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EVALUATION OF EGG CHARACTERISTICS USING THE SIZE CLASSIFICATION AND GRADING SYSTEM FOR MALLARD DUCK EGGS

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ABSTRACT

This study investigated the characteristics of 307 eggs randomly collected from 7 mallard breeds that were raised in the same production and management system using the size classification and grading system for mallard duck eggs. Egg distribution by size classification based on egg weight was 17.26% extra-large (>78 g), 55.37% large (68–78 g), 24.76% medium (57–67 g), and 2.61% small (<57 g). Egg distribution by grade classification based on Haugh unit values was 21.17% Grade-AA, 47.56% Grade-A, 28.01% Grade-B, and 3.26% Grade-C. Based on the median of egg weight and Haugh unit values, the Itik-Pinas (IP) breeds (IP–Itim, IP–Khaki, Kayumanggi–IP), Khaki Campbell, Tsaiya, and White Mallard eggs were classified as large and Grade-A. Pekin eggs were classified as extra–large and Grade-AA. Bigger egg sizes corresponded to a significant increase (*P*<0.05) in short and long circumference, and weight of yolk, albumen, and eggshell. On the other hand, higher egg grades corresponded to a significant increase (*P*<0.05) in albumen height only. The new size and grade classification system may be applied to compare eggs from different mallard breeds in major egg-producing regions. However, it should be validated and improved further using larger data sets and considering local consumer preferences.

Key words: egg characteristics, grading, size classification, mallard duck eggs

INTRODUCTION

Egg grading is the grouping of eggs into lots having similar characteristics according to quality and size (weight). Eggs may be graded based on the interior quality of the egg and the appearance and condition of the eggshell (American Egg Board, 2012). Size refers to the minimum weight per dozen eggs. It does not refer to the dimensions of an egg or how big it looks. Hence, eggs of any weight (size) class may also differ in quality (USDA, 2017).

In the Philippines as in the United States, chicken eggs are sorted and sold using a 6–sizes classification system (jumbo, extra-large, large, medium, small, and peewee) based on egg weight (PNS, 2005; USDA, 2000). By comparison, the 4–sizes classification system

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(extra-large, large, medium, and small) is used in the United Kingdom and Europe (British Egg Industry Council, 1996).

While there already exist standards, grades, and weight classes for individual eggs of domesticated chickens in many countries of the world, an egg grading and weight classification system for duck eggs is notably lacking. Such information is important for the local duck egg industry which was able to produce 49.57 thousand metric tons of duck eggs of assorted sizes in 2019, worth 5.017 billion pesos (PSA, 2020). The development and use of a classification system based on official standards of size and quality will be important to sustain the production, processing, marketing, and trade of duck eggs.

The dominant type of mallard ducks (*Anas platyrynchos*) used for the commercial production of duck eggs is the Philippine mallard duck (PMD) locally known as "*itik*". Egg production from the PMD can be variable depending on location/province (Dagaas *et al*., 2006), strain (Datuin and Magpantay, 2013), nutrition (Romjali *et al*., 2004), production/housing system (Escobin *et al*., 2008), and molting (Dagaas *et al*., 2006). Unfortunately, local information on mallard egg characteristics in relation to size and quality standards has not yet been studied.

In this regard, this study is aimed to evaluate the weight, shape, internal and external quality of randomly-collected duck eggs from 7 breeds – the Itik–Pinas (IP) breeds (i.e., IP–Itim, IP–Khaki, and Kayumanggi–IP), Khaki Campbell, Pekin, Tsaiya, and White Mallard using the size classification and grading system proposed for mallard duck eggs. The assigned size and grade (quality) classification of eggs from the seven mallard breeds were also compared with those of mallard breeds from other countries based on published reports containing both egg weight and Haugh unit values.

MATERIALS AND METHODS

This study was conducted in compliance with the requirements of the Institutional Animal Care and Use Committee of the University of the Philippines Los Baños (with Assigned Protocol No. 2019-0034) in collaboration with the National Swine and Poultry Research and Development Center (NSPRDC), Bureau of Animal Industry (BAI), Department of Agriculture.

The proposed size classification system was developed based on the mean egg weight of mallard duck eggs (72.6 g), see Bondoc *et al*. (2020). Patterned after the 4–sizes classification system for chicken eggs in the United Kingdom and Europe, the range of values for both large- and medium-sized duck eggs was set in 10-gram intervals. The range for large eggs was initially computed as 72.6g ± 5 g or rounded off to 68–78 g. Eggs that weigh 7 g and above were considered extra-large. Medium-sized eggs weighed at 57–67 g. Eggs less than 57 g were considered small.

The grade classification system originally applied for chicken eggs (USDA, 2000) was used in mallard duck eggs to describe the egg white and its corresponding Haugh unit (HU), i.e., Grade-AA (72 HU or more), Grade-A (60–71 HU), Grade-B (31–59 HU), and Grade-C (30 HU or less).

A total of 307 eggs were randomly collected from 7 mallard breeds, namely IP–Itim, IP–Khaki, Kayumanggi–IP (i.e., F1 cross between IP–Itim and IP–Khaki), Khaki Campbell, Pekin, Tsaiya, and White Mallard at the NSPRDC, BAI-DA in Tiaong, Quezon from May 10, 2019 to February 4, 2020. At least 16 eggs in total were collected for each breed. The

The total number of eggs sampled per breed however may vary depending on the number of available laying hens per breed in the farm. Newly laid eggs were individually pencil marked with the corresponding breed and date of egg collection (to determine the age of lay –in weeks). All mallard breeds were fed the same diet and raised in similar production and management system. The duck laying pellet feeds were analyzed at the Analytical Service Laboratory of the Animal Nutrition Division, Institute of Animal Science (IAS), College of Agriculture and Food Science (CAFS), UPLB and found to contain 18.90% crude protein, 3.84% crude fat, 4.15% crude fiber, 6.89% moisture, 12.23% ash, 3.86% calcium, and 0.98% phosphorus using the Semi-micro Kjeldahl distillation, Soxhlet extraction, Weende method, oven drying, ashing at 600oC, Titrimetric, and Colorimetric-UV-Vis method, respectively.

Newly laid eggs were immediately and carefully transported to the General Physiology Laboratory of the IAS, CAFS, UPLB where they were evaluated within 24 hr after their collection. The egg characteristics included: (1) egg size and shape – egg weight, short circumference, long circumference, and long-short circumference ratio, (2) internal egg quality /composition traits – yolk weight, albumen weight, percent yolk, percent albumen, and yolk–albumen ratio, (3) internal egg quality / non-composition traits – yolk color, albumen height, and Haugh unit value, and (4) external egg quality – shell weight, percent shell, and shell thickness at the tip, middle, and bottom portions.

Following the procedures used by Bondoc *et al*. (2020), the egg weight, yolk color, albumen height and Haugh unit were measured using the Orka egg analyzer (ORKA Food Technology LLC, Utah, USA). Yolk and albumen weight (g), shell thickness (mm), and short and long circumference (cm) was measured using a digital weighing scale, Tactix® Digital Caliper (Meridian International Co., Ltd, Shanghai, China), and common measuring tape, respectively. The formulas used to compute Haugh unit values, egg component percentages, yolk-albumen ratio, and long-short circumference ratio were as follows:

Haugh unit = $100 \log_{10} (H - 1.7 W^{0.37} + 7.6)$, where H = height of the albumen; and W = egg weight (Haugh, 1937).
Egg components percentage (%) = (component weight (g) × 100) / egg weight (g)
Yolk–albumen ratio = yolk weight (g) / albumen weight (g)
Long-short circumference ratio = long circumference (cm) / short circumference (cm). A long-short circumference ratio greater than 1.00 implies a more elongated shape.

Pearson product–moment correlation coefficients between egg characteristics and egg weight (the basis for size classification), Haugh unit values (the basis for egg quality grading), and hen age at lay were determined using CORR procedure of SAS (2009).

The general least squares procedures for unbalanced data were used to examine the principal sources of variation affecting egg weight and shape dimensions, internal and external egg quality traits. The following linear "fixed effects" model was used to determine, using an F-test (SAS 2009), $y_{ijklm} = \mu + Breed_i + Size_j + Grade_k + Age_l + e_{ijklm}$ where y_{ijklm} is the dependent variable (i.e., egg weight, shape, and egg quality traits), μ is overall mean, $Breed_i$ is the fixed effect of the i^{th} mallard breed, $Size_j$ is the fixed effect of the j^{th} size classification (extra–large, large, medium and small), $Grade_k$ is the fixed effect of the k^{th} grade classification (AA, A, B, and C), Age_l is the l^{th} covariate effect of the age of lay or hen age (in weeks), and e_{ijklm} is error term assumed to be normally distributed with variance of errors as constant across observations.

The least square means for each egg characteristic were used to compare between breeds, between size categories, and between grade classes, while adjusted for the effects of hen age at lay. To account for data outliers and skewed distribution within a breed, the median of egg weight and Haugh unit values were used to compare between breeds according to the new size classification and egg grading systems. Duncan's Multiple Range test (DMRT) was used to compare between treatment means. Statistical significance was set at $P<0.05$.

Based on published reports containing both egg weight and Haugh unit values, the eggs from different mallard breeds from other countries were categorized based on the proposed size and grade (quality) classification system and compared with the results of this study.

RESULTS AND DISCUSSION

Table 1 shows that egg weight was highly and positively correlated ($P<0.01$) with yolk weight (r = 0.79) and albumen weight (r = 0.82). The correlation coefficient was even higher with the egg circumference, i.e., short circumference (r = 0.92) and long circumference (r = 0.91). Egg weight was low to moderately correlated with percent yolk (r = 0.23), percent albumen (r = 0.17), albumen height (r = 0.33), long-short circumference ratio (r = 0.16), and shell weight (r = 0.47). Egg weight was negatively correlated with percent shell (r = – 0.39) and average shell thickness (r = – 0.11). Egg weight was not related ($P>0.05$) to yolk–albumen ratio and yolk color. The size classification system for mallard duck eggs based on egg weight may thus be justified as egg weight may also reflect the amount of yolk and albumen present in them.

The Haugh unit value together with the visual examination of the yolk are commonly used to evaluate the internal quality of eggs from domesticated chickens (USDA 2000). In this study, the Haugh unit value in mallard duck eggs was highly correlated ($P<0.01$) with albumen height (r = 0.92), but lowly correlated (P<0.05) with albumen weight (r = 0.14) and percent albumen (r = 0.17). Haugh unit values were also lowly correlated ($P<0.05$) in with long circumference (r = 0.12) and long-short circumference ratio (r = 0.14). The Haugh unit value, however, was negatively correlated with yolk weight (r = –0.12), percent yolk (r = –0.24), and yolk–albumen ratio (r = –0.22). The Haugh unit value was not related ($P>0.05$) to egg weight, implying that mallard duck eggs of any weight (size) class may also differ in albumen quality. The Haugh unit value was also not related ($P>0.05$) to short circumference, yolk color, shell weight, percent shell, average shell thickness, and age at lay.

Age at lay, which averaged 46.33 ± 16.5 weeks old, was lowly correlated with long-short circumference ratio (r = 0.12) and percent shell (r = 0.14). Age at lay however was negatively correlated with egg weight (r = –0.15), short circumference (r = –0.19), yolk weight (r = –0.16), albumen weight (r = –0.22), percent albumen (r = –0.17), yolk color (r = –0.28), and average shell thickness (r = –0.12). The age at lay was not related ($P>0.05$) to long circumference, percent yolk, yolk–albumen ratio, albumen height, Haugh unit value, and shell weight. While there are very few studies that consider the effect of hen age at lay on egg weight and albumen quality in mallard ducks, the results in this study were in agreement with Applegate *et al*. (1998) who reported that egg weight was lower in older Pekin ducks. On the contrary, Kokoszyński *et al*. (2007) showed that the quality of egg albumen (its height and Haugh units) and yolk deteriorated with the age of Pekin ducks.

Table 1. Pearson correlation coefficients between mallard duck egg characteristics and egg weight and Haugh Unit values, and age at lay.

	Egg weight	Haugh unit	Age at lay
Egg size and shape dimensions			
Egg weight	–	ns	-0.15**
Short circumference	0.92**	ns	-0.19**
Long circumference	0.91**	0.12*	ns
Long-short circumference ratio	0.16*	0.14*	0.12*
Internal egg quality			
Composition traits			
Yolk weight	0.79**	-0.12*	-0.16**
Albumen weight	0.82**	0.14*	-0.22**
% Yolk	0.23**	-0.24**	ns
% Albumen	0.17**	0.17**	-0.17**
Yolk–Albumen ratio	ns	-0.22**	ns
Non-composition traits			
Yolk color	ns	ns	-0.28**
Albumen height	0.33**	0.92**	ns
Haugh unit	ns	–	ns
External egg quality			
Shell weight	0.47**	ns	ns
% Shell	-0.39**	ns	0.14*
Shell thickness – tip	ns	0.13*	-0.12*
Shell thickness – middle	-0.12*	0.11*	-0.12*
Shell thickness – bottom	ns	ns	ns
Shell thickness – average	-0.11*	ns	-0.12*

ns means correlation coefficient (r) is not significantly different from zero (P>0.05).
*Correlation coefficient (r) is significantly different from zero (P<0.05).
**Correlation coefficient (r) is significantly different from zero (P<0.01).

Table 2 shows that the differences in egg characteristics from the seven mallard breeds were significant.

Among the Itik–Pinas (IP) breeds, the IP–Itim eggs had the highest long-short circumference ratio (1.16), yolk weight (20.7 g), percent yolk (30.06%), yolk–albumen ratio (0.68), yolk color (7.8). The IP–Khaki eggs had the highest mean egg weight (68.0 g), median egg weight (73.0 g), long circumference (15.91 cm), albumen weight (32.4 g), percent albumen (47.63%), and median Haugh unit value (68.05 HU). The Kayumanggi–IP eggs had the highest short circumference (14.00 cm), albumen height (4.44 mm), mean Haugh unit value (54.00 HU), shell weight (10.0 g), percent shell (14.92%), and average shell thickness (0.41 mm). Mean egg weight was not significantly different (P>0.05) among the

Table 2. Mean square F tests for the effects of breed, size, grade, and covariate effect of age at lay on egg weight, shape dimensions, internal and external egg qualities of mallard duck eggs.

Trait	Independent variables			Grade		CV, %
	Breed	Size	Grade	Age at lay	Regression coeff. (by Age at Lay)	
Egg size and shape dimensions						
Egg weight	**	**	ns	ns	0.015 ± 0.017	4.00
Short circumference	**	**	ns	*	-0.0064 ± 0.0029	1.94
Long circumference	**	**	ns	ns	0.0062 ± 0.0039	2.26
Long-short circum. ratio	**	ns	ns	**	0.0010 ± 0.0003	2.63
Internal egg quality						
Composition traits						
Yolk weight	**	**	**	*	0.024 ± 0.012	9.34
Albumen weight	**	**	ns	*	-0.042 ± 0.017	9.01
% Yolk	**	**	**	ns	0.026 ± 0.016	8.77
% Albumen	**	**	*	**	-0.065 ± 0.020	7.42
Yolk–Albumen ratio	**	**	**	**	0.002 ± 0.001	15.44
Non-composition traits						
Yolk color	**	**	**	**	-0.070 ± 0.014	35.18
Albumen height	**	**	**	ns	-0.003 ± 0.003	8.64
Haugh unit	*	ns	**	ns	-0.038 ± 0.027	7.29
External egg quality						
Shell weight	**	**	ns	*	-0.013 ± 0.006	10.71
% Shell	**	**	ns	*	-0.021 ± 0.008	10.76
Shell thick. – tip	**	ns	ns	**	-0.0013 ± 0.0002	11.00
Shell thick. – middle	**	ns	ns	**	-0.0015 ± 0.0002	9.58
Shell thick. – bottom	**	ns	ns	**	-0.0014 ± 0.0002	10.24
Shell thick. – average	**	ns	ns	**	-0.0014 ± 0.0002	9.36

ns - no significant effect of independent variable ($P>0.05$).
*highly significant effect of independent variable ($P<0.05$).
**highly significant effect of independent variable ($P<0.01$).

IP breeds, ranging from 67.6 g to 68.0 g (Table 3).

Among the other mallard breeds, the dual-purpose Khaki Campbell, which was originally created by crossing Rouen male with Malaysian Indian Runner female in the Netherlands, had the highest yolk color (6.2), shell weight (10.5g), percent shell (15.89%), and average shell thickness (0.41mm). The eggs from the Pekin breed, which was developed in the United States out of ducks brought in from China, had the highest mean egg weight (73.0 g), median egg weight (85.2 g), short circumference (14.03 cm), long circumference (16.54 cm), and long-short circumference ratio (1.18), yolk weight (22.6 g), albumen weight (35.1 g), percent albumen (47.67%), albumen height (4.90 mm), mean Haugh unit value (55.49 HU), and median Haugh unit value (75.95 HU). The eggs from the Tsaiya breed originally from Taiwan had significantly (P<0.05) highest percent yolk (30.58%) and yolk–albumen ratio (0.73). The eggs from the White Mallard breed also developed by the NSPRDC, BAI-DA out of the cross between Pekin and the Philippine mallard had the lowest mean egg weight (65.6 g), short circumference (13.58 cm), albumen height (4.09 mm), and Haugh unit value (50.97 HU), see Table 3.

The range of values for egg weight, composition, and shell thickness in this study were generally within the range found in published literature. For example, Huang and Lin (2011) reported that the range of egg weight, percent yolk, percent albumen, percent shell, and shell thickness across a wide variety of duck breeds are 60–90 g, 28–35%, 45–58%, 11–13%, and 0.36–0.42 mm, respectively.

Age of lay, as a covariate, had significant effects on the short circumference, long-short circumference ratio, yolk weight, albumen weight, percent albumen, yolk–albumen ratio, yolk color, shell weight, percent shell, and shell thickness at the tip, middle, and bottom portions. An increase in one week of age in duck layers was related to an increase in long-short circumference ratio (+0.001), yolk weight (+0.024 g), yolk–albumen ratio (+0.002), shell weight (–0.01 mm), and percent shell (–0.02%), and a reduction in short circumference (–0.006 mm), albumen weight (–0.042 g), percent albumen (–0.065%), yolk color (–0.07) and average shell thickness (–0.001 mm), see Table 2. Age of lay had no significant effect (P>0.05) on egg weight, long circumference, percent yolk, albumen height, and Haugh unit value. The results suggest that older ducks tend to produce elongated eggs with a lower short circumference, lower albumen and shell weight, and thinner eggshells, but with higher yolk weight and slightly paler yolk.

The distribution of mallard duck eggs according to the new size classification system was 17.26% extra-large, 55.37% large, 24.76% medium, and 2.61% small (see Table 4). A bigger egg size (P<0.05) was consistently observed with increasing short and long circumference, yolk weight, albumen weight, albumen height, and shell weight (Table 5). The long-short circumference ratio, Haugh unit values, and shell thickness were not significantly different among the four egg size categories (P>0.05).

Based on the median of egg weight values, the eggs from IP–Itim (72.2 g), IP–Khaki (73.0 g), Kayumangi–IP (70.9 g), Khaki Campbell (69.4 g), Tsaiya (68.1 g), and White Mallard (69.1 g) were classified as large. Pekin eggs (85.2 g) were classified as extra-large (see Table 3).

By comparison, the published weight of eggs from Philippine mallard ducks were 59.1–71.6 g (Romjali *et al*., 2004), 64.7–71.3 g (Dagaas *et al*., 2006), 68.2–73.0 g (Escobin *et al*., 2008), 67.5–78.9 g (Datuin and Magpantay, 2013), suggesting that eggs from Philippine Mallard ducks from across the country at different production and feeding systems may be

Table 3. Egg weight, shape dimensions, internal and external egg qualities in different mallard breeds.

Trait	Itik–Pinas (IP) - Itim	Itik–Pinas (IP) - Khaki	Kayumanggi – IP	Khaki Campbell	Pekin	Tsaiya	White Mallard
Egg size and shape dimensions							
Egg wt. – mean, g	67.59 ± 0.46^{bc}	68.04 ± 0.48^{b}	67.67 ± 0.67^{bc}	66.53 ± 0.93^{c}	72.97 ± 0.83^{a}	67.62 ± 0.78^{bc}	65.60 ± 0.83^{c}
Egg wt. – median, g	72.25	73.05	70.85	69.35	85.2	68.10	69.05
Short circumference, cm	13.64 ± 0.05^{c}	13.81 ± 0.05^{b}	14.00 ± 0.11^{a}	13.94 ± 0.12^{a}	14.03 ± 0.08^{a}	13.63 ± 0.08^{c}	13.58 ± 0.09^{c}
Long circumference, cm	15.77 ± 0.06^{c}	15.91 ± 0.07^{b}	15.74 ± 0.14^{c}	15.93 ± 0.16^{bc}	16.54 ± 0.11^{a}	16.03 ± 0.10^{b}	15.85 ± 0.11^{c}
Long-short circum. ratio	1.16 ± 0.01^{a}	1.15 ± 0.01^{a}	1.12 ± 0.01^{b}	1.14 ± 0.01^{b}	1.18 ± 0.01^{a}	1.17 ± 0.01^{a}	1.17 ± 0.01^{a}
Internal egg quality							
Composition traits							
Yolk weight, g	20.70 ± 0.34^{b}	19.43 ± 0.34^{c}	18.85 ± 0.48^{c}	18.82 ± 0.67^{c}	22.56 ± 0.60^{a}	21.01 ± 0.56^{b}	19.62 ± 0.60^{c}
Albumen weight, g	30.28 ± 0.46^{c}	32.42 ± 0.49^{b}	32.05 ± 0.68^{bc}	30.80 ± 0.95^{c}	35.07 ± 0.85^{a}	29.13 ± 0.79^{c}	29.40 ± 0.85^{c}
% Yolk	30.06 ± 0.42^{a}	28.12 ± 0.44^{b}	27.51 ± 0.62^{b}	28.09 ± 0.87^{b}	30.24 ± 0.78^{a}	30.58 ± 0.72^{a}	29.56 ± 0.77^{a}
% Albumen	45.04 ± 0.53^{b}	47.63 ± 0.55^{a}	47.34 ± 0.78^{a}	46.24 ± 1.08^{ab}	47.67 ± 0.97^{a}	43.23 ± 0.90^{c}	44.89 ± 0.97^{bc}
Yolk–Albumen ratio	0.68 ± 0.02^{b}	0.60 ± 0.02^{c}	0.58 ± 0.02^{c}	0.61 ± 0.03^{c}	$0.64 \pm 0.03b^{c}$	0.73 ± 0.03^{a}	0.67 ± 0.03^{bc}

Table 3. Continuation...

Trait	Itik–Pinas (IP) - Itim	Itik–Pinas (IP) - Khaki	Kayumanggi – IP	Khaki Campbell	Pekin	Tsaiya	White Mallard
Non-composition traits							
Yolk color	7.79 ± 0.37^{a}	6.44 ± 0.39^{b}	7.76 ± 0.54^{a}	6.16 ± 0.76^{b}	3.57 ± 0.68^{c}	3.66 ± 0.63^{c}	5.19 ± 0.68^{c}
Albumen height, mm	4.23 ± 0.07^{c}	4.36 ± 0.07^{bc}	4.44 ± 0.10^{b}	4.48 ± 0.14^{b}	4.90 ± 0.13^{a}	4.26 ± 0.12^{bc}	4.09 ± 0.13^{c}
Haugh unit – mean	51.75 ± 0.72^{b}	53.55 ± 0.75^{a}	54.00 ± 1.06^{a}	54.47 ± 1.47^{a}	55.49 ± 1.32^{a}	52.80 ± 1.23^{b}	50.97 ± 1.32^{c}
Haugh unit – median	60.70	68.05	66.05	66.45	75.95	61.30	61.00
External egg quality							
Shell weight, g	9.46 ± 0.16^{b}	8.99 ± 0.17^{c}	9.98 ± 0.24^{ab}	10.51 ± 0.33^{a}	8.48 ± 0.30^{d}	9.75 ± 0.28^{b}	9.11 ± 0.30^{c}
% Shell	14.17 ± 0.23^{c}	13.46 ± 0.24^{d}	14.92 ± 0.33^{b}	15.89 ± 0.46^{a}	12.16 ± 0.42^{e}	14.63 ± 0.39^{bc}	14.07 ± 0.42^{c}
Shell thick. – tip, mm	0.36 ± 0.01^{b}	0.36 ± 0.01^{b}	0.41 ± 0.01^{a}	0.40 ± 0.01^{a}	0.32 ± 0.01^{c}	0.35 ± 0.01^{b}	0.34 ± 0.01^{c}
Shell thick. – middle, mm	0.37 ± 0.01^{b}	0.37 ± 0.01^{b}	0.41 ± 0.01^{a}	0.42 ± 0.01^{a}	0.33 ± 0.01^{c}	0.35 ± 0.01^{bc}	0.34 ± 0.01^{c}
Shell thick. – bottom, mm	0.37 ± 0.01^{b}	0.37 ± 0.01^{b}	0.41 ± 0.01^{a}	0.42 ± 0.01^{a}	0.33 ± 0.01^{c}	0.35 ± 0.01^{bc}	0.34 ± 0.01^{c}
Shell thick. – average, mm	0.37 ± 0.01^{b}	0.37 ± 0.01^{b}	0.41 ± 0.01^{a}	0.41 ± 0.01^{a}	0.33 ± 0.01^{c}	0.35 ± 0.01^{bc}	0.34 ± 0.01^{c}

Least square means in the same row without common letter superscripts are significantly different ($P<0.05$).

Table 4. Number and distribution of eggs using the proposed size classification system for mallard duck eggs.

Breed	Size (weight) classification				Total
	Extra–large	Large	Medium	Small	
Itik–Pinas (IP) breeds					
IP–Itim	15	62	18	3	98
IP–Khaki	9	59	24	0	92
Kayumanggi–IP	6	22	11	5	44
Sub-total	30	143	53	8	234
Other mallard breeds					
Khaki Campbell	2	9	7	0	18
Pekin	18	2	0	0	20
Tsaiya	2	8	9	0	19
White Mallard	1	8	7	0	16
Sub-total	23	27	23	0	73
Total	53 (17.26%)	170 (55.37%)	76 (24.76%)	8 (2.61%)	307 (100.00%)

classified as medium to large. When compared with local mallard breeds in other countries, the large eggs of IP- duck breeds used in this study were bigger than the medium-sized eggs from the Longyan breed from China that weighed 60.8–62.4 g (Wang *et al*., 2014) and 60.4–66.9 g (Xia *et al*., 2019). The eggs from the Shan Ma breed also in China weighed 66.9–67.8 g (Chen *et al*., 2015) and 49.6–67.0 g (Lin *et al*., 2016), suggesting that Shan Ma eggs may be classified as small to medium. In India, most duck eggs are classified as medium, as produced by the Pati, Nageswari, Tripura, and Manipur breeds whose average egg weight was 58.0 g, 61.0 g, 57.8 g, and 66.3 g, respectively (Phookan *et al*., 2018). Similarly, the average egg weight for Pati, Nageswari and Chara-Chemballi was 57.8 g, 60.2 g, and 66.2 g, respectively (Sarma *et al*., 2017). Eggs from the Tamil Nadu ducks are classified as small since the average egg weight was 54.8 g only (Kavitha *et al*., 2017).

The size of eggs from commercial/transboundary breeds used in this study such as the Tsaiya and Pekin were also comparable to reports of the same breeds in other countries. The large eggs from the Tsaiya breed used in this study were like the medium to large-sized eggs from the Brown Tsaiya breeds in Taiwan, with an average egg weight of 62.4–68.8 g (Cheng *et al*., 1995). The extra-large eggs from the Pekin breed used in the study were similar to the large to extra-large eggs from the Pekin breed in the United States (Applegate *et al*., 1998) and in Poland (Kokoszyński *et al*., 2007), with an average egg weight of 77.5–88.6 g and 71.7–86.7 g, respectively.

The distribution of mallard duck eggs by grade classification based on Haugh unit value was 21.17% Grade-AA, 47.56% Grade-A, 28.01% Grade-B, and 3.26% Grade-C (Table 6). A superior egg grade was consistently observed with higher albumen height only. The differences in egg weight, shape dimensions, albumen weight, shell weight, and shell thickness among the four egg grades were small (P>0.05), see Table 7.

Table 5. Egg weight, shape dimensions, internal and external egg qualities of mallard duck eggs in different size (weight) classification.

	Size (weight) classification			
	Extra–large	**Large**	**Medium**	**Small**
Egg size and shape dimensions				
Egg weight – mean, g	82.14 ± 0.49[a]	73.65 ± 0.34[b]	65.69 ± 0.43[c]	50.53 ± 1.10[d]
Egg weight – median, g	82.60	73.50	65.40	51.00
Short circumference, cm	14.73 ± 0.05[a]	14.26 ± 0.04[b]	13.68 ± 0.05[c]	12.55 ± 0.12[d]
Long circumference, cm	17.21 ± 0.07[a]	16.50 ± 0.05[b]	15.82 ± 0.06[c]	14.34 ± 0.15[d]
Long-short circum. Ratio	1.17 ± 0.01	1.16 ± 0.00	1.16 ± 0.00	1.14 ± 0.01
Internal egg quality				
Composition traits				
Yolk weight, g	25.59 ± 0.35[a]	22.84 ± 0.24[b]	20.09 ± 0.31[c]	12.06 ± 0.79[d]
Albumen weight, g	37.43 ± 0.50[a]	33.40 ± 0.35[b]	29.18 ± 0.44[c]	25.22± 1.12[d]
% Yolk	31.18 ± 0.46[a]	31.01 ± 0.32[a]	30.56 ± 0.40[a]	23.91± 1.02[b]
% Albumen	45.44 ± 0.57[b]	45.23 ± 0.39[b]	44.29 ± 0.50[b]	49.07± 1.28[a]
Yolk–Albumen ratio	0.69 ± 0.02[a]	0.69 ± 0.01[a]	0.70 ± 0.02[a]	0.49 ± 0.04[b]
Non-composition traits				
Yolk color	6.43 ± 0.40[ab]	6.30 ± 0.28[b]	6.97 ± 0.35[a]	3.48 ± 0.90[c]
Albumen height, mm	4.93 ± 0.08[a]	4.60 ± 0.05[b]	4.25 ± 0.07[c]	3.79 ± 0.17[d]
Haugh unit – mean	53.05 ± 0.78	52.76 ± 0.54	52.35 ± 0.68	55.02 ± 1.74
Haugh unit – median	67.00	64.60	66.40	65.90
External egg quality				
Shell weight, g	10.86 ± 0.18a	9.94 ± 0.12[b]	9.04 ± 0.15[c]	8.04 ± 0.39[d]
% Shell	13.30 ± 0.24[c]	13.57 ± 0.17[bc]	13.84 ± 0.21[b]	16.04 ± 0.55[a]
Shell thick. – tip, mm	0.36 ± 0.01	0.36 ± 0.00	0.36 ± 0.01	0.38 ± 0.02
Shell thick. – middle, mm	0.37 ± 0.01	0.37 ± 0.00	0.37 ± 0.01	0.38 ± 0.01
Shell thick. – bottom, mm	0.36 ± 0.01	0.37 ± 0.01	0.36 ± 0.01	0.38 ± 0.01
Shell thick. – average, mm	0.36 ± 0.01	0.36 ± 0.00	0.36 ± 0.01	0.38 ± 0.01

Table 6. Number and distribution of eggs using the proposed grade (quality) classification system.

Breed	Grade categories				Total
	AA	A	B	C	
Itik–Pinas (IP) breeds					
IP–Itim	18	35	43	2	98
IP–Khaki	22	52	14	4	92
Kayumanggi–IP	7	28	9	0	44
Sub-total	47	115	66	6	234
Other mallard breeds					
Khaki Campbell	4	6	6	2	18
Pekin	11	7	2	0	20
Tsaiya	1	11	6	1	19
White Mallard	2	7	6	1	16
Sub-total	18	31	20	4	73
Total	65 (21.17%)	146 (47.56%)	86 (28.01%)	10 (3.26%)	307 (100.00%)

Based on the median of Haugh unit values, the eggs from IP-Itim (60.70 HU), IP-Khaki (68.05 HU), Kayumanggi-IP (66.05 HU), Khaki Campbell (66.45 HU), Tsaiya (61.30 HU), and White Mallard (61.00 HU) were classified as Grade-A. Pekin eggs (75.95 HU) were classified as Grade-AA (see Table 3).

By comparison, higher Haugh unit values for eggs from different mallard breeds were reported in other countries, ranging from Grade-A to Grade-AA. In China, the small to medium-sized Shan ma duck eggs had an average Haugh unit value ranging from 69.1–75.6 HU, which was classified as Grade-A to Grade-AA (Chen *et al*., 2015). The average Haugh unit value for the medium-sized eggs from the Longyan breed ranged from 70.67–75.93 HU, which was classified as Grade-AA (Wang *et al*., 2014). In India, the medium-sized eggs from the Pati, Nageswari, Tripura, and Manipur breeds were classified as Grade-AA, with the average Haugh unit values of 79.48 HU, 85.04 HU, 79.13 HU, and 88.04 HU, respectively (Phookan *et al*., 2018). Similarly, the eggs from the Pati, Nageswari, and Chara-Chemballi were classified as Grade-AA, with the average Haugh unit values of 80.28 HU, 84.74 HU, and 87.23 HU, respectively (Sarma *et al*., 2017). The small-sized eggs from Tamil Nadu ducks were also classified as Grade-AA, with the average Haugh unit value of 99.64 HU (Kavitha *et al*., 2017). Eggs from the Pekin breed in Poland were also classified as Grade-AA (73.50–84.10 HU) according to Kokoszyński *et al*. (2007).

The Haugh unit is a measure of the viscosity of the thick albumen due to the high ovomucin content (Burley and Vahedra, 1989). A high Haugh unit value indicates better internal quality of the egg, i.e., fresher and higher quality eggs having thicker albumen. The thick albumen limits yolk movement while the thin albumen permits greater movement – the less movement, the thicker the albumen and the higher the grade. However, the Haugh unit is also influenced by the age and strain of birds (Silversides and Scott, 2001). Haugh unit in

Table 7. Egg weight, shape dimensions, internal and external egg qualities of mallard duck eggs in different grade categories.

	Grade Categories			
	AA	A	B	C
Egg size and shape dimensions				
Egg weight – mean, g	67.87 ± 0.47	68.03 ± 0.49	68.02 ± 0.43	68.10 ± 0.98
Egg weight – median, g	72.70	72.00	72.75	74.90
Short circumference, cm	13.75 ± 0.05	13.82 ± 0.04	13.83 ± 0.04	13.83 ± 0.10
Long circumference, cm	16.06 ± 0.06	15.99 ± 0.05	15.93 ± 0.06	15.90 ± 0.13
Long-short circum. ratio	1.17 ± 0.01	1.16 ± 0.00	1.15 ± 0.01	1.15 ± 0.01
Internal egg quality				
Composition traits				
Yolk weight, g	19.26 ± 0.34^{c}	20.17 ± 0.27^{b}	20.98 ± 0.31^{a}	20.16 ± 0.70^{ab}
Albumen weight, g	31.39 ± 0.48	31.62 ± 0.39	30.55 ± 0.43	31.67 ± 1.00
% Yolk	28.02 ± 0.44^{c}	29.26 ± 0.35^{b}	30.25 ± 0.40^{a}	29.12 ± 0.91^{ab}
% Albumen	46.26 ± 0.54^{a}	46.38 ± 0.44^{a}	44.93 ± 0.49^{b}	46.46 ± 1.13^{ab}
Yolk–Albumen ratio	0.62 ± 0.02^{b}	0.64 ± 0.01^{b}	0.69 ± 0.02^{a}	0.63 ± 0.04^{b}
Non-composition traits				
Yolk color	6.12 ± 0.38^{ab}	4.57 ± 0.31^{c}	5.59 ± 0.35^{b}	6.91 ± 0.79^{a}
Albumen height, mm	6.42 ± 0.07^{a}	5.21 ± 0.06^{b}	3.90 ± 0.06^{c}	2.04 ± 0.15^{d}
Haugh unit – mean	77.20 ± 0.74^{a}	67.21 ± 0.60^{b}	52.73 ± 0.67^{c}	16.04 ± 1.54^{d}
Haugh unit – median	76.50	67.00	52.80	16.05
External egg quality				
Shell weight, g	9.67 ± 0.17	9.35 ± 0.14	9.26 ± 0.15	9.60 ± 0.35
% Shell	14.47 ± 0.23	13.99 ± 0.19	13.92 ± 0.21	14.37 ± 0.48
Shell thick. – tip, mm	0.38 ± 0.01	0.37 ± 0.01	0.36 ± 0.01	0.35 ± 0.01
Shell thick. – middle, mm	0.38 ± 0.01	0.37 ± 0.01	0.37 ± 0.01	0.37 ± 0.01
Shell thick. – bottom, mm	0.37 ± 0.01	0.37 ± 0.01	0.36 ± 0.01	0.37 ± 0.01
Shell thick. – average, mm	0.38 ± 0.01	0.37 ± 0.00	0.36 ± 0.01	0.36 ± 0.01

Least square means in the same row without common letter superscripts are significantly different ($P<0.05$).

chicken eggs is influenced by storage time and temperature, nutrition, and disease (Roberts, 2004). The use of Haugh unit as a marketing tool for high-quality duck eggs, however, may be limited since the Haugh unit value could only be determined by the "breakout" method requiring special handling and costly equipment. Furthermore, a standard description of the clarity and firmness or thickness of a duck egg's albumen viewed by candling that is reasonably correlated with the broken-out appearance or quality in terms of albumen height and Haugh unit value will initially be required (USDA, 2000). As a practical alternative to guarantee the freshness of duck eggs, expiration dates may be placed on consumer (duck egg) packages to indicate freshness or maximum time frame for quality. Expiration dates are usually calculated from the date the eggs are packed into the consumer package and may not exceed 30 days, including the date of pack (USDA, 2000).

The new size classification and egg grading system may be used in the development of the Philippine National Standards for duck eggs. When used as a basis for establishing grades, the standards of egg quality, however, would have to be validated by experience and research as desired by producers, marketers, and consumers of duck eggs. Future experiments on the use of the new size classification and egg grading system involving large sample sizes from major egg-producing regions will be important in breed improvement (selection) and conservation programs for the locally adapted mallard breeds.

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