ISSN 1682-8356
ansinet.com/ijps

INTERNATIONAL JOURNAL OF

POULTRY SCIENCE

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http://ansinet.com

OPEN ACCESS International Journal of Poultry Science

ISSN 1682-8356
DOI: 10.3923/ijps.2021.87.97

Research Article
Grading and Size Classification of Chicken Eggs Produced by Native, Egg-Type, Meat-Type, Dual-Purpose and Fancy-Type Breeds Under Philippine Conditions

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Abstract

Background and Objective: The egg grading and size classification system used for commercial chicken breeds and hybrids is proposed for Philippine native chickens. In this regard, this study aimed to compare the egg characteristics of native breeds to egg-type, meat-type, dual-purpose and fancy-type breeds. **Materials and Methods:** A total of 315 eggs from 14 chicken breeds was used in this study. The size, shape, internal and external egg quality characteristics were analyzed. Egg parameters were analyzed by least square procedures to account for the effects of breed, size, grade classification and hen age. **Results:** Egg weight was highly correlated ($p<0.01$) with yolk weight ($r = 0.72$), albumen weight ($r = 0.90$) and shell weight ($r = 0.71$) but not related ($p>0.05$) to Haugh Unit. According to the size classification system the eggs were 4.1% jumbo, 7.3% extra-large, 20.3% large, 21.9% medium, 39.7% small and 6.7% peewee. Egg distribution by grade classification based on Haugh Unit was 13.3% Grade AA, 40.6% Grade A, 43.2% Grade B and 2.9% Grade C. **Conclusion:** Philippine native chickens (Banabang Kalabaw, Joloano, Paraoakan and Palawan Lasak), Black Silkies and White Silkies eggs were classified as small, while White Rock eggs were classified as medium. Black Australorp, Barred Plymouth Rock, New Hampshire, Rhode Island Red and Taiwan Yellow eggs were classified as large. Nagoya and White Leghorn eggs were classified as extra-large. The Philippine native chickens, Barred Plymouth Rock, New Hampshire, Taiwan Yellow and White Leghorn eggs were classified as Grade A. Eggs from White Rock, Black Silkies, White Silkies, Black Australorp, Nagoya and Rhode Island Red were classified as Grade B.

Key words: Egg grading, size classification, commercial chicken breeds, egg production, egg yolk, albumen

Citation: O.L. Bondoc, R.C. Santiago, A.R. Bustos, A.O. Ebron and A.R. Ramos, 2021. Grading and size classification of chicken eggs produced by native, egg-type, meat-type, dual-purpose and fancy-type breeds under Philippine conditions. Int. J. Poult. Sci., 20: 87-97.

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Chicken eggs are the most commonly consumed protein-rich food in the Philippines, with a per capita consumption of 5.78 kg in 2018[1]. Based on the 2015 Philippine Dietary Survey, chicken eggs ranked 7th among the 30 commonly consumed food items in the Philippines. Egg intake ranked 6th in urban areas but only 9th in rural areas. Egg consumption also ranked 5th and 12th among the rich and poorest households respectively[2]. Chicken egg production in 2018 was 533.91 thousand metric tons, i.e., 84.02% were produced by commercial layer farms and 15.98% from native chickens and their upgrades in backyard farms[3].

Unfortunately, eggs produced by local breeds in rural households are not subjected to the standard egg grading and size classification system used by some commercial layer farms. In the grading process, for example, eggs are examined for interior quality (condition of the white and yolk and size of the air cell) and exterior quality (cleanliness and soundness of the shell) at the time when eggs are packed. Eggs are then sorted according to weight (size) based on the average weight per dozen[4]. A similar egg grading and size classification systems is thus proposed for native chickens. However, basic information on egg characteristics will be required not only to promote the proper management and improvement of native chickens[5,6] but also to understand their implications on human health and nutrition in rural areas.

In this regard, this study evaluated the size, shape, internal and external quality of chicken eggs which were classified using the standard egg grading (based on albumen quality or Haugh Unit) and size classification system. The egg characteristics from four native chicken breeds (Banabang Kalabaw, Joloano, Paraoakan and Palawan Lasak) were compared with other adapted egg-type, meat-type, dual-purpose and fancy-type breeds in the Philippines. The results of the study were also compared with selected reports containing both egg weight and Haugh Unit values of indigenous breeds and commercial hybrids of some countries in Asia, Africa and Europe.

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 in collaboration with the National Swine and Poultry Research and Development Center (NSPRDC), Bureau of Animal Industry (BAI), Department of Agriculture.

Data Collection: A total of 315 eggs were randomly collected from 14 chicken breeds (*Gallus gallus domesticus* L.) consisting of 4 Philippine native chickens (Banabang Kalabaw, Joloano, Paraoakan and Palawan Lasak), 1 egg-type (White Leghorn), 1 meat-type (White rock), 6 dual-purpose (Black Australorp, Barred Plymouth Rock, Nagoya, New Hampshire, Rhode Island Red and Taiwan Yellow) and 2 fancy-type breeds (Black Silkies and White Silkies). The birds were housed by breed, fed the same diet and raised in similar semi-intensive farm conditions at the NSPRDC, BAI-DA in Tiaong, Quezon. The chicken laying mash were analyzed at the government-accredited Optimal Laboratories, Inc., Lipa City, Batangas and found to contain 17.31% crude protein, 5.41% crude fat, 1.81% crude fiber, 10.24% moisture, 14.88% ash, 4.14% calcium and 0.82% phosphorus using the Semi-micro Kjeldahl distillation, Soxhlet extraction, Weende method, oven drying, ashing at 600°C, Titrimetric and Colorimetric-UV-Vis method respectively.

Newly laid eggs from May 10, 2019 to January 31, 2020 were measured for their size and shape (egg weight, short and long circumference and short-long circumference ratio), internal egg quality (yolk weight, albumen weight, percent yolk, percent albumen, yolk-albumen ratio, yolk color, albumen height, Haugh Unit) and external egg quality (shell weight, percent shell, shell thickness at the tip, middle and bottom portions and average shell thickness).

The egg weight, yolk color, albumen height and Haugh Unit were measured using the Orka Egg Analyzer (ORKA Food Technology LLC, Utah, USA). The Haugh Unit[7] was calculated as:

$$100 \log_{10} (H-1.7 W^{0.37}+7.6)$$

where, H = height of the albumen and W = egg weight. The grade classification system[8] to describe albumen and their corresponding Haugh Unit was as follows: Grade AA (72 or more), Grade A (60-71), Grade B (31-59) and Grade C (30 or less). Yolk was separated from the albumen using a yolk separator. Yolk and albumen weight were measured separately using digital weighing scale. Percentages of egg components (yolk, albumen and shell) as well as the ratio to egg weight were determined using the following equation:

$$\text{Egg components (\%)} = \frac{\text{Component weight (g)}}{\text{Egg weight (g)}} \times 100$$

Yolk-albumen ratio was computed as:

$$\text{Yolk} - \text{albumen ratio} = \frac{\text{Yolk weight (g)}}{\text{Albumen weight (g)}}$$

The proportion and weight of shell including the shell membrane and shell thickness (without the membrane) at the tip, middle and butt portions were recorded using the Tactix® Digital Caliper (Meridian International Co., Ltd, Shanghai, China). The short and long circumference were recorded using the common measuring tape and used to compute long-short circumference ratio, whose value when more than 1.00 implies a more elongated shape.

The modified size classification system prescribed by the Philippine National Standard[9] was used-Jumbo (>70 g), Extra-large (65-69 g), Large (60-64 g), Medium (55-59 g), Small

Table 1: Number and distribution of chicken eggs based on size classification

	Size classification						
Breed	Jumbo	Extra-large	Large	Medium	Small	Peewee	Total
Native chickens							
Banabang Kalabaw	0	0	3	6	34	2	45
Joloano	0	0	2	5	14	2	23
Paraoakan	0	2	3	8	32	2	47
Palawan Lasak	0	0	1	4	13	2	20
Sub-total	0	2	9	23	93	8	135
Other chicken breeds							
White leghorn*	7	2	5	2	0	0	16
Black australorp**	0	3	9	10	1	0	23
Barred plymouth rock**	2	2	4	7	1	0	16
Nagoya**	4	6	5	0	1	0	16
New Hampshire**	0	2	14	3	0	0	19
Rhode Island Red**	0	4	6	9	0	0	19
Taiwan Yellow**	0	1	10	4	1	0	16
White rock***	0	1	2	10	8	0	21
Black silkies****	0	0	0	1	10	4	15
White silkies****	0	0	0	0	10	9	19
Sub-total	13	21	55	46	32	13	180
Total	13 (4.1%)	23 (7.3%)	64 (20.3%)	69 (21.9%)	125 (39.7%)	21 (6.7%)	315

*Egg-type, **Dual-purpose, ***Meat-type, ****Fancy-type

Table 2: Number and distribution of chicken eggs based on grade (quality) classification

	Grade classification				
Breed	AA	A	B	C	Total
Native chickens					
Banabang Kalabaw	9	19	17	0	45
Joloano	2	11	10	0	23
Paraoakan	10	23	13	1	47
Palawan Lasak	0	11	9	0	20
Sub-total	21	64	49	1	135
Other chicken breeds					
White Leghorn*	6	7	3	0	16
Black Australorp**	2	9	11	1	23
Barred Plymouth Rock**	4	10	2	0	16
Nagoya**	1	4	8	3	16
New Hampshire**	0	10	6	3	19
Rhode Island Red**	1	5	13	0	19
Taiwan Yellow**	2	6	7	1	16
White Rock***	3	5	13	0	21
Black Silkies****	0	3	12	0	15
White Silkies****	2	5	12	0	19
Sub-total	21	64	87	8	180
Total	42 (13.3%)	128 (40.6%)	136 (43.2%)	9 (2.9%)	315

*Egg type, **Dual-purpose, ***Meat-type, ****Fancy-type

(45-54 g) and Peewee (<45 g). Eggs were not grouped based on shell color. The number and distribution of chicken eggs by size and grade classification is shown in Table 1 and 2 respectively.

Statistical analysis: Pearson product–moment correlation coefficients among size and shape with internal and external quality of chicken eggs were determined using CORR procedure of SAS[10].

The general least squares procedures for unbalanced data were used to examine the principal sources of variation affecting each size, shape, internal and external quality trait. The following linear "Fixed effects" model was used to determine, using an F-test[10],

$$y_{ijklm} = \mu+Breed_i+Size_j+Grade_k+Age_l+e_{ijklm}$$

where, y_{ijklm} is the dependent variable (size, shape and egg quality traits), μ is overall mean, $Breed_i$ is the fixed effect of the i^{th} breed, $Size_j$ is the fixed effect of the j^{th} size classification (jumbo, 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 hen age (weeks) and e_{ijklm} is error term assumed to be normally distributed with variance of errors as constant across observations.

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

RESULTS AND DISCUSSION

Correlations of egg weight, Haugh Unit and hen age with egg characteristics: Table 3 shows that egg weight was highly correlated ($p<0.01$) with yolk weight ($r = 0.72$), albumen weight ($r = 0.90$) and shell weight ($r = 0.71$). Egg weight, however, was negatively correlated with percent yolk ($r = -0.32$), percent shell ($r = -0.18$) and yolk-albumen ratio ($r = -0.44$). Egg weight was also highly correlated ($p<0.01$) with size in terms of its short circumference ($r = 0.88$) and long circumference ($r = 0.92$). Egg weight was weakly correlated with yolk color ($r = 0.16$) and average shell thickness ($r = 0.23$). The results of this study were in agreement with Johnston and Gous[11] who reported that the proportion of yolk is negatively correlated with egg size and that larger eggs contain greater

Table 3: Relationships (Pearson correlation coefficients) of size and shape, Haugh Unit and hen age with internal and external quality traits in chicken eggs

	Egg weight	Short circumference	Long circumference	Long-short circumference ratio	Haugh Unit	Hen age
Egg size and shape						
Egg weight	-	0.88**	0.92**	0.16*	ns	0.21**
Short circumference		-	0.81**	-0.15*	ns	0.19**
Long circumference			-	0.46**	ns	0.19**
Long-short circumference ratio				-	ns	ns
Internal egg quality						
Composition traits						
Yolk weight	0.72**	0.65**	0.68**	0.16**	-0.22**	0.34**
Albumen weight	0.90**	0.80**	0.84**	0.21**	ns	0.16**
Yolk (%)	-0.32**	-0.25**	-0.26**	ns	-0.29**	0.15**
Albumen (%)	0.51**	0.44**	0.48**	0.14*	-0.19**	ns
Yolk-albumen ratio	-0.44**	-0.38**	-0.39**	ns	-0.26**	ns
Non-composition traits						
Yolk color	0.16**	0.14*	0.18**	ns	-0.16**	-0.15**
Albumen height	0.35**	0.32**	0.31**	ns	0.91**	ns
Haugh unit	ns	ns	ns	ns	-	-0.15**
External egg quality						
Shell weight	0.71**	0.61**	0.62**	0.12*	ns	ns
Shell (%)	-0.18**	-0.16**	-0.18**	ns	0.14*	-0.13*
Shell thickness-tip	0.14**	0.18**	ns	-0.17**	ns	ns
Shell thickness-middle	0.23**	0.23**	0.14*	-0.12*	ns	ns
Shell thickness-bottom	0.23**	0.22**	ns	-0.17**	ns	ns
Shell thickness-average	0.23*	0.24**	ns	-0.17**	ns	ns

ns: correlation coefficient (r) is not significantly different from zero ($p>0.05$). *: r is significantly different from zero ($p<0.05$). **: r is significantly different from zero ($p<0.01$)

absolute amounts of the three components than smaller eggs but relatively less yolk and more albumen. In the analysis of eggs from different weight categories, shell percentage was also reported to be lowest in larger eggs[12].

The Haugh Unit which is a measure of the viscosity of the thick albumen due to the high ovomucin content[13] and thus may reflect the freshness of an egg[14], was highly correlated with albumen height (r = 0.91) but not correlated (p>0.05) with albumen weight. The Haugh Unit was negatively correlated (p<0.01) with yolk weight (r = -0.22), percent yolk (r = -0.29), percent albumen (r = -0.19), yolk color (r = -0.16) and age of the laying hen (r = -0.15). The latter was in agreement with Silversides and Scott[15] who showed that albumen quality declines with bird age. On the contrary, Zita *et al.*[16] reported that the Haugh Units in different chicken genotypes increased with hen age from 20 weeks to 60 weeks. The Haugh Unit in this study was not related (p>0.05) to egg weight and shape, shell weight and shell thickness.

Hen age was significantly (p<0.01) correlated with egg weight (r = 0.21), yolk weight (r = 0.34), albumen weight (r = 0.17), percent yolk (r = 0.15), yolk color (r = 0.15) and percent shell (r = -0.12) but not correlated (p>0.05) with egg shape, percent albumen, yolk–albumen ratio, albumen height, shell weight and shell thickness (Table 3). This was in agreement with Johnston and Gous[11] who showed that the percent yolk increases as the hen ages. Furthermore, Sahan *et al.*[17] reported that yolk percentage as well as egg weight, yolk and albumen weight and yolk-albumen ratio also increased as hen age increased but the albumen percentage decreased.

Breed comparisons in terms of egg size and shape, internal and external egg quality: Table 4 shows that breed had significant effects on all measures of egg size, shape, internal and external quality. By comparison, similar significant effects of hen breed[18], strain[16], purebred and hybrid chickens[19] were already reported on the proportional content of yolk and albumen in the chicken egg. Eggshell quality was likewise reported to be affected by the hen strain[12]. While yolk color is largely affected by feed, mainly by the presence of xanthophyll carotenoids (luthein and zeaxanthin), this study showed that yolk color was also affected by breed. This was similar to the results of Lordelo *et al.*[18] who reported that yolk color was markedly lighter in eggs laid by native chicken breeds in Portugal than the Hybrid group. They also showed that commercial hens produced eggs that were heavier and more rounded in shape but with lower Haugh Units than eggs from the indigenous chicken breeds.

Table 5 shows significant differences (p<0.05) in egg size and shape, internal and external quality traits among native

Table 4: Mean square F tests for the effects of breed, egg size, egg grade and covariate effect of hen age on egg quality traits and shape dimensions of chicken eggs

Traits	Breed	Egg size	Egg grade	Hen age	CV (%)
Egg size and shape					
Egg weight	**	**	ns	*	3.53
Short circumference	**	**	ns	*	2.62
Long circumference	**	**	ns	ns	2.49
Long-short circumference ratio	*	*	ns	ns	3.20
Internal egg quality					
Composition traits					
Yolk weight	**	**	*	*	9.41
Albumen weight	**	**	**	ns	10.13
Yolk (%)	**	ns	**	ns	9.38
Albumen (%)	**	**	**	ns	8.90
Yolk-albumen ratio	**	**	**	ns	17.69
Non-composition traits					
Yolk color	**	ns	ns	ns	22.01
Albumen height	**	**	**	ns	12.29
Haugh unit	*	ns	**	ns	9.60
External egg quality					
Shell weight	**	**	*	ns	10.90
Shell (%)	**	**	ns	ns	11.27
Shell thickness-tip	**	*	ns	ns	11.24
Shell thickness-middle	**	ns	ns	ns	10.19
Shell thickness-bottom	**	*	ns	ns	11.15
Shell thickness-average	**	**	ns	ns	9.89

ns: correlation coefficient (r) is not significantly different from zero (p>0.05). *: r is significantly different from zero (p<0.05). **: r is significantly different from zero (p<0.01).

Table 5: Egg size, shape, internal and external qualities in native, meat-type and fancy-type chicken breeds

Traits	Banabang Kalabaw*	Joloano*	Paraoakan*	Palawan-lasak*	White Rock**	Black Silkies***	White Silkies***
Egg size and shape							
Egg weight-mean (g)	57.42±0.41^{c}	57.63±0.49^{c}	58.56±0.38^{b}	56.79±0.54^{cd}	57.68±0.69^{bc}	56.55±0.67^{cd}	56.05±0.64^{d}
Egg weight-median (g)	50.20	52.20	52.40	49.80	55.50	46.60	45.60
Short circumference (cm)	12.85±0.08^{c}	12.93±0.08^{c}	13.10±0.07^{b}	12.88±0.09^{c}	12.96±0.13^{bc}	12.82±0.13^{bc}	12.95±0.12^{bc}
Long circumference (cm)	15.16±0.08^{b}	15.14±0.09^{b}	15.16±0.08^{b}	14.90±0.10^{c}	15.30±0.14^{b}	15.13±0.14^{b}	14.82±0.14^{c}
Long-short circum. ratio	1.18±0.01^{ab}	1.17±0.01^{ab}	1.16±0.01^{b}	1.16±0.01^{b}	1.18±0.01^{ab}	1.18±0.01^{ab}	1.17±0.01^{ab}
Internal egg quality							
Composition traits							
Yolk weight (g)	16.94±0.31^{bc}	15.92±0.38^{c}	17.13±0.30^{b}	17.16±0.41^{bc}	15.99±0.53^{c}	17.29±0.52^{ab}	16.95±0.49^{bc}
Albumen weight (g)	26.31±0.54^{c}	27.89±0.65^{b}	27.30±0.51^{b}	25.38±0.71^{c}	27.76±0.92^{bc}	26.17±0.89^{bc}	26.67±0.85^{bc}
Yolk (%)	29.65±0.56^{ab}	27.60±0.68^{c}	29.39±0.54^{b}	30.64±0.74^{ab}	27.78±0.96^{c}	31.04±0.93^{a}	30.48±0.89^{ab}
Albumen (%)	45.22±0.84^{b}	48.08±1.01^{a}	46.30±0.80^{b}	43.82±1.11^{c}	47.67±1.43^{ab}	45.38±1.39^{bc}	47.19±1.32^{ab}
Yolk-albumen ratio	0.67±0.02^{ab}	0.58±0.03^{b}	0.64±0.02^{b}	0.72±0.03^{a}	0.59±0.04^{b}	0.71±0.04^{ab}	0.64±0.04^{b}
Non-composition traits							
Yolk color	7.11±0.34^{cd}	6.86±0.40^{cd}	7.51±0.32^{bc}	6.69±0.44^{cd}	6.86±0.57^{cd}	9.58±0.55^{a}	7.59±0.53^{bc}
Albumen height (mm)	4.02±0.10^{ab}	3.90±0.12^{ab}	4.06±0.09^{ab}	3.84±0.13^{b}	3.98±0.17^{ab}	3.65±0.17^{bc}	3.66±0.16^{bc}
Haugh unit-mean	56.59±1.17^{a}	55.76±1.40^{ab}	56.63±1.10^{ab}	55.48±1.54^{ab}	56.64±1.98^{ab}	52.95±1.93^{b}	54.05±1.84^{ab}
Haugh unit*median	65.40	60.50	65.70	60.70	57.20	51.90	55.50
External egg quality							
Shell weight (g)	6.48±0.15^{c}	6.25±0.18^{cd}	6.86±0.14^{bc}	6.73±0.20^{bc}	6.17±0.26^{c}	6.45±0.25^{c}	5.84±0.23^{d}
Shell (%)	11.35±0.28^{bc}	10.84±0.33^{c}	11.82±0.26^{bc}	12.08±0.36^{a}	10.83±0.47^{c}	11.51±0.46^{bc}	10.20±0.43^{c}
Shell thick-tip, mm	0.33±0.01^{b}	0.34±0.01^{ab}	0.33±0.01^{b}	0.33±0.01^{b}	0.32±0.01^{b}	0.31±0.01^{b}	0.31±0.01^{b}
Shell thick-middle (mm)	0.34±0.01^{ab}	0.35±0.01^{ab}	0.34±0.01^{ab}	0.33±0.01^{b}	0.33±0.01^{b}	0.34±0.01^{ab}	0.32±0.01^{b}
Shell thick-bottom (mm)	0.32±0.01^{ab}	0.32±0.01^{ab}	0.32±0.01^{ab}	0.31±0.01^{ab}	0.32±0.01^{ab}	0.33±0.01^{ab}	0.32±0.01^{ab}
Shell thick-ave (mm)	0.33±0.01^{ab}	0.33±0.01^{ab}	0.33±0.01^{ab}	0.32±0.01^{b}	0.32±0.01^{b}	0.33±0.01^{ab}	0.32±0.01^{b}

*Philippine Native breed, **Meat-type, ***Fancy-type. Least square means (and standard error) in the same row followed by the same letter are not significantly different from one another (p>0.05)

Table 6: Egg size, shape, internal and external qualities in egg-type and dual-purpose chicken breeds

Traits	black Australorp**	Barred Plymouth Rock**	Nagoya**	New Hampshire**	Rhode Island Red**	Taiwan Yellow**	White Leghorn*
Egg size and shape							
Egg weight-mean (g)	58.17±0.65^{b}	60.25±0.69^{ab}	58.91±0.69^{b}	58.14±0.71^{b}	59.78±0.65^{ab}	60.31±0.66^{ab}	60.37±0.67^{a}
Egg weight-median (g)	61.00	60.90	67.95	62.30	60.10	61.70	67.45
Short circumference (cm)	12.97±0.12^{b}	13.47±0.13^{a}	13.16±0.13^{a}	12.94±0.14^{b}	13.45±0.13^{a}	13.48±0.13^{a}	13.28±0.13^{a}
Long circumference (cm)	15.46±0.14^{a}	15.70±0.15^{a}	15.49±0.14^{a}	15.38±0.15^{b}	15.48±0.14^{a}	15.45±0.14^{a}	15.33±0.14^{b}
Long-short circum. ratio	1.19±0.01^{a}	1.16±0.01^{b}	1.18±0.01^{ab}	1.19±0.01^{a}	1.15±0.01^{c}	1.15±0.01^{c}	1.15±0.01^{c}
Internal egg quality							
composition traits							
Yolk weight (g)	16.11±0.50^{c}	17.39±0.53^{ab}	18.13±0.54^{a}	17.22±0.55^{ab}	16.35±0.50^{bc}	17.07±0.51^{bc}	16.46±0.52^{bc}
Albumen weight (g)	27.64±0.86^{bc}	29.62±0.91^{a}	26.33±0.92^{bc}	25.92±0.94^{c}	29.37±0.86^{ab}	29.11±0.88^{ab}	29.47±0.89^{ab}
Yolk (%)	27.84±0.90^{c}	28.82±0.96^{b}	30.45±0.97^{ab}	29.74±0.99^{ab}	27.39±0.91^{c}	28.40±0.92^{b}	27.65±0.94^{c}
Albumen (%)	46.86±1.35^{ab}	48.68±1.43^{ab}	44.41±1.44^{bc}	43.86±1.48^{c}	49.03±1.35^{a}	48.04±1.38^{ab}	48.33±1.40^{ab}
Yolk-albumen ratio	0.61±0.04^{b}	0.59±0.04^{b}	0.70±0.04^{ab}	0.72±0.04^{ab}	0.56±0.04^{b}	0.59±0.04^{b}	0.58±0.04^{b}
Non-composition traits							
Yolk color	8.03±0.54^{b}	7.86±0.57^{bc}	9.42±0.57^{a}	7.83±0.59^{bc}	7.33±0.54^{bc}	6.82±0.55^{c}	5.75±0.56^{d}
albumen height (mm)	3.79±0.16^{b}	4.11±0.17^{ab}	3.45±0.17^{c}	3.68±0.18^{b}	4.07±0.16^{ab}	4.07±0.16^{ab}	4.17±0.17^{a}
Haugh Unit-mean	54.09±1.87^{ab}	56.11±1.98^{ab}	48.78±2.00^{c}	52.56±2.05^{c}	56.51±1.87^{ab}	55.76±1.91^{ab}	56.84±1.94^{ab}
Haugh Unit-median	58.20	68.60	43.55	60.60	55.50	61.15	68.50
External egg quality							
Shell weight (g)	6.99±0.24^{b}	6.94±0.24^{b}	6.81±0.26^{b}	6.72±0.26^{b}	7.65±0.24^{a}	7.20±0.24^{a}	7.46±0.25^{a}
Shell (%)	12.15±0.44^{ab}	11.45±0.47^{bc}	11.79±0.47^{b}	11.77±0.48^{b}	12.84±0.44^{a}	11.94±0.45^{bc}	12.28±0.46^{ab}
Shell thick-tip (mm)	0.33±0.01^{b}	0.31±0.01^{b}	0.34±0.01^{a}	0.27±0.01	0.36±0.01^{a}	0.36±0.01^{a}	0.33±0.01^{b}
Shell thick-middle (mm)	0.32±0.01^{b}	0.33±0.01^{b}	0.33±0.01^{b}	0.31±0.01^{b}	0.36±0.01^{a}	0.36±0.01^{a}	0.34±0.01^{ab}
Shell thick-bottom (mm)	0.31±0.01^{b}	0.29±0.01^{bc}	0.31±0.01^{b}	0.28±0.01^{c}	0.34±0.01^{a}	0.34±0.01^{a}	0.32±0.01^{ab}
Shell thick-ave. (mm)	0.32±0.01^{b}	0.31±0.01^{b}	0.33±0.01^{ab}	0.28±0.01^{c}	0.35±0.01^{a}	0.35±0.01^{a}	0.33±0.01^{ab}

*Egg-type, **Dual-purpose. Least square means (and standard error) in the same row followed by the same letter are not significantly different from one another (p>0.05)

Table 7: Size, shape, internal and external qualities of chicken eggs in different size classifications

	Size classification					
Traits	Jumbo	Extra-large	Large	Medium	Small	Peewee
Egg size and shape						
Egg weight-mean (g)	70.74±0.66^{a}	65.98±0.48^{b}	61.49±0.33^{c}	56.79±0.30^{d}	50.71±0.31^{e}	44.43±0.55^{f}
Egg weight-median (g)	72.30	67.00	62.35	57.10	50.20	43.00
Short circumference (cm)	13.84±0.11^{a}	13.56±0.08^{b}	13.37±0.06^{c}	13.01±0.05^{d}	12.71±0.06^{e}	12.05±0.10^{f}
Long circumference (cm)	16.27±0.13^{a}	16.03±0.09^{b}	15.58±0.06^{c}	15.25±0.06^{d}	14.62±0.06^{e}	13.90±0.11^{f}
Long-short circumference ratio	1.18±0.01^{a}	1.18±0.01^{a}	1.16±0.01^{ab}	1.17±0.01^{ab}	1.15±0.01^{b}	1.16±0.01^{ab}
Internal egg quality composition traits						
Yolk weight (g)	19.81±0.51^{a}	18.90±0.37^{b}	17.35±0.25^{c}	16.78±0.23^{d}	15.10±0.24^{e}	13.25±0.42^{f}
Albumen weight (g)	34.98±0.88^{a}	31.79±0.64^{b}	30.00±0.43^{c}	26.09±0.40^{d}	22.88±0.41^{e}	19.24±0.73^{f}
Yolk (%)	28.24±0.92^{a}	28.73±0.67^{a}	28.25±0.45^{a}	29.52±0.42^{a}	29.79±0.43^{a}	29.85±0.76^{a}
Albumen (%)	49.22±1.38^{a}	48.09±1.00^{a}	48.74±0.68^{a}	45.93±0.63^{b}	44.98±0.64^{b}	42.84±1.14^{c}
Yolk-albumen ratio	0.58±0.04^{c}	0.61±0.03^{bc}	0.58±0.02^{c}	0.65±0.02^{b}	0.67±0.02^{ab}	0.72±0.03^{a}
Non-composition traits						
Yolk color	8.33±0.55^{a}	7.56±0.40^{ab}	7.66±0.37^{ab}	7.38±0.25^{b}	7.29±0.25^{b}	6.87±0.45^{b}
Albumen height (mm)	4.42±0.16^{a}	4.39±0.12^{a}	4.05±0.08^{b}	3.72±0.07^{c}	3.47±0.08^{d}	3.28±0.11^{e}
Haugh unit-mean	54.41±1.91^{a}	56.24±1.38^{a}	54.58±0.94^{a}	53.57±0.87^{a}	54.51±0.89^{a}	56.14±1.58^{a}
Haugh unit-median	65.80	57.30	60.60	61.50	61.10	55.90
External egg quality						
Shell weight (g)	7.92±0.24^{a}	7.17±0.18^{b}	7.05±0.31^{b}	6.54±0.11^{c}	6.17±0.11^{d}	5.66±0.20^{e}
Shell (%)	11.13±0.45^{cd}	10.80±0.33^{d}	11.43±0.22^{c}	11.50±0.20^{c}	12.17±0.21^{b}	12.75±0.37^{a}
Shell thickness-tip (mm)	0.34±0.01^{a}	0.32±0.01^{ab}	0.33±0.01^{ab}	0.31±0.01^{b}	0.33±0.01^{ab}	0.32±0.01^{ab}
Shell thickness-middle (mm)	0.37±0.01^{a}	0.34±0.01^{b}	0.34±0.01^{b}	0.33±0.01^{b}	0.33±0.01^{b}	0.32±0.01^{b}
Shell thickness-bottom (mm)	0.34±0.01^{a}	0.33±0.01^{a}	0.32±0.01^{a}	0.31±0.01^{bc}	0.31±0.01^{bc}	0.29±0.01^{c}
Shell thickness-average (mm)	0.35±0.01^{a}	0.33±0.01^{ab}	0.33±0.01^{ab}	0.32±0.00^{bc}	0.32±0.01^{bc}	0.30±0.01^{c}

Least square means (and standard error) in the same row followed by the same letter are not significantly different from one another (p>0.05)

chicken breeds. The Paraoakan had the highest egg weight (58.6 g). The Palawan Lasak eggs had the highest yolk weight (17.2 g), percent yolk (30.64%), yolk-albumen ratio (0.72) and percent shell (12.08%). The Joloano eggs had the highest albumen weight (27.9 g) and percent albumen (48.08%). The egg shape, yolk color, albumen height, Haugh Unit, shell weight and shell thickness were not significantly different (p>0.05) among native chicken breeds.

Table 6 shows significant differences (p<0.05) in egg size and shape, internal and external quality traits among egg-type and dual-purpose breeds. The egg-type White Leghorn had the highest egg weight (60.4 g), albumen height (4.17 mm) and Haugh Unit (56.84). Nagoya eggs had the highest yolk weight (18.1 g) and percent yolk (30.45%). Eggs from the Barred Plymouth Rock had the highest albumen weight (29.6 g), while New Hampshire eggs had the highest yolk-albumen ratio (0.72). The Rhode Island Red eggs had the highest percent albumen (49.03%), shell weight (7.6 g) and percent shell (12.84%). Taiwan Yellow had the highest shell thickness (0.35 mm). Black Australorp eggs were of the most elongated shape.

Comparison of eggs from egg-type and meat-type breeds showed that the White Leghorn had significantly higher (p<0.05) egg weight, yolk weight, shell weight, percent shell and rounder eggs than the meat-type White Rock breed.

The fancy-type and bantam-sized Black Silkies had the highest percent yolk (31.04%) and yolk color (9.58) among all chicken breeds. The Black Silkies eggs had significantly higher (p<0.05) yolk color score and shell weight than the other fancy-type White Silkies eggs.

Breed comparisons according to the egg size classification system: The distribution of eggs according to the size classification system was 4.1% jumbo, 7.3% extra-large, 20.3% large, 21.9% medium, 39.7% small and 6.7% peewee (Table 1). The median of egg weight values was 72.3 g (jumbo), 67.0 g (extra-large), 62.4 g (large), 57.1 g (medium), 50.2 g (small) and 44.0 g (peewee). A bigger egg size was consistently observed with increasing short circumference, long circumference, yolk weight and albumen weight. Percent yolk and Haugh Unit values were not significantly different (p>0.05) among the six egg size categories (Table 7).

Based on the median of egg weight values, the eggs from Banabang Kalabaw (50.2 g), Joloano (52.2 g), Paraoakan (52.4 g) and Palawan Lasak (49.8 g), Black Silkies (46.6 g) and White Silkies (45.6 g), were classified as small.

Table 8: Size, shape, internal and external qualities of chicken eggs in different grade classifications

	Grade classification			
Traits	AA	A	B	C
Egg size and shape				
Egg weight-mean (g)	58.77±0.34[a]	58.74±0.21[a]	58.18±0.21[a]	57.74±0.70[a]
Egg weight-median (g)	56.05	56.00	54.40	62.70
Short circumference	13.08±0.06[ab]	13.13±0.04[a]	13.03±0.04[b]	13.12±0.12[ab]
Long circumference	15.32±0.07[a]	15.32±0.04[a]	15.26±0.04[a]	15.21±0.13[a]
Long-short circumference ratio	1.17±0.01[a]	1.17±0.00[a]	1.17±0.00[a]	1.16±0.01[a]
Internal egg quality				
Composition traits				
Yolk weight (g)	16.65±0.26[a]	16.53±0.16[a]	17.06±0.16[a]	17.22±0.54[a]
Albumen weight (g)	27.97±0.45[a]	28.16±0.28[a]	26.74±0.28[b]	27.11±0.92[ab]
Yolk (%)	28.40±0.47[b]	28.32±0.29[b]	29.62±0.29[a]	29.91±0.97[a]
Albumen (%)	47.17±0.71[a]	47.49±0.44[a]	45.33±0.44[b]	46.54±1.45[ab]
Yolk-albumen ratio	0.61±0.02[b]	0.61±0.01[b]	0.67±0.01[a]	0.65±0.04[ab]
Non-composition traits				
Yolk color	7.38±0.28[a]	7.63±0.17[a]	7.53±0.17[a]	7.53±0.58[a]
Albumen height (mm)	5.74±0.08[a]	4.61±0.05[b]	3.21±0.05[c]	2.00±0.17[d]
Haugh unit-mean	75.08±0.98[a]	65.77±0.61[b]	49.76±0.60[c]	29.04±2.01[d]
Haugh unit-median	75.30	66.30	51.95	27.00
External egg quality				
Shell weight (g)	7.06±0.12[a]	6.92±0.08[ab]	6.78±0.08[b]	6.25±0.26[c]
Shell (%)	12.12±0.23[a]	11.82±0.14[ab]	11.72±0.14[b]	10.88±0.47[c]
Shell thickness-tip	0.32±0.01[a]	0.33±0.00[a]	0.33±0.00[a]	0.31±0.01[a]
Shell thickness-middle	0.34±0.01[a]	0.34±0.00[a]	0.34±0.00[a]	0.33±0.01[a]
Shell thickness-bottom	0.31±0.01[a]	0.32±0.00[a]	0.32±0.00[a]	0.32±0.01[a]
Shell thickness-average	0.31±0.01[a]	0.32±0.00[a]	0.32±0.00[a]	0.32±0.01[a]

Least square means (and standard error) in the same row followed by the same letter are not significantly different from one another (p>0.05)

White Rock eggs (55.5 g) were classified as medium. The eggs from Black Australorp (61.1 g), Barred Plymouth Rock (60.9 g), New Hampshire (62.3 g), Rhode Island Red (60.1 g) and Taiwan Yellow (61.7 g) were large. The eggs from Nagoya (68.0 g) and White Leghorn (67.4 g) were classified as extra-large.

When compared local chicken breeds with other countries, the small-sized eggs of Philippine native breeds were similar with the small size-eggs reported for 9 local breeds in Asia (Kamrupa and Vanaraja[20], Nicobari and Nishibari or Brown Nicobari x White Leghorn[21], Aseel[22] and Bhubaneswar local chickens[23] from India; Naked Neck from Pakistan[24] and Ho and Dong Tao from Vietnam[25]), 3 local breeds in Africa (Cameroon local barred chickens[26], Yirgalem local chickens from Ethiopia[27] and Naked Neck from Nigeria[28]) and 9 local breeds in Europe (Ardennaise from Belgium[29] ; Ermellinata di Rovigo from Italy[19]; Amarela, Pedres Portuguesa and Preta Lusitanica from Portugal[18] and Araucana, Barnevelder, Cornish Game and J-Line from Scotland[30]).

The size of eggs from commercial/transboundary breeds used in this study were not the same compared to reports of the same breeds in other countries. For example, the medium-sized White Rock and large-sized Barred Plymouth Rock eggs in this study were bigger than the small-sized White Rock and Barred Plymouth Rock eggs reported in Bangladesh[31]. The large-sized New Hampshire eggs in this study were bigger than the medium-sized New Hampshire eggs in the Slovak Republic[32]. The large-sized Rhode Island Red eggs in this study were bigger than the small-sized Rhode Island Red eggs reported in Mexico[33] and the medium-sized Rhode Island Red eggs reported in Bangladesh[31], Slovak Republic[32,34] Poland[35] and . The extra-large eggs of White Leghorn in this study were similar to those reported in Poland[34] and Czech Republic[36] but bigger than the small-sized White Leghorn eggs reported in India[37] and the medium-sized White Leghorn eggs reported in Bangladesh[31] and in India[38].

Breed comparisons according to the egg grade classification system: The distribution of chicken eggs by grade classification based on Haugh Unit was 13.3% Grade AA, 40.6% Grade A, 43.2% Grade B and 2.9% Grade C (Table 2). The median of Haugh Unit values was 75.30 (Grade AA), 66.30 (Grade A), 51.95 (Grade B) and 27.00 (Grade C). A superior egg grade was consistently observed with higher albumen height. Egg weight and shape, yolk weight, yolk color and shell thickness were not significantly different (p>0.05) among the four grade classes (Table 8).

Based on the median of Haugh Unit values, the eggs from Banabang Kalabaw (65.40), Joloano (60.50), Paraoakan (65.70), Palawan Lasak (60.70), Barred Plymouth Rock (68.60), New Hampshire (60.60), Taiwan Yellow (61.15) and White Leghorn (68.50) were classified as Grade A. The eggs from White Rock (57.20), Black Silkies (51.90), White Silkies (55.50), Black Australorp (58.20), Nagoya (43.55) and Rhode Island Red (55.50) were classified as Grade B.

By comparison, the small-sized eggs reported from 21 local breeds from Asia, Africa and Europe were classified as Grade AA, except for the Bhubaneswar local chickens from India[23] and the Amarela from Portugal[18] which were classified as Grade A. Furthermore, the eggs of various sizes from the White Rock, Barred Plymouth Rock, New Hampshire, Rhode Island Red and White Leghorn reported in other countries were classified as Grade AA, except for the small and medium-sized eggs for the Barred Plymouth Rock and White Leghorn reported in Bangladesh[31] which were classified as Grade B.

The breed/strain differences in egg quality traits presented in this study compared to those produced in other countries may have been confounded by the variations in internal factors (general health, hen age and production stage) and external factors (housing system, nutrition, microclimate and stress levels)[39].

Implications of egg characteristics to human health and nutrition: In the Philippines, a simple description of a chicken egg used in the Nutritional Guidelines for Filipinos (NGF), Daily Nutritional Guide Pyramid (DNGP) and the Food Exchange Lists (FEL) for Meal Planning used by Registered Nutritionist-Dietitians refers to a medium-size egg providing 8 g of protein and 6 g of fat per 55 g edible portion[40].

By integrating the egg characteristics from Philippine native chickens with the existing "Food Composition Tables", consumers including health and nutrition professionals will benefit from a better understanding of the variety of chicken eggs available and accurately determining adequacy of nutrients available from eggs especially in rural areas.

Factors that determine the fluctuations in internal egg quality, especially related to the yolk need to be further investigated according to consumer preference and cultural background. The health-conscious consumer, for example, may find the egg from native chicken breed with a comparatively smaller yolk to be more acceptable. This shift in preference may be due to the increased awareness of the dangers of high cholesterol contained primarily in the egg yolk. On the other hand, the egg processor also has an interest in yolk size, since yolk has a higher market value than albumen. The breed or strain differences in yolk yield presented in this study should enable the egg processor to optimize his profitability by selecting flocks that lay eggs with a high yolk-albumen ratio.

CONCLUSION

The eggs from Philippine native chickens (Banabang Kalabaw, Joloano, Paraoakan and Palawan Lasak), like that of the fancy-type and bantam-sized breeds, were small. The weight of yolk, albumen and shell were lower than the bigger eggs from adapted meat-type, egg-type and dual-purpose chicken breeds. The size classification system based on egg weight provides useful information not only for consumers and egg producers but also for profiling breed characteristics in conservation and genetic improvement studies.

On the other hand, the quality of eggs from native chickens was classified as Grade A-similar to that of Barred Plymouth Rock, New Hampshire, Taiwan Yellow and White Leghorn eggs. However, this study showed that egg weight was not related to the egg grading system based on Haugh Unit values. And since eggs of any quality grade may differ in size, egg grading may have limited applications in local breed characterization and improvement programs.

SIGNIFICANCE STATEMENT

This study contributes to the meager information available on the comparative assessment of egg size, shape and internal and external quality in adapted chicken breeds in the Philippines. Such information can be used in promoting a local egg grading and size classification system especially for native chicken breeds in the rural areas, while ensuring their proper management and improvement. This study will not only help establish distinct egg characteristic profiles for Philippine native breeds that may be compared to that of local chicken breeds in Asia, Africa and Europe but also consumers and egg producers benefit from a better understanding of the characteristics of the variety of chicken eggs available in the country.

ACKNOWLEDGMENTS

This research was supported by grants from the Philippine Agriculture and Fisheries Biotechnology Program under the Department of Agriculture Biotechnology Program (DA-BIOTECH)-R1807. The authors acknowledge the assistance of Ms. Vea Roven E. Arellano and Mr. Mat M. San Agustin of NSPRDC, BAI-DA, Tiaong, Quezon for their helpful collaboration and availability in samples collection. The

authors would also like to thank Mr. Mark C. Agsunod for his valuable assistance in handling and analysis of chicken egg samples.

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