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Research Article

Drip loss assessment by standard bag and filter paper wetness method and their relationships with broiler chicken meat quality classification

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Abstract

This study investigates the effectiveness of two methods— the standard bag method and filter paper wetness (FPW) method—in assessing drip loss (DL) and their potential application in broiler chicken meat quality classification. The standard bag method measures drip loss by suspending meat samples in plastic bags to capture expelled fluids over a set period, whereas the filter paper wetness method involves pressing the meat onto filter paper to evaluate the amount of moisture released. In this study, samples from broiler chickens were assessed using both methods, and the resulting drip loss values were compared against meat quality categories such as PSE (pale, soft, exudative), normal, and DFD (dark, firm, dry) classifications. Both methods are widely used for evaluating drip loss, but their reliability and correlation with meat quality classification have not been extensively compared. Thirty broiler chickens were selected, and their breast meat was evaluated to understand the relationships between water-holding capacity (WHC), pH, lightness (L*), and other meat quality attributes. To facilitate this analysis, samples were categorized into three meat quality classes: Pale, Soft, and Exudative (PSE); Normal; and Dark, Firm, and Dry (DFD). The study aimed to assess the correlation between WHC and other evaluated characteristics and employed linear regression analyses to examine FPW and WHC as functions of 24-hour drip loss. Results showed that 5% DL corresponded to 64.77 mg water in FPW and was equivalent to 93.61% in WHC, establishing benchmarks for broiler meat quality classification. Using these 5% DL equivalents (93.61% WHC), along with immediate pH and lightness criteria, samples were accurately categorized across all quality classes. The high R^2 values ($R^2 = 0.83$, and $P < 0.0001$.) observed between WHC (%) and DL (%), as well as between FPW (mg) and DL (%) ($R^2 = 0.82$, and $P < 0.0001$.), underscored the reliability of these assessment methods. This study supports the efficacy of using WHC and FPW in the classification of broiler chicken meat quality, providing a reliable and quantifiable approach to meat quality evaluation. These findings have significant implications for meat industry practices, enabling precise classification and enhancing quality control in poultry meat production.

Introduction

Poultry meat is among the most affordable and widely consumed sources of protein globally due to its economic viability (Hashem et al., 2024). The loss of fluids from broiler is significant for the industry due to its economic implications. Water constitutes approximately 75% of meat weight, and the capacity of muscle to retain moisture is key to many meat quality parameters (Huff-Lonergan and Lonergan, 2005). The significant economic issues associated with weight losses during the storage, cooking, freezing, and thawing of meat are linked to the retention of water within the muscle tissue (Islam et al., 2019). Therefore, the study of meat hydration holds significance in both scientific and economic contexts (Hamm,1961). Drip loss has emerged as a critical criterion in meat quality assessment particularly understanding the physiochemical properties, prompting the development of various methodologies for its determination (Hossain et al., 2021; Ali et al., 2022). Faster-growing broilers, often raised under intensive production systems, tend to have higher muscle deposition but lower WHC, leading to increased drip loss and potential for Pale, Soft, and Exudative (PSE) meat. On the other hand, birds raised in semi-intensive or free-range systems exhibit better muscle integrity, improved WHC, and lower drip loss, enhancing meat texture and consumer acceptability (Hashem et al., 2020). Drip loss measurement methods provide valuable insights into meat quality decline, as factors like lipid oxidation and proximate composition significantly affects its deterioration (Murshed et al., 2014). The percentage drip loss assessed using the bag method (DL), as established by Honikel (Honikel, 1987), is internationally acknowledged as the standard methodology; nonetheless, it necessitates extensive space and meticulous sample handling. The filter-paper wetness (FPW) approach, as delineated by Kauffman *et al.* (Kauffman, 1986), is acknowledged as the most straightforward and rapid technique for assessing meat water-holding capacity (WHC), and it has been found to exhibit a strong correlation with drip loss (DL) measures. The variability in applied methodologies renders the comparison of drip loss results in

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the literature challenging. Consequently, initiatives have been undertaken to establish international reference techniques to guarantee comparability in drip loss measurements (Honikel, 1998). The primary purpose of this work was to examine the correlation between the DL method, an established measurement of drip loss, and the other promising measurements filter paper wetness. The second purpose was to examine the correlations between these WHC measures and broiler chicken meat quality characteristics

Materials and Methods

Experimental site

This experiment was conducted at Meat Science Laboratory under the Department of Animal Science, Bangladesh Agricultural University, Mymensingh.

Required equipment and preparation of instruments

The necessary equipment included a HANNA meat pH meter, Minolta colorimeter, a Scan speed 1730R centrifugal machine, qualitative filter-paper (125mm in diameter, Whatman Grade1), Laboratory Precision Balance. Additional accessories like zipper bag, container, icebox, refrigerator, knife, chopping board, tissue paper, gloves. Necessary instruments were cleaned with hot water and detergent powder and then autoclaved and dried properly before starting the experimental activities.

Sample collection and preparation

Broiler samples were collected from local commercial market known as Kamal Ranjit Market, Bangladesh Agricultural University, Mymensingh. Every morning at 7:00 a.m. for 3 successive days, 30 broiler chicken, 10 randomly collected per day from different producers of this local market. Then the bird samples were immediately transferred to the Animal Science Laboratory, Bangladesh Agricultural University, Mymensingh. After that removing the carcass, deboning and cleaning was done. After deboning breast part were collected and prepared for analysis. Three slices with 2.5cm thickness were cut from the breast part of each sample. Slices were allocated at random for the drip loss methods: a slice was used for filter paper wetness (FPW) and lightness measurements; another slice was used for the drip loss bag method; and the last slice was used for measuring water holding capacity.

Physicochemical properties measurements

pH value estimation

The pH of the breast muscle was determined shortly after slaughtering (15 min postmortem) using a HANNA Meat pH Meter and then packaged, stored at a refrigeration temperature of 4°C for a duration of 24 hours.

Determination of drip loss

Standard Bag Method

Samples were stored in refrigerator at 4°C for 24 hours for measuring drip loss. Meat samples were placed in airtight plastic bags filled with air and stored at 4°C for 24 hours (Honikel, 1998). Drip loss was determined by calculating the percentage of weight loss following suspension.

Filter Paper Wetness Method

Filter-paper wetness was determined in a single replicate, according to the methodology described by Kauffman *et al.* (Kauffman et al., 1986). The slice was exposed to the environment (blooming) at room temperature for 30min before being analyzed. A qualitative filter-paper (125mm in diameter, Whatman Grade1) was weighed, placed on the meat surface for 3s, and then weighed again. The FPW was expressed as the weight (mg) of the absorbed exudate.

Color value estimation

Color values like lightness (CIEL*), redness (CIEa*), and yellowness (CIEb*) for several patties were determined utilizing a colorimeter (Konica Minolta CR-400, Tokyo, Japan). Each sample was measured thrice. The measurement for chroma (C*) value and hue angle (h°) value was carried out utilizing two equations of {(a*+b*)1/2} and {tan−1(b*/a*)}, respectively.

Water holding capacity

The Water holding capacity was measured as per Kim et al. (Kim et al., 2020). Thawed samples (1 g each) were encased in absorbent cotton and positioned in a centrifugal tube. The samples were subjected to centrifugation using a centrifuge separator (1730R, Lynge, Denmark) at 3,000×g for 10 minutes at 4°C, after which the samples were weighed.

Broiler meat Classification into Quality Categories

Meat samples were classified according to lightness (L∗) (Qiao et al, 2001), pH15min (Ristic & Damme, 2013) into one of the following three quality classes, as defined by

Pale, soft, and exudative (PSE): L∗ > 53 and pH15min ≤ 5.8

Normal: L∗= 44 – 53, and pH15min between 5.9-6.2

Dark, firm, and dry (DFD): L∗ < 44, and pH15min ≥ 6.3

Statistical model and analysis

The statistical analyses were performed on JMP® Pro 17.0.0 (JMP Statistical Discovery LLC) software at a significance level of 5%. The bird was considered a block, because the analytical methods were measured in each bird. Pearson's correlation analysis was performed among the quality attributes, whose coefficients (r) were tested by Student's t-test. Regression analyses of WHC (%) and FPW (mg) as a function of DL (%) were performed to determine the equivalent values between these WHC parameters. ANOVA and (when necessary) Tukey's test were conducted to evaluate differences in WHC measured by all analytical methods among the meat quality categories, classified according to the reference criteria.

Results and Discussion

Mean values, standard deviations, and coefficients of variation of pH, L∗, and water-holding capacity (WHC) obtained with different methodologies are presented in Table 1.

Table 1: Means, standard error (SE), minimum (Min), maximum (Max), and coefficients of variation (CV) for meat quality characteristics measured on broiler meat (breast meat; n = 30)

Characteristic	Mean	SE	Min	Max	CV (%)
pH	5.93	0.03	5.70	6.40	2.94
L*	49.69	0.56	42.88	55.23	6.24
a*	3.80	0.15	2.23	5.44	21.06
b*	10.88	0.23	8.19	13.54	11.69
DL (%)	4.39	0.09	3.33	5.36	11.84
WHC (%)	94.15	0.09	93.39	95.12	0.54
FPW (mg)	53.74	1.91	35.24	75.01	19.52

DL = drip loss after 24 h storage; WHC = water-holding capacity; and FPW = filter-paper wetness (mg).

Correlations between WHC and other evaluated meat characteristics

The correlation analysis of broiler breast meat quality attributes reveals significant interrelationships among pH, color, and water-holding capacity, consistent with previous findings. The pH measured at 15 min postmortem (pH 15min) demonstrated a strong negative correlation with lightness (L∗, r = -0.83, P < 0.01) and yellowness (b∗, r = -0.73, P < 0.01), suggesting that lower pH values are associated with paler and less yellow meat. This aligns with the well documented effects of pH on meat color, where rapid pH decline leads to protein denaturation, resulting in lighter meat (Huff-Lonergan and Lonergan, 2005). Additionally, pH15 min showed strong negative correlations with drip loss (DL, r = -0.77, P < 0.01), and filter-paper wetness (FPW, r = 0.70, P < 0.01), indicating that lower pH is associated with higher water loss. These findings are consistent with those of Swatland (Swatland, 2004), who observed that reduced water-holding capacity is commonly linked to lower pH. L∗ value showed strong positive correlation with drip loss (DL, r = 0.89, P <0.01). WHC (water-holding capacity) was negatively correlated with DL (r = -0.78, P < 0.01) and FPW (r = -0.87, P < 0.01), indicating that higher WHC is associated with lower drip loss and filter-paper wetness**.** The influence of slaughter age on meat quality also aligns with these findings, as older animals tend to exhibit higher WHC and lower drip loss, likely due to increased muscle maturity and protein stability. Moreover, variations in collagen integrity across different ages impact water retention, further reinforcing the correlations between pH, WHC, and drip loss in meat quality assessment (Hossain et al., 2021; Rana et al., 2014).

Table 2: Correlation coefficients among the broiler meat (breast meat; n = 30) quality attributes

Characteristic	pH15min	L*	a*	b*	DL (%)	WHC (%)
L*	-0.83**					
a*	-0.16	0.08				
b*	-0.73**	0.89**	0.13			
DL (%)	-0.77**	0.89**	0.08	0.88**		
WHC (%)	0.65**	-0.79**	0.06	-0.78**	-0.91**	
FPW (mg)	-0.70**	0.83**	0.01	0.80**	0.90**	-0.87**

DL = drip loss after 24 h storage; WHC = water-holding capacity; and FPW = filter-paper wetness (mg).

*$P < 0.05$. **$P < 0.01$.

Broiler meat classification into quality categories according to WHC

The table presents a comparative analysis of broiler breast meat quality attributes across three quality classes: Pale, Soft, and Exudative (PSE), Normal, and Dark, Firm, and Dry (DFD). The pH at 15minutes postmortem (pH 15min) varies significantly among these classes, with DFD meat showing the highest pH (6.37 ± 0.07), while PSE meat exhibits the lowest pH (5.75 ± 0.04). Lightness (L*) also follows this trend, with PSE meat being significantly lighter (54.36 ± 0.37) compared to Normal (48.74 ± 0.21) and DFD meat (43.31 ± 0.69). Redness (a*) does not show significant differences between the groups, but yellowness (b*) decreases from PSE (12.75 ± 0.19) to Normal (10.48 ± 0.11) and DFD (8.47 ± 0.37). Water-holding capacity (WHC) is assessed using Drip Loss (DL), WHC%, and Filter Paper Wetness (FPW). PSE meat shows the highest drip loss (5.12 ± 0.09%) and the lowest WHC% (93.51 ± 0.12), while DFD meat retains the most water with the lowest drip loss (3.39 ± 0.17%) and the highest WHC% (95.07 ± 0.22). The FPW values also follow a similar pattern, with PSE meat showing the highest value (67.70 ± 2.32 mg), Normal meat showing intermediate values (50.77 ± 1.34 mg), and DFD meat showing the lowest FPW value (36.10 ± 4.34 mg).

Table 3: Meat quality characteristics (mean ± standard error) of three quality groups

	Quality class		
Characteristics	**PSE**	**Normal**	**DFD**
N	7	21	2
pH15min	5.75 ± 0.04[c]	5.95 ± 0.02[b]	6.37 ± 0.07[c]
L*	54.36 ± 0.37[a]	48.74 ± 0.21[b]	43.31 ± 0.69[c]
a*	4.06 ± 0.30[a]	3.67 ± 0.17[a]	4.23 ± 0.57[a]
b*	12.75 ± 0.19[a]	10.48 ± 0.11[b]	8.47 ± 0.37[c]
DL (%)	5.12 ± 0.09[a]	4.25 ± 0.05[b]	3.39 ± 0.17[c]
WHC (%)	93.51 ± 0.12[a]	94.28 ± 0.06[b]	95.07 ± 0.22[c]
FPW (mg)	67.70 ± 2.32[a]	50.77 ± 1.34[b]	36.10 ± 4.34[c]

DL = drip loss after 24 h storage; WHC = water-holding capacity; and FPW = filter-paper wetness (mg). [a–c]Means followed by different letters in the row differ (P < 0.05) by Tukey's test.To use FPW (mg) or WHC (%) values in the classification of meat into quality categories, it is first necessary to determine the values equivalent to 5% DL.

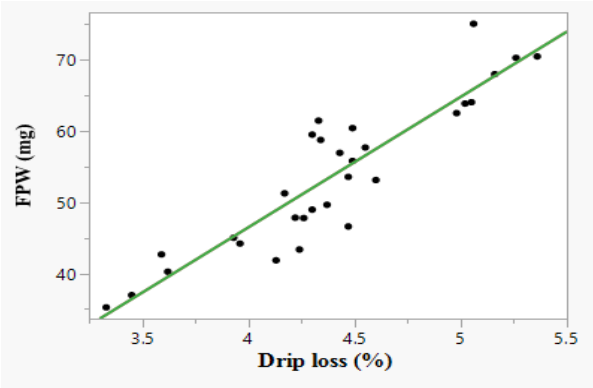

Figure 1: Linear regression of filter-paper wetness (FPW) as a function of 24 h drip loss.

FPW = -26.7199 + 18.2978*DL

$R^2 = 0.82$, and $P < 0.0001$.

5% drip loss equivalent to 64.77 mg water.

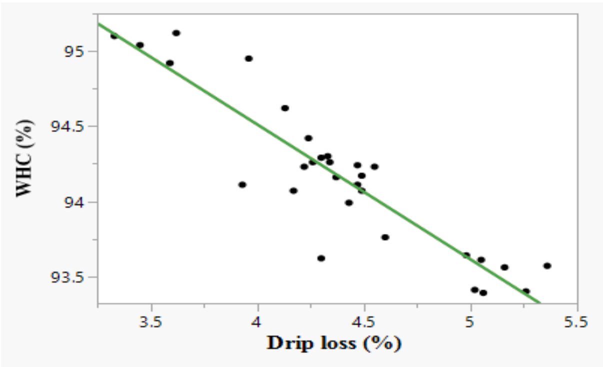

Figure 2: Linear regression of water-holding capacity (%) as a function of 24 h drip loss.

WHC (%) = 98.1039 - 0.8981*DL

$R^2 = 0.83$, and $P < 0.0001$.

5% DL is equivalent to 93.61 % WHC

Using approximate values of 5% DL equivalents 93.61 % WHC, together with immediate pH and L* criteria, samples were distributed according to the WHC method (Table 4).

Table 4: Frequency (%) of occurrence of each quality class

Quality class	DL (%)	WHC (%)	FPW (mg)
PSE	23	23	23
Normal	70	70	70
DFD	7	7	7

All quality classes were accurately identified, as evidenced by the high R^2 values observed between WHC (%) and DL (%), also between FPW (mg) and DL (%). The results obtained in this study on drip loss (DL) assessment through the standard bag method and filter paper wetness (FPW) are critical in understanding the relationships between these measures and the overall meat quality classification of broiler chicken meat. This section provides an in-depth discussion of the findings, emphasizing the practical and theoretical implications for broiler meat quality assessment.

Drip loss and water holding capacity (WHC) correlation

The results show that a 5% DL is equivalent to 64.77 mg of water loss, which aligns closely with a WHC of 93.61%. This strong association between DL and WHC highlights that as the drip loss increases, the ability of the meat to retain water decreases proportionally (Kaić et al., 2023). This inverse relationship is important for understanding meat quality, as WHC is a key indicator of juiciness and overall consumer acceptability (O'Quinn et al., 2018; Liu et al., 2022). The WHC percentage provides insights into the meat's texture and moisture retention capacity, which are essential attributes in classifying meat quality (Huff-Lonergan & Lonergan, 2005).

Effectiveness of quality classification

The study successfully differentiated between three meat quality classes: Pale, Soft, and Exudative (PSE), Normal, and Dark, Firm, and Dry (DFD) (Qiao et al, 2001; Ristic & Damme, 2013). The distribution of these quality classes was observed as follows:

- PSE: 23%

-Normal: 70% - DFD: 7%

These findings reveal that the majority of broiler meat falls under the "Normal" classification, which is ideal for commercial sale and consumer preference (Barbut et al., 2022). The low percentage of DFD meat suggests limited issues with meat dryness or firmness (Freitas et al., 2017)., while the presence of 23% PSE indicates a proportion of meat that may have lower quality due to paleness and higher drip loss (Offer & Knight, 1988; Woelfel, 2000; Van et al., 2000; Barbut, 2009; Krzęcio-Nieczyporuk et al., 2023).

Correlations among drip loss, WHC and FPW

High R^2 values between WHC (%) and DL (%), as well as between FPW (mg) and DL (%), indicate a strong predictive relationship between these variables (Joo & S., 2018). This demonstrates that FPW can serve as a reliable alternative to DL for assessing water loss in meat (Torres et al., 2017; Joo & S., 2018). In practical terms, For rapid, cost-effective, and precise field assessments, the filter paper wetness method proved worthy of consideration and are comparable in accuracy with the standard bag method (Kauffman et al., 1986). Additionally, the high R^2 values emphasize the robustness of both methods in predicting and classifying meat quality accurately.

Implications for meat processing and quality assurance

The correlation between DL and WHC, alongside the efficacy of the FPW method, provides meat processors with valuable information on how these variables impact the perceived quality of broiler meat. High WHC is preferred as it suggests better retention of water, leading to a juicier and more desirable product (Bowker et al., 2014; Davoodi et al., 2020; Yu et al., 2023). Heat stress weakens collagen in livestock, increasing drip loss, which further compromises WHC and overall meat quality (Haque et al., 2017). For long-term storage, vacuum packaging combined with freezing provides the best protection against oxidation and excessive drip loss. In commercial meat supply, modified atmosphere packaging (MAP) with refrigeration ensures an extended shelf life while reducing drip loss (Rahman et al., 2023). Meat classified as PSE, however, typically presents challenges in terms of moisture retention and shelf-life (Yang et al., 2022; Lesiów et al., 2024), underscoring the need for rapid quality assessment methods to prevent such meat from reaching consumers.

Limitations and recommendations for future research

Although the study confirms the reliability of FPW and DL methods for meat quality assessment, further research could enhance the classification of meat quality, especially in identifying sub-categories within the Normal class to detect minor quality variations. Additionally, investigating the impact of external factors like feed, stress, and slaughtering conditions on DL and WHC could provide more comprehensive insights.

Overall, the study highlights the strong predictive capabilities of WHC and FPW in assessing broiler chicken meat quality and underscores the potential for FPW as a rapid quality control method. The classification accuracy across PSE, Normal, and DFD classes, supported by robust R^2 values, suggests that both drip loss and water holding capacity are reliable indicators of meat quality. The findings thus contribute to the development of effective meat quality assessment methods that can benefit poultry producers and processors by improving quality control measures and meeting consumer demands.

Conclusion

The study concludes that each analytical method for drip loss assessment provides distinct advantages and limitations in relation to broiler meat quality classification. The standard bag method was found to be most effective for distinguishing between the Normal and PSE meat categories, aligning well with L* and pH15min thresholds. Filter paper wetness, the simplest method, showed limited accuracy in classifying DFD samples due to lower sensitivity to drip loss variations. Overall, the study suggests that combining multiple methods could improve classification accuracy and recommends the standard bag method as the preferred choice when resources permit, as it offers the most consistent alignment with established quality criteria for broiler chicken meat.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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