The APC was performed using the procedures developed by the AOAC and the American Public Health Association (APHA), following the AOAC Official Methods of Analysis with modification, as stated in the Bacteriological Analytical Manual (BAM) (Maturin and Peeler, 2001). The plates were inverted and incubated for 24 hrs at 35°C. The computation of APC followed the modified APHA guidelines (Maturin and Peeler, 2001).

2.4 Molecular detection of Salmonella spp.

The isolation, DNA extraction, and molecular detection of *Salmonella* spp. using PCR (Santos *et al*., 2020) were outsourced to the National Institute of Molecular Biology and Biotechnology (BIOTECH) using the PCR-based *Salmonella* DNA Amplification System™ (DAS™) kit. Pooled ground samples of each chicken breast and thigh per stall were submitted to BIOTECH.

2.5 Statistical analysis

The data were analyzed using two-way analysis of variance (ANOVA) and the differences between means were computed using Tukey's Honestly Significant Difference (HSD) test for samples showing a significant difference at $p<0.05$. The Pearson correlation coefficient was computed to describe the relationship among the physicochemical and microbiological characteristics of samples. Statistical analysis was conducted using the IBM Statistical Package for Social Sciences (SPSS) 27 software, and the visualization of correlation was performed using R version 4.3.1.

3. Results and discussion

3.1 Changes in the physicochemical characteristics of chicken broilers

The temperatures of chicken breasts and thighs from three different stalls range from 20.96 to 26.29 and 17.17 to 26.51°C, respectively, as shown in Table 1. The

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recorded temperatures were higher than those reported by Fernandes *et al*. (2016) i.e., chilling temperatures and below (<4°C) to maintain other physicochemical properties and to control the growth of undesirable microorganisms. Similarly, the study by Suwattitanum and Wattanachant (2014) mentioned that the storage temperature of broiler breast meats at 0-4°C maintains the quality and WHC of the meats. The higher temperatures reflect the actual practice of public market vendors to place chicken meats on display without keeping the recommended chilling temperatures until purchase. It is suggested that the effect of purchasing times on the recorded temperatures of both chicken breasts and thighs differs significantly across stalls. Chicken breasts that were purchased at 11 AM had significantly higher temperatures compared to the samples bought at 7 AM and 3 PM; however, no significant difference could be observed between those purchased at 7 AM and 3 PM. For chicken thighs, those that were purchased at 7 AM are significantly different than the ones purchased at 11 AM and 3 PM, but those bought at 11 AM have no significant differences from the ones at 3 PM.

Table 1. Temperature of chicken breasts and thighs purchased at different stalls and purchasing times.

Stall No.	Purchasing time	Temperature (°C)
Breast		
1	7:00 AM	20.96±0.50^{b}
	11:00 AM	24.74±0.08^{a}
	3:00 PM	22.92±1.36^{b}
2	7:00 AM	22.42±0.60^{b}
	11:00 AM	23.97±0.42^{a}
	3:00 PM	22.72±0.94^{b}
3	7:00 AM	22.36±0.40^{b}
	11:00 AM	26.29±0.46^{a}
	3:00 PM	22.54±1.23^{b}
Thigh		
1	7:00 AM	21.66±0.40^{b}
	11:00 AM	24.02±1.26^{a}
	3:00 PM	22.28±0.39^{a}
2	7:00 AM	17.17±2.03^{b}
	11:00 AM	25.21±0.40^{a}
	3:00 PM	24.79±0.47^{a}
3	7:00 AM	24.01±1.57^{b}
	11:00 AM	26.51±0.29^{a}
	3:00 PM	25.61±0.15^{a}

Values are presented as mean±SD of triplicate. Values with different superscripts within the same stall are statistically significantly different (p<0.05).

The pH values of chicken breasts and thighs are shown in Table 2 to be 6.36 to 6.59 and 6.76 to 7.04, respectively. No significant differences in pH means can be observed for all purchasing times and stalls. The normal pH range for chicken breasts ranges from 5.7 to 6.1. It is also stated that pH levels lower than 5.7 are considered acidic, while those higher than 6.1 are considered dark, firm, and dry (DFD) (Beauclercq *et al*., 2022). For chicken thighs, a pH range of 5.7 to 5.9 must be observed, since lower than the recommended range shows pale, soft, and exudative (PSE), and higher than the recommended range demonstrates DFD anomalies (Fernandes *et al*., 2016). Having said that, the recorded pH values of chicken breasts and thighs are observed to be greater than 6.1 and 5.9, respectively, indicating DFD anomalies. High pH values for both chicken meats compared to normal may imply a reduced glycogen reserve, indicating that the animals must have been exposed to longer stress before slaughtering. This results in lower lactic acid production, maintaining the high pH value of the chicken meat (Kralik *et al*., 2017).

Table 2. pH values of chicken breasts and thighs purchased at different stalls and purchasing times.

Stall No.	Purchasing time	pH
Breast		
1	7:00 AM	6.59±0.22
	11:00 AM	6.48±0.16
	3:00 PM	6.36±0.18
2	7:00 AM	6.49±0.03
	11:00 AM	6.40±0.16
	3:00 PM	6.58±0.18
3	7:00 AM	6.51±0.04
	11:00 AM	6.55±0.10
	3:00 PM	6.51±0.04
Thigh		
1	7:00 AM	6.89±0.08
	11:00 AM	6.98±0.04
	3:00 PM	6.79±0.11
2	7:00 AM	6.83±0.04
	11:00 AM	6.79±0.22
	3:00 PM	6.76±0.11
3	7:00 AM	6.83±0.19
	11:00 AM	7.04±0.28
	3:00 PM	6.76±0.05

Values are presented as mean±SD of triplicate. Values with different superscripts within the same stall are statistically significantly different (p<0.05).

The meat colors of chicken breasts and thighs, specifically the L*, a*, and b*, are presented in Table 3. The color of chicken breast for lightness was higher than the recorded L* value of approximately 47 by Fernandes *et al*. (2016). In the study of Li *et al*. (2014), normal chicken breasts have an L* value of 58.06, while those of

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PSE-like breast meats have 63.14. Furthermore, border values for the color of chicken breast were determined: L* > 53 is lighter than normal; 48 < L* < 53 is normal; and L* < 48 is darker than normal (Qiao *et al*., 2001). The recorded values for lightness were consistent with normal to lighter-than-normal border values, which is similar to Li *et al*. (2014). The a* values are higher than the study of Fernandes *et al*. (2016), while some b* values are a little higher or lower.

The L*, a*, and b* values for chicken thighs that are recorded in Table 3 are inconsistent with the findings of Fernandes *et al*. (2016), who found L* values of 45.47 to 46.46. The a* and b* values were observed to be 2.06 to 2.11 and 5.05 to 5.39, respectively, which are both included in the recorded range of color values from the samples. On the other hand, Bohrer (2018) recorded a mean lightness of 50.04, which is lower than the recorded L* values from the samples. Additionally, his findings on mean redness and yellowness values are contradictory to the recorded ones in Table 3. The differences may be the result of how these chicken meats are kept at chilling and freezing temperatures compared to the ones sold at the public market in Batong Malake with temperatures higher than these, as shown in Table 1. Freezing temperatures result in more lipid and pigment oxidation, resulting in more yellowish meat (Fernandes *et al*., 2016).

Table 3. Meat color of chicken breasts and thighs purchased at different stalls and purchasing times.

Stall No.	Purchasing time	Color		
		*L**	*a**	*b**
Breast				
1	7:00 AM	52.78±2.50[b]	4.98±1.41[a]	5.06±0.95[a]
	11:00 AM	62.31±2.71[a]	2.10±0.66[b]	4.86±0.54[ab]
	3:00 PM	64.71±0.86[a]	2.39±0.21[b]	4.39±0.96[b]
2	7:00 AM	56.80±1.80[b]	1.25±0.31[b]	4.34±0.84[a]
	11:00 AM	60.67±1.88[a]	3.46±1.41[a]	4.52±0.93[ab]
	3:00 PM	56.08±3.07[a]	2.59±0.82[a]	4.26±1.06[b]
3	7:00 AM	58.30±4.19[b]	5.28±2.19[a]	5.51±1.08[a]
	11:00 AM	55.65±1.49[a]	1.94±0.66[b]	3.19±2.32[ab]
	3:00 PM	58.60±1.42[a]	1.82±0.52[b]	0.64±1.75[b]
Thigh				
1	7:00 AM	62.72±3.30	2.33±0.35	1.80±0.21
	11:00 AM	62.67±4.74	2.06±0.21	1.88±0.25
	3:00 PM	64.74±2.08	2.16±0.40	2.32±0.36
2	7:00 AM	59.02±1.79	3.13±0.21	1.95±1.01
	11:00 AM	59.17±7.40	6.24±1.84	5.34±2.33
	3:00 PM	62.47±2.12	3.85±1.53	1.86±1.38
3	7:00 AM	57. 42±7.33	4.87±0.49	1.50±1.82
	11:00 AM	55.96±2.47	4.86±1.21	0.25±1.01
	3:00 PM	63.06±3.36	4.89±0.75	2.36±0.33

Values are presented as mean±SD of triplicate. Values with different superscripts within the same stall are statistically significantly different (p<0.05). L*, a*, and b* denote lightness, redness, and yellowness, respectively.

The impact of purchasing times on the L*, a*, and b* values of chicken breasts is suggested to be varied across stalls. Table 3 shows that there is a significant difference between the mean L* and a* values of chicken breast meats purchased at 7 AM and 11 AM and 7 AM and 3 PM; however, there is no significant difference between 11 AM and 3 PM. For mean b*, there is a significant difference between 7 AM and 3 PM for chicken breasts. For chicken thighs, the effect of purchasing times on a* and b* values, except for L* values, is implied to be different across stalls. Furthermore, there is no notable difference between the mean L*, a*, and b* values for all purchasing times of chicken thighs.

The WHC for chicken breasts and thighs is presented in Table 4. The WHC of chicken breasts was determined to be 48.04 to 65.40%, while chicken thighs were 60.38 to 76.17%. The recorded WHC values of chicken breasts were lower than the findings of Fernandes *et al*. (2016) wherein the samples were stored under freezing conditions, while the recorded values for chicken thighs were comparable to the same reference. The formation of ice crystals due to freezing, followed by thawing, had increased the WHC of chicken meats. Furthermore, the relatively higher temperature influences reduced WHC in chicken meats due to the occurrence of protein denaturation (Kralik *et al*., 2017). No significant difference can be observed in the mean percentage WHC among the purchasing times for chicken breasts. For chicken thighs, the impact of purchasing times on the mean percentage WHC is suggested to be varied across stalls. Only the means of the chicken thighs purchased between 11 AM and 3 PM have shown a significant difference.

Lipid oxidation in chicken meat is detected when TBARS values are determined. When TBA is present, pink chromogens are formed, which can be detected with a maximum absorbance of 532 to 535 nm (King *et al.*, 2023). Samples with high TBARS values are then observed to have a pink color. There is a significant difference in the mean TBARS values between the chicken breasts purchased at 7 AM and 11 AM. However, no significant differences can be observed in the mean TBARS values for thighs among the three purchasing times, as presented in Table 5. Furthermore, the TBARS values for chicken breasts and thighs range from 0.0299 to 0.0696 mg MDA/kg and 0.0311 to 0.0877 mg MDA/kg, respectively. The results are lower

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Table 4. Water-holding capacity of chicken breasts and thighs purchased at different stalls and purchasing times.

Stall No.	Purchasing time	Water-holding capacity (%)
Breast		
1	7:00 AM	48.04±3.08
	11:00 AM	50.98±1.60
	3:00 PM	52.64±7.36
2	7:00 AM	59.55±1.31
	11:00 AM	64.34±4.20
	3:00 PM	58.36±0.16
3	7:00 AM	59.88±3.95
	11:00 AM	58.25±8.16
	3:00 PM	65.40±3.09
Thigh		
1	7:00 AM	60.38±2.09^{ab}
	11:00 AM	57.47±2.08^{b}
	3:00 PM	61.40±1.20^{a}
2	7:00 AM	57.33±1.22^{ab}
	11:00 AM	58.61±0.81^{b}
	3:00 PM	59.39±1.92^{a}
3	7:00 AM	70.64±2.68^{ab}
	11:00 AM	64.00±6.41^{b}
	3:00 PM	76.17±4.16^{a}

Values are presented as mean±SD of triplicate. Values with different superscripts within the same stall are statistically significantly different (p<0.05).

Table 5. TBARS value of chicken breasts and thighs purchased at different stalls and purchasing times.

Stall No.	Purchasing time	TBARS (mg MDA/kg)
Breast		
1	7:00 AM	0.07±0.03^{a}
	11:00 AM	0.04±0.01^{b}
	3:00 PM	0.06±0.02^{ab}
2	7:00 AM	0.07±0.03^{a}
	11:00 AM	0.05±0.01^{b}
	3:00 PM	0.03±0.01^{ab}
3	7:00 AM	0.06±0.02^{a}
	11:00 AM	0.04±0.02^{b}
	3:00 PM	0.05±0.02^{ab}
Thigh		
1	7:00 AM	0.03±0.01
	11:00 AM	0.04±0.01
	3:00 PM	0.05±0.01
2	7:00 AM	0.09±0.04
	11:00 AM	0.07±0.04
	3:00 PM	0.06±0.03
3	7:00 AM	0.05±0.02
	11:00 AM	0.03±0.01
	3:00 PM	0.04±0.01
Acceptable TBARS value[1]		<0.2

Values are presented as mean±SD of triplicate. Values with different superscripts within the same stall are statistically significantly different (p<0.05). [1]Sujiwo *et al*. (2018).

compared with the study of Kapase *et al*. (2023), who found a TBARS value of 0.25 mg MDA/kg and 0.36 mg MDA/kg for chicken breasts and thighs, respectively. The recorded values could indicate that the purchased chicken broilers were fresh, given that values lower 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; Chandra Mohan *et al*., 2017).

3.2 Changes in aerobic plate count of chicken broilers

The APC is presented in Table 6 for both chicken breasts and thighs, which range from 5.20 to 7.41 log CFU g^{-1} and 4.99 to 6.45 log CFU g^{-1}, respectively. According to Bureau Circular No. 7 s. 2001, the acceptable range for fresh or frozen raw chicken is 5×10^5 CFU g^{-1} (5.70 log CFU g^{-1}) to 10^7 CFU g^{-1} (7.0 log CFU g^{-1}). Similarly, it is stated that if the total number of bacterial populations is over 7 log CFU g^{-1} in APC, the meat quality has deteriorated (Knox *et al*., 2008). This means that most of the recorded APC values from all stalls are within the acceptable range, except for the purchased chicken breast at 11 AM from Stall 2 (94.44%).

The APC values sometimes exceeded the upper limit, 7.0 log CFU g^{-1}, resulting from the holding temperature and time before they were purchased. This is because ambient temperatures and longer periods affect the overall quality of meat, including its physicochemical and microbiological properties (Suwattitanum and Wattanachant, 2014). The recorded APC means for chicken breasts purchased at 11 AM are observed to have significant differences from the ones purchased at 7 AM and 3 PM; meanwhile, only 7 AM and 11 AM are significantly different from chicken thighs.

3.3 Relationship among the physicochemical and microbiological characteristics of chicken broilers

The relationships among the physicochemical and microbiological characteristics of chicken breasts and thighs were determined using the Pearson correlation coefficient (r), as presented in Figures 1 and 2, respectively. For chicken breasts, no statistically significant relationships can be seen between temperature and other physicochemical properties. However, it can be observed in Figure 1 that pH and lightness, L*, have a moderate significant negative correlation (r = -0.48, p<0.05). This can mean that as the

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Table 6. Aerobic plate count (APC) of chicken breasts and thighs purchased at different stalls and purchasing times.

Stall No.	Purchasing time	APC (log CFU g^{-1})
Breast		
1	7:00 AM	5.27±0.06[b]
	11:00 AM	6.13±0.70[a]
	3:00 PM	5.35±0.03[b]
2	7:00 AM	5.20±0.09[b]
	11:00 AM	7.41±1.24[a]
	3:00 PM	5.46±0.07[b]
3	7:00 AM	5.26±0.07[b]
	11:00 AM	6.89±1.12[a]
	3:00 PM	5.32±0.02[b]
Thigh		
1	7:00 AM	4.99±0.39[b]
	11:00 AM	6.45±0.84[a]
	3:00 PM	5.46±0.24[ab]
2	7:00 AM	5.14±0.11[b]
	11:00 AM	5.31±0.13[a]
	3:00 PM	5.29±0.11[ab]
3	7:00 AM	5.20±0.07[b]
	11:00 AM	5.47±0.14[a]
	3:00 PM	5.39±0.10[ab]
Acceptable APC value[1]		<7.0

Values are presented as mean±SD of triplicate. Values with different superscripts within the same stall are statistically significantly different (p<0.05). [1]Food and Drug Administration (2023).

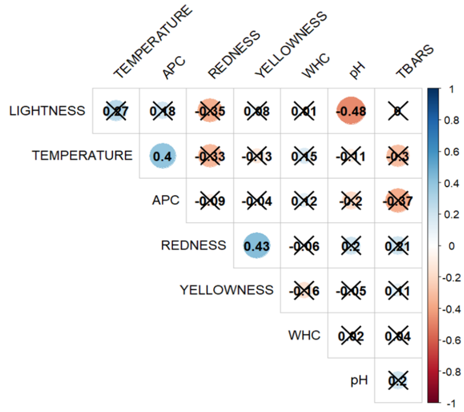

Figure 1. Correlogram of Pearson correlation coefficient (r) among the physicochemical and microbiological characteristics of chicken breasts. Blue corresponds to a positive correlation, while red indicates a negative correlation.

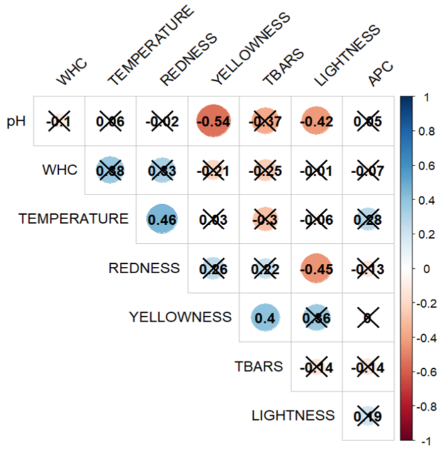

Figure 2. Correlogram of Pearson correlation coefficient (r) among the physicochemical and microbiological characteristics of chicken thighs. Blue corresponds to a positive correlation, while red indicates a negative correlation. r values that are not crossed exhibit significance at p<0.05.

pH of the chicken breast increases, its meat color relative to lightness decreases, which is consistent with the study by Sujiwo *et al*. (2018). This finding was supported by Kralik *et al*. (2017), who determined a negative correlation between pH and CIE L* value for their chicken meat samples (r = −0.285 and r = -0.438). Salakova *et al*. (2009) also found a negative correlation between pH and L* for fresh and cooked chicken breast meat. Furthermore, the study by Barbut *et al*. (2008) reported that chicken meats with higher L* values, which indicate a PSE-like appearance, had a lower pH, while chicken meats that were considered DFD, with lower L* values, had a higher pH.

Low glycogen levels due to slaughter stress indicate that less glycogen can be converted to lactic acid, which in turn maintains the high pH of chicken meat (Kralik *et al*., 2017). This prevents the postmortem increase in meat reflectance, thus leaving the appearance of the chicken in a DFD state. Swatland (2008) hypothesized that a high pH in chicken meat transmitted more light into its depth than that with a low pH; hence, a darker meat color. Meats with a low pH, on the other hand, scatter more light back to the observer. He found that the recorded reflectance values were significantly higher in low-pH meat compared to high-pH meat, resulting in a paler color of the meat. In addition, a* and b* have a significant positive correlation (r = 0.43, p<0.05), as shown in Figure 1. This is supported by Kim *et al*. (2010); however, the relationship was inconsistent with the findings by Qiao *et al*. (2001) that there was a significant negative correlation between the mentioned parameters after postmortem collections. Similarly, Fletcher *et al*. (2000) found that the a* of raw broiler breast was negatively correlated with b*. The inconsistencies among the studies might be caused by the different numbers and nature of the samples used.

The relationships between APC and the physicochemical characteristics of chicken breasts are also presented in Figure 1. The temperature and APC in chicken breasts have a significant positive correlation with each other (r = 0.40, p<0.05), while the rest exhibited no statistically significant relationship. The significant relationship between temperature and APC

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shows that as the temperature increases, the APC also increases. When conducting APC, mesophilic bacteria, such as *Salmonella* spp. and *Escherichia coli*, are expected to grow in the medium. In the study by Hayat *et al*. (2021), high populations of *Salmonella* spp. and coliforms such as *E. coli* were observed at high temperatures. The same findings were observed by Ghollasi-Mood *et al*. (2016) wherein the microbial population increases rapidly at higher temperatures. Moreover, Park *et al*. (2013) found that the counts of aerobic mesophilic bacteria increase with increasing temperature. Mesophilic bacteria optimally grow at moderate temperatures (20 to 45°C), given that an increase in temperature will also increase the enzyme activity of these microorganisms, thus allowing them to grow and multiply (Schiraldi and De Rosa, 2014). It should be noted, however, that very high temperatures will result in protein denaturation, resulting in the death of the microorganism. Temperature greatly influences bacterial populations.

For chicken thighs (Figure 2), temperature and a*, have a significant positive correlation (r = 0.46, $p<0.05$), which indicates that a low temperature can result in a low redness value, and vice versa. Hayat *et al*. (2021) reported in their studies that the redness values of broiler chickens were higher in the treatment with a higher temperature compared with other treatments. Suwattitanum and Wattanachant (2014) also observed higher redness values at high broiler internal temperatures. It is then suggested that redness values are associated with myoglobin concentrations in skeletal muscle (Bekhit and Faustman, 2005; Kim *et al*., 2010; Hayat *et al*., 2021). In relation, there is an enzymatic system that regulates the conversion of metmyoglobin, the oxidized myoglobin, back to myoglobin, which is called metmyoglobin-reducing activity (MRA). Low temperatures, such as freezing, have roles in the loss of MRA, which results in lower concentrations of myoglobin, thus lowering the redness value (Hayat *et al*., 2021).

Chicken thigh pH has a significant negative correlation with L* (r = -0.42, $p<0.05$), similar to chicken breast, and b* (r = -0.54, $p<0.01$). As stated above, the negative correlation between pH and L* value is supported by the studies of Kralik *et al*. (2017), Salakova *et al*. (2009), and Barbut *et al*. (2008). This result indicated that higher pH results in a lower L* value, since high pH (low pH) has lower (higher) meat reflectance, hence the darker (paler) meat color. Concerning pH and yellowness, the determined negative correlation indicates that a high pH results in a lower b* value. Allen *et al*. (1997) reported a negative correlation between the two parameters in chicken meat samples. Other studies, however, found that there was a positive correlation between pH and b* (Yang and Chen, 1993).

Furthermore, L* and a* have a significant negative correlation (r = -0.45, $p<0.05$). The studies by Qiao *et al*. (2001) and Fletcher *et al*. (2000) found the same relationship between the mentioned color groups on raw chicken meats. A higher L* value can increase light scattering, lowering the amount of absorbed light, which results in a reduced red appearance in the meat (Hayat *et al*., 2021). Lastly, TBARS and b* are significantly positively correlated (r = 0.40, $p<0.05$) with each other. The result implies that the higher the TBARS value, the higher the meat yellowness as well. This is inconsistent with the findings of Wang *et al*. (2021), wherein they found a negative correlation between the lipid oxidation rate (TBARS) and yellowness, indicating that a great decline in yellowness was observed for a greater lipid oxidation rate. Furthermore, this implies that oxidation (high TBARS value) converts oxymyoglobin to metmyoglobin (brown color), indicating a faster decline in the color of meat (Kralik *et al*., 2017; Sujiwo *et al*., 2018).

3.4 PCR-based detection of Salmonella spp.

All samples were found to be negative for *Salmonella* spp. in all stalls (Table 7), which was inconsistent with the study by Gonzales *et al*. (2021), wherein *Salmonella* spp. was detected in 1.25% of their chicken samples that were procured from the public markets of Los Baños, Laguna. In Ozamis City public market, 80% of their chicken thigh samples and 20% of their chicken breast samples were found to be contaminated by *Salmonella* spp. (Recto *et al*., 2016). Raw poultry meat, especially chicken, is mostly associated with *Salmonella* spp. contamination. Improper handling, inadequate facilities, and inappropriate storage conditions may cause the presence of *Salmonella* spp. in food (Gonzales *et al*., 2021). Public markets are often generalized as less hygienic relative to supermarkets (Pascual *et al*., 2020), hence, there is a stereotype that meats sold there are usually associated with undesirable microorganisms. The absence of *Salmonella* spp. can indicate the quality and safety of poultry meat, ensuring food safety and protecting public health (Gonzales *et al*., 2021). It is said that all chickens contain this microorganism in their digestive tract, so mishandling practices may result in higher susceptibility to contamination, especially for the thigh part that is relatively closer to the anus (Recto *et al*., 2016). It should be noted, however, that *Salmonella* spp. is not the only pathogen that can be present in chicken meat, hence the total microbial population should also be considered when it comes to evaluating the quality and safety of

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chicken meat.

The handling practices of the retailers when they sell commercial broilers in the public market of Batong Malake were not explicitly known. Neither interviews nor surveys were performed when conducting the experiment. However, based on the recorded physicochemical and microbiological properties of commercial broilers, their handling practices can be assumed. The higher temperature of commercial broilers than chilled and frozen ones implied that the chickens were placed on display until they were bought without keeping their chilling or freezing temperature. This could be why all chicken breasts and thighs purchased at 11 AM had the highest temperature among all purchasing times. It can be assumed that chickens at 7 AM were new, and then some were left on display until they were bought at 11 AM, and when the majority of chickens on display were already bought, they would replace them with new ones coming from their chiller. Inconsistencies were found in other physicochemical characteristics, but most of them could indicate freshness. Relating to temperature, some recorded chicken breasts and thighs APC were near the upper limit (>7.0 log CFU g^{-1}), and one even exceeded it. Although *Salmonella* spp. was absent from all stalls, the high APC should still be considered. Concerning all that, it could be recommended to the sellers that they store the chickens at the recommended chilling or freezing temperatures and maintain these temperatures until the chickens are sold to control the growth of microorganisms.

4. Conclusion

This study revealed that the majority of the recorded physicochemical properties for meat quality and safety could indicate the freshness of the purchased chicken broilers at the Batong Malake public market. This study exhibited significant moderate positive correlations between a* and b* values (r = 0.43) for chicken breasts; between temperature and a* (r = 0.46); and between TBARS and b* (r = 0.40) for thighs. On the other hand, significant negative correlations were observed between pH and L* for chicken breasts and thighs (r = -0.48 and r = -0.42, respectively), between pH and b* (r = -0.54), and between L* and a* (r = -0.45) for chicken thighs. Furthermore, temperature was found to be positively correlated with APC. With this, it is suggested that retailers in the public market store their commercial broilers at the recommended temperatures. However, there were still some inconsistencies in the findings relative to the related literature. This could be the result of the differing practices used by the sellers in the public market, which were limitedly known. With that, it is then recommended that the handling practices of these sellers be studied.

Conflict of interest

The authors declare no conflict of interest.

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