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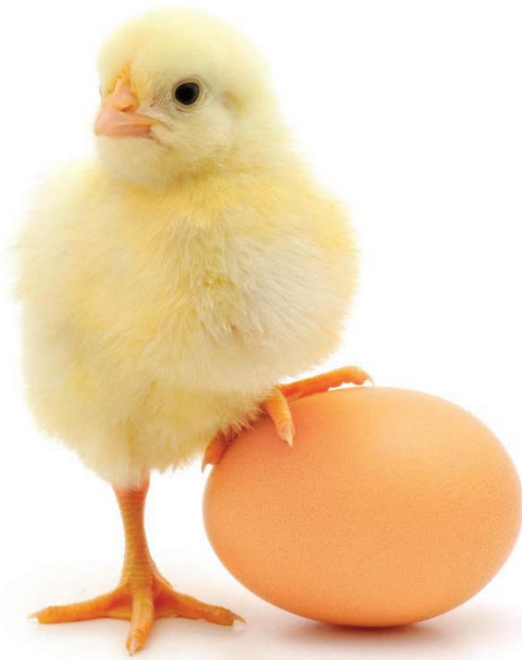

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Research Article
Egg Components in Balut Produced from Three Itik-Pinas (IP) Mallard Breeds in the Philippines

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Abstract
Background and Objective: Balut is a popular Filipino food made from boiled mallard egg containing a developing embryo. The technical characteristics of balut are not well known and understood. This study aimed to compare the egg composition, shell thickness and egg shape dimensions of two types of balut- at 15 days of incubation (B15d) and 18 days of incubation (B18 d), produced by Itik-Pinas (IP) duck breeds (IP-Itim, IP-Khaki and Kayumanggi-IP). **Materials and Methods:** A total of 434 balut out of 524 randomly collected eggs from three IP breeds were produced using an artificial incubator. Balut characteristics were analyzed by least square procedures for unbalanced data to account for the effects of breed, balut type, "breed×balut type" interaction and duck hen's age on the composition, shell thickness and egg shape dimensions of balut. **Results:** Balut is comprised of the developing embryo (23.70%), yolk (32.54%), albumen (16.24%), fluid portion (9.87%) and shell (17.73%). B15d balut had significantly ($p<0.01$) lower embryo weight and higher weight of yolk, albumen, fluid and shell than B18d balut. Shell thickness, short and long circumference and long-short circumference ratio was not different between B15d and B18d balut. IP-Itim had the lowest embryo weight (6.6 g) and highest yolk weight (22.3 g) in B15d balut. Kayumanggi-IP had the lowest albumen weight (13.7 g) in B15d balut and lowest embryo weight (20.3 g) in B18d balut. Albumen weight and yolk weight in B18 balut were not significantly different among the IP duck breeds ($p>0.05$). **Conclusion:** The technical characteristics of B15d and B18d balut may be considered in the choice of breed to be used in balut production according to consumer preferences.

Key words: Balut, egg components, mallard ducks, duck eggs, Filipino food

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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

Balut made from incubated duck eggs is a Filipino food and popular in several ASEAN countries (Laos, Cambodia, Vietnam, Thailand) and China[1]. Balut has a fertilized egg embryo that is boiled and eaten from the shell. It is generally incubated for 14-18 days before being boiled for consumption. (The normal incubation period for duck eggs to hatch is 28 days). There are two types of balut produced and sold in the market, namely "*balut mamatong*" (i.e., embryo is floating above the yolk and the white) and "*balut sa puti*" (i.e., embryo is covered with white)[2].

The dominant type of duck used for egg production is the Philippine mallard duck locally known as "itik", with the prevalent colors of black (Pateros-type) and brown (Khaki Campbell-type). These ducks are non-sitters and are good producers of eggs that are relatively large in size[3]. From 2012-2017, the Itik-Pinas (IP) duck breeds-IP-Itim, IP-Khaki and Kayumanggi-IP were developed for commercial duck egg production at the National Swine and Poultry Research and Development Center (NSPRDC), Department of Agriculture-Bureau of Animal Industry (DA-BAI) in Tiaong, Quezon. The IP-Itim and IP-Khaki breeds were derived from the Pateros-type and Khaki Campbell-type foundation stocks, respectively. The Kayumanggi-IP breed is an F_1 crossbred progeny from a mating between IP-Khaki (male line) and IP-Itim (female line). It is produced and promoted nationwide by the NSPRDC as an improved breed for duck farmers due to the brown plumage color exclusive for females and black color for males. The plumage color for this specific cross is an example of a sex-linked trait wherein the recessive sex-linked black plumage is more common in males, thus providing a practical and inexpensive method of sexing day-old ducks.

While a few studies reported the quality of fresh duck eggs in terms of egg weight, shell thickness and yolk color[3-5] and egg composition[6,7], very limited literature is available on the technical characteristics of balut. Considering the importance of balut production in the duck egg industry[8] and the lack of uniform standards for grading of balut, this study aimed to compare the characteristics of two types of balut (B15d and B18d) in terms of egg composition, shell thickness and egg shape dimensions produced by the three IP duck breeds.

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: A total of 524 duck eggs were randomly collected for incubation in seven batches from three Itik-Pinas (IP) breeds (IP-Itim, IP-Khaki and Kayumanggi-IP). The IP breeds were raised in similar farm conditions at NSPRDC, DA-BAI in Tiaong, Quezon. At the time of the study, large purebred flocks of IP-Itim and IP-Khaki and a small flock of Kayumanggi-IP were available at NSPRDC. Each purebred flock was about four times larger than the Kayumanggi-IP. This was because Kayumanggi-IP ducks produced by crossbreeding at NSPRDC were mostly distributed to smallholder farmers as part of its livelihood support program.

Date of egg collection and corresponding flock or family was marked on the eggs with pencil, each pen was consisting of about 4 males and 20 females. The newly collected eggs were placed in an artificial incubator under similar temperature and relative humidity conditions to avoid undue differences in embryo development and to ensure data consistency. The incubated eggs in a batch were candled at day 7 to separate the infertile eggs from the fertilized eggs, which were further classified into penoy and balut. Penoy are fertilized eggs in which developing embryo dies in the first week of incubation. Both penoy and infertile eggs are considered by-products in balut production and sold at a lower price. Balut are fertilized eggs which were allowed to grow until 15 days (B15d balut)or 18 days (B18d balut) in the incubator. Balut eggs were divided into equal lots and evaluated at the 15th and 18th day of incubation.

Of the 524 eggs put in the incubator, about 10.05% were identified as infertile eggs, 7.76% were penoy and 82.19% balut (Table 1). Eggs from IP-Itim produced 82.19% balut, 7.76% penoy and 10.05% infertile eggs. In contrast, the IP-Khaki eggs produced 87.5% balut, 8.06% penoy and only 4.44% infertile eggs. Eggs from Kayumanggi-IP produced 64.19% balut, 7.02% penoy and 28.07% infertile eggs, suggesting a low fertility rate for the crossbred mallard ducks. Balut were boiled for 30 min and cooled prior to dissection. The weight of egg components was determined using a

Table 1: Number and distribution of incubated eggs, by breed and type

	IP-Itim	IP-Khaki	Kayumanggi IP	Total
Balut	180	217	37	434
B15d balut	93	114	19	226
B18d balut	87	103	18	208
Penoy	17	20	4	41
Infertile eggs	22	11	16	49
Total	219	248	57	524
	(41.79%)	(47.33%)	(10.88%)	(100.00%)

digital weighing scale (cap. 0~500 g/0.1 g). The components of balut include the embryo, yolk, albumen, fluid portion and shell. The balut component's percentage (%) was calculated as:

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

Shell thickness at the tip, middle and butt portions were measured using the Tactix® Digital Caliper (Meridian International Co., Ltd, Shanghai, China). Egg shape dimensions (i.e., short and long circumference) were recorded using the common measuring tape and used to compute long-short circumference ratio, the value more than 1.00 implies a more elongated shape.

Statistical analysis: Pearson product-moment correlation coefficients among balut components and their relationships with shell thickness and egg shape dimensions were determined using the CORR procedure of SAS[9].

The general least squares procedures for unbalanced data using the GLM procedure of SAS[9] were performed to analyze the effect of the principal sources of variation on each balut characteristic using the mathematical model:

$$y_{ijkl} = \mu + \text{Breed}_i + \text{Type}_j + (\text{Breed} \times \text{Type})_{ij} + \text{Age}_k + e_{ijkl}$$

where, y_{ijkl} is the dependent variable (weight and proportion of each balut component, shell thickness, egg shape dimensions), μ is overall mean, Breed_i is the effect of i^{th} breed (IP-Itim, IP-Khaki and Kaumanggi-IP), Type_j is effect of the j^{th} type of balut (B15d and B18d) and $(\text{Breed} \times \text{Type})_{ij}$ is interaction effect between the ith breed and jth type of balut, Age_k is the k^{th} covariate effect of duck hen's age (weeks) and e_{ijkl} is error term assumed to be normally distributed with variance of errors as constant across observations. Statistical significance was set at $p<0.05$. The least square means and standard error for B15d and B18d balut were used to compare the difference between balut types, while the "Breed×balut type" interaction effects were used to compare the difference between breeds.

RESULTS AND DISCUSSION

Balut components: Table 2 shows that balut is comprised of the developing embryo (14.6 g or 23.70%), yolk (20.6 g or 32.54%), albumen (10.5 g or 16.24%), fluid portion (6.5 g or 9.87%) and shell (11.2 g or 17.73%). The percentage of embryo was negatively correlated ($p<0.01$) with percent yolk, albumen and fluid (r = -0.50, r = -0.93 and r = -0.78, respectively).

Table 2: Simple descriptive statistics for egg weight, composition, shell thickness and egg shape dimensions of balut

	Average±SD	Range
Egg weight (g)	63.33±5.23	41.5-78.7
Embryo weight (g)	14.61±8.20	3.3-31.4
Yolk weight (g)	20.58±3.14	11.1-30.8
Albumen weight (g)	10.47±4.55	0.8-19.0
Fluid weight (g)	6.47±3.24	0.4-15.1
Shell weight (g)	11.20±1.57	6.0-17.4
Percent embryo	23.70±12.95	5.27-46.68
Yolk (%)	32.54±4.01	18.56-47.71
Albumen (%)	16.24±7.02	1.32-30.64
Fluid (%)	9.87±4.78	0.61-22.44
Shell (%)	17.73±2.39	9.29-28.24
Shell thick. tip (mm)	0.36±0.04	0.23-0.47
Shell thick. middle (mm)	0.36±0.04	0.24-0.49
Shell thick. butt (mm)	0.36±0.04	0.23-0.49
Shell thick. average (mm)	0.36±0.04	0.24-0.48
Short circumference (mm)	14.23±0.40	12.8-15.8
Long circumference (cm)	16.35±0.47	14.5-17.8
Long-short circum ratio	1.15±0.03	1.00-1.23

Egg weight was not related to embryo weight ($p>0.05$), (Table 3). However, egg weight was positively correlated ($p<0.01$) with the weight of yolk (r = 0.60), fluid (r = 0.41), shell (r = 0.39) and albumen (r = 0.23), suggesting that egg weight may provide a better estimate of the amount of yolk rather than albumen or fluid present in balut.

Fluid portion was the most variable among the edible components of balut, (i.e., coefficient of variation, CV = 34.20%) followed by embryo, albumen and yolk with CV values of 22.81%, 21.60% and 10.74%, respectively (Table 4).

The duck hen's age (ranging from 66.0-98.6 weeks old) had significant ($p<0.01$) positive effects on the percentage of embryo and negative effects on the percentage of albumen, fluid and shell. This implies that balut from older ducks contained more embryo but with lower albumen and fluid content. However, the duck hen's age had no significant effect on yolk (percent) ($p>0.05$).

Developing embryo: The embryo in balut at the 15th and 18th day of incubation corresponds to embryo stage No. 38 and No. 41, respectively based on the HH embryonic staging system for ducks as reported by Li *et al.*[10]. At these stages, embryo weight was negatively correlated ($p<0.01$) with the weight of albumen (r = -0.90), fluid (r = -0.71) and yolk (r = -0.36), (Table 3). These correspond to an increase in embryo weight and a proportionate loss in weight of the other egg components as the embryo absorbs the albumen, fluid and yolk inside the egg. At this point, the loss in weight of albumen and fluid is usually higher than in yolk.

A 15 days old balut contained a higher volume of albumen and sub-embryonic fluid, and is thus called "*balut mamatong*" -the embryo appears to sit on top of the

Table 3: Pearson correlation coefficients among balut components and their relationship with shell thickness and egg shape dimensions

	Egg weight	Embryo weight	Yolk weight	Album. weight	Fluid weight	Shell weight	Embryo percent	Yolk percent	Albumen percent	Fluid percent	Shell percent
Egg weight		ns	0.60**	0.23**	0.41**	0.39**	ns	ns	ns	0.26**	-0.24**
Embryo weight			-0.36**	-0.90**	-0.71**	-0.24**	0.99**	-0.50**	-0.93**	-0.74**	-0.28**
Yolk weight				0.39**	0.31**	0.12*	-0.46**	0.84**	0.29**	0.26**	-0.26**
Albumen weight					0.72**	0.28**	-0.93**	-0.35**	0.98**	0.71**	-0.15*
Fluid weight						0.23**	-0.76*	0.14**	0.65**	0.98**	ns
Shell weight							-0.29**	-0.11*	0.21**	0.17**	0.80**
Embryo (%)								-0.50**	-0.93**	-0.78**	-0.25**
Yolk (%)									-0.33**	0.13**	-0.16**
Albumen (%)										0.68**	0.20**
Fluid (%)											ns
Shell thickness-tip	-0.10*	-0.23**	-0.17**	0.17**	0.25**	0.19**	-0.19**	-0.15**	0.16**	0.26**	0.26**
Shell thickness-middle	-0.13**	-0.24**	-0.20**	0.17**	0.27**	0.13*	-0.19**	-0.16**	0.17**	0.28**	0.28**
Shell thickness-butt	-0.10*	-0.16**	-0.17**	0.11*	0.22**	0.14**	-0.12*	-0.15**	0.10*	0.21**	0.21**
Shell thickness-average	-0.11*	-0.22**	-0.19**	0.16**	0.26**	0.16**	-0.18**	-0.16**	0.15**	0.27**	0.27**
Short circumference	0.77**	0.18**	0.40**	ns	0.17**	0.28**	ns	ns	-0.10*	ns	-0.21**
Long circumference	0.86**	0.13**	0.52**	0.12*	0.24*	0.34**	ns	ns	ns	0.13**	-0.26**
Long-short circum. ratio	0.12*	ns	0.14**	ns	ns	ns	ns	ns	ns	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)

Table 4: Mean square F tests results for the effects of breed, balut type, "breed×balut type" interaction and covariate effect of duck hen's age on the composition, shell thickness and egg shape dimensions of balut

	Breed	Balut type	"Breed×balut type" interaction	Duck hen's age, $_{\text{by.Hen age}}$	CV (%)
Egg weight	*	ns	ns	** 0.156±0.029	7.94
Embryo weight	**	**	0	** 0.166±0.019	23.10
Yolk weight	*	**	0	** 0.062±0.016	13.89
Albumen weight	ns	*	ns	**-0.036±0.013	22.49
Fluid weight	ns	**	ns	** -0.038±0.014	36.65
Shell weight	ns	**	ns	ns	12.69
Embryo (%)	**	**	*	** 0.211±0.031	22.81
Yolk (%)	**	**	**	ns	10.74
Albumen (%)	ns	**	ns	** - 0.103±0.020	21.60
Fluid (%)	ns	**	ns	** -0.085±0.019	34.20
Shell (%)	ns	**	ns	** - 0.037±0.013	13.81
Shell thickness-tip	*	**	ns	** -0.0035±0.0002	8.96
Shell thickness-middle	**	**	ns	** -0.0031±0.0002	8.40
Shell thickness-butt	*	**	ns	** -0.0031±0.0001	9.66
Shell thickness-average	*	**	ns	** -0.0032±0.0002	13.15
Short circumference	**	ns	ns	ns	2.76
Long circumference	ns	ns	ns	** 0.0099±0.0027	2.85
Long-short circum. ratio	**	ns	ns	** 0.0005±0.0002	2.47

bigger yolk and albumen sacs. The older 18-day old balut with relatively lower volume of albumen and sub-embryonic fluid is called "*balut sa putl*" -a bigger embryo is covered with white membrane when boiled, while the hard, white albumen is smaller as it was absorbed by the growing embryo.

In this study, embryo weight and percentage were significantly (p<0.05) higher (21.71%)in B18d balut than B15d balut (13.7%) (Table 5). The significant "breed×balut type" interaction effects (p<0.05) on embryo weight showed that embryo weight in B15d balut was highest in Kayumanggi-IP (8.8 g) and lowest in IP-Itim (6.6 g). The embryo weight in B18d balut, on the other hand, was the highest in IP-Khaki (23.2 g) and the lowest in Kayumanggi-IP (20.3 g), (Table 6).

Yolk: Yolk in balut refers to the solidified yolk and yolk sac membrane. The yolk is the main source of lipids, fats and energy for tissue growth during embryonic development[11]. The yolk is also responsible to initiate body growth and development of the small intestine and other organs of the developing embryo[12].

According to Li *et al.*[10] and Byerly[13], the yolk sac grows peripherally to completely surround the yolk at the 9th or 10th day (15 or 16 day in ducks). The yolk then decreases in size at 15th or 16th day (18 or 19 d in ducks) due to the excretion of water into the allantois. The size of both yolk and yolk sac continue to decrease until hatching time. In this regard, yolk weight was positively correlated (p<0.01) with albumen weight (r = 0.39) and fluid weight (r = 0.31), (Table 3).

Table 5: Egg weight, composition, shell thickness and egg shape dimensions of B15d and B18d balut

	B15d balut	B18d balut
Egg weight (g)	63.89±0.50[a]	62.67±0.46[b]
Embryo weight (g)	7.91±0.30[b]	21.59±0.31[a]
Yolk weight (g)	21.77±0.26[a]	19.86±0.26[b]
Albumen weight (g)	14.03±0.21[a]	6.42±0.22[b]
Fluid weight (g)	8.55±0.21[a]	4.20±0.22[b]
Shell weight (g)	11.53±0.15[a]	10.66±0.14[b]
Embryo (g)	12.82±0.53[b]	34.53±0.50[a]
Yolk (g)	34.27±0.34[a]	31.74±0.32[b]
Albumen (g)	21.84±0.35[a]	10.23±0.32[b]
Fluid (g)	12.97±0.33[a]	6.61±0.31[b]
Shell (g)	18.10±0.23[a]	17.20±0.22[b]
Shell thick. tip (mm)	0.36±0.00[a]	0.35±0.00[b]
Shell thick. middle (mm)	0.36±0.00[a]	0.35±0.00[b]
Shell thick. butt (mm)	0.36±0.00[a]	0.35±0.00[a]
Shell thick. average (mm)	0.36±0.00[a]	0.35±0.00[b]
Short circumference (cm)	14.16±0.04[b]	14.24±0.04[a]
Long circumference (cm)	16.34±0.04[a]	16.35±0.04[a]
Long-short circum. ratio	1.15±0.00[a]	1.15±0.00[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)

Yolk weight and percentage in B15d balut were slightly higher than that of the B18d balut by about 1.9 g and 2.54%, respectively (Table 5). The significant "breed×balut type" interaction effects (p<0.05) on yolk weight showed that yolk weight in B15d balut was the highest in IP-Itim (22.3 g) and the lowest in IP-Khaki (21.1 g). Yolk weight in B18d balut, on the other hand, was the highest in Kayumanggi-IP (21.1 g) and the lowest in IP-Khaki ducks (19.2 g), (Table 6).

Albumen: Albumen in balut refers to the solidified albumen and sub-embryonic fluid in the albumen sac generated out of the chorio-allantois membranes and is found under the developing embryo. The albumen is the main water source for the developing embryo as it contains about 10.5% protein and 88.5% of water. It is also the main source of proteins for tissue synthesis in the developing embryo[14].

According to Li *et al.*[10] and Stern[15], the albumen is rapidly dehydrated by the movement of water into the yolk to form sub-embryonic uid, which reaches its maximum volume (14 mL) on the day 7 (8.5 day in ducks). Thereafter, the volume of fluid is reduced and by day 14-15 (18.7-20 day in ducks), the albumen sac has disappeared. The continuous removal of water results in a reduction in the volume of albumen[16]. Ingestion of albumen by the embryo through the intestinal epithelium or the yolk sac begins at about day 12-13 (15 or 16 day in ducks) but is more active after day 14 (17 day in ducks)[17]. At this stage in incubation, albumen proteins end up first in the amniotic fluid starting from day 14-20 (17-26.1 day in ducks), then in the stomach contents on day 16-20 (19-26.1 day in ducks) and finally in the yolk sac at day 16-17 (19-21.5 day in ducks) before hatching[18].

Albumen weight in balut was highly correlated with fluid weight (r = 0.72) (Table 3). This is because albumen ows into the amniotic cavity and simultaneously into the yolk sac during embryo development[19].

Albumen weight and percentage in B15d balut were significantly higher (p<0.05) than that of B18d balut by about 7.6 g and 11.61%, respectively (Table 5). Albumen weight, however, was not affected by "breed × balut type" interaction (p>0.05). Albumen weight ranged from 13.7-14.4 g in B15d balut and 6.2-6.7 g in B18d balut across the IP duck breeds, (Table 6).

Fluid: The fluid portion (embryonic fluids) in balut is a mixture of amniotic fluid and allantoic fluid. The amniotic fluid is found in the extra-embryonic sac (amnion) as it provides a shock-absorbing environment to protect the embryo from infection, mechanical injury, desiccation and adhesion[20]. The allantoic fluid is found in the allantoic cavity formed by the allantois which when fully developed surrounds the embryo completely. The allantoic fluid is known to contain wastes that result from the embryo's metabolism. However, the allantoic fluid, just like plasma and amniotic fluid, also contains numerous free amino acids, albumen proteins, glucose and related compounds involved in lipid, vitamin metabolisms and metal ion transport in the developing embryo[21-23]. The differences in concentration of amino compounds and glucose between the two fluid compartments are maintained by an allantois/amnion barrier[21].

According to Li *et al.*[10] and Carinci and Manzoli-Guidotti[24], the amniotic fluid volume is approximately 3 mL after 10 days of incubation (13 d in ducks); it increases up to 15 days (18 day in ducks), then decreases slowly up to 17 days (21.5 day in ducks) and drops quickly on the 18th day (23.5 day in ducks). The drop in amniotic fluid is expected when the embryo starts to imbibe the amniotic fluid around day 13 of incubation (16 day in ducks) and continues until internal pipping (day 19 of incubation -24.8 day in ducks)[20]. On the other hand, the allantois which appears on the fourth day of incubation (5 day in ducks) increases very rapidly in wet weight until it reaches its maximum value on the 10th day (13 day in ducks). The wet weight then decreases until about the 15th day (18 day in ducks)[13].

Fluid weight and percentage in B15d balut were significantly higher (p<0.05) than that of the B18d balut by about 4.4 g and 6.36%, respectively (Table 5). Fluid weight in balut, however, was not affected by "breed×balut type" interaction (p>0.05). Fluid weight ranged from 8.5-8.6 g in B15d balut and 4.1-4.3 g in B18d balut across the IP duck breeds (Table 6).

Table 6: Egg weight, composition, shell thickness and egg shape dimensions (LSM±SE) of balut in different Itik-Pinas breeds

	B15d Balut			B18d Balut		
	IP-Itim	IP-Khaki	Kayumanggi-IP	IP-Itim	IP-Khaki	Kayumanggi-IP
Egg weight (g)	63.00 ± 0.52^{ab}	64.22 ± 0.50^{a}	64.45 ± 1.30^{a}	62.05 ± 0.54^{b}	63.90 ± 0.50^{a}	62.05 ± 1.19^{ab}
Embryo weight (g)	6.59 ± 0.35^{d}	8.39 ± 0.32^{c}	8.75 ± 0.78^{c}	21.22 ± 0.36^{b}	23.24 ± 0.33^{a}	20.30 ± 0.80^{b}
Yolk weight (g)	22.27 ± 0.30^{a}	21.12 ± 0.27^{b}	21.92 ± 0.66^{ab}	19.28 ± 0.31^{c}	19.20 ± 0.28^{c}	21.09 ± 0.67^{ab}
Albumen weight (g)	13.99 ± 0.24^{a}	14.43 ± 0.22^{a}	13.67 ± 0.54^{a}	6.73 ± 0.25^{b}	6.24 ± 0.23^{b}	6.28 ± 0.56^{b}
Fluid weight (g)	8.49 ± 0.25^{a}	8.62 ± 0.22^{a}	8.55 ± 0.54^{a}	4.13 ± 0.25^{b}	4.23 ± 0.23^{b}	4.22 ± 0.56^{b}
Shell weight (g)	11.63 ± 0.16^{a}	11.45 ± 0.15^{a}	11.52 ± 0.40^{a}	10.73 ± 0.17^{b}	11.02 ± 0.15^{b}	10.56 ± 0.38^{a}
Percent embryo	10.60 ± 0.56^{d}	13.29 ± 0.54^{c}	14.57 ± 1.40^{c}	34.29 ± 0.58^{b}	36.43 ± 0.53^{a}	32.86 ± 1.28^{b}
Percent yolk	35.31 ± 0.36^{a}	33.24 ± 0.35^{b}	34.27 ± 0.90^{ab}	31.05 ± 0.39^{c}	30.09 ± 0.34^{d}	34.09 ± 0.82^{ab}
Percent albumen	22.21 ± 0.36^{ab}	22.46 ± 0.35^{a}	20.86 ± 0.91^{b}	10.83 ± 0.38^{c}	9.79 ± 0.35^{d}	10.06 ± 0.83^{cd}
Percent fluid	13.33 ± 0.35^{a}	13.14 ± 0.34^{a}	12.44 ± 0.87^{a}	6.56 ± 0.36^{b}	6.55 ± 0.33^{b}	6.71 ± 0.80^{b}
Percent shell	18.56 ± 0.24^{a}	17.88 ± 0.23^{b}	17.85 ± 0.60^{ab}	17.38 ± 0.25^{b}	17.26 ± 0.23^{c}	16.97 ± 0.57^{c}
Shell thick. tip (mm)	0.36 ± 0.00^{a}	0.36 ± 0.00^{a}	0.35 ± 0.01^{a}	0.35 ± 0.00^{a}	0.35 ± 0.00^{a}	0.33 ± 0.01^{b}
Shell thick. middle (mm)	0.37 ± 0.00^{a}	0.37 ± 0.00^{a}	0.35 ± 0.01^{b}	0.36 ± 0.00^{a}	0.35 ± 0.00^{b}	0.34 ± 0.01^{c}
Shell thick. butt (mm)	0.36 ± 0.00^{a}	0.36 ± 0.00^{a}	0.35 ± 0.01^{a}	0.36 ± 0.00^{a}	0.35 ± 0.00^{a}	0.33 ± 0.01^{b}
Shell thick. average (mm)	0.36 ± 0.00^{a}	0.36 ± 0.00^{a}	0.35 ± 0.01^{a}	0.36 ± 0.00^{a}	0.35 ± 0.00^{a}	0.34 ± 0.01^{b}
Short circumference (cm)	14.14 ± 0.04^{b}	14.27 ± 0.04^{a}	14.08 ± 0.09^{b}	14.19 ± 0.04^{b}	14.35 ± 0.04^{a}	14.17 ± 0.09^{ab}
Long circumference (cm)	16.29 ± 0.05^{b}	16.32 ± 0.04^{b}	16.42 ± 0.11^{ab}	16.36 ± 0.05^{a}	16.43 ± 0.05^{a}	16.26 ± 0.11^{ab}
Long-short circum. ratio	1.15 ± 0.00^{b}	1.14 ± 0.00^{b}	1.17 ± 0.01^{a}	1.15 ± 0.00^{b}	1.14 ± 0.00^{b}	1.15 ± 0.01^{b}

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)

Shell: The shell in balut is the outer covering of egg including the shell membranes. It is known to protect the developing embryo from mechanical injury and serves as a barrier against bacterial infection[25] while allowing embryo respiration through the pores in the eggshell[26]. The pores provide escape route for water vapor while the inner side of the shell serves as a source of calcium for the development of embryonic bones[27]. The allantois membrane is responsible to transport calcium from egg shell[28].

Shell weight of balut was negatively correlated (p<0.01) with embryo weight (r = -0.24), positively correlated with yolk weight (r= 0.12), albumen weight (r = 0.28) and fluid (r = 0.23). Shell weight and percentage in B15d balut was slightly higher than that of the B18d balut by about 0.9 g and 0.9% only, respectively (Table 5). Shell weight of balut was not significantly affected by "breed×balut type" interaction (p>0.05). Shell weight ranged from 11.4-11.6 g in B15d balut and 10.6-11.0 g in B18d balut across the IP duck breeds (Table 6).

Shell thickness: Shell thickness has long been used as an indication of shell strength in commercial egg production (chicken) since the percentage of cracked eggs are found to increase with thinner shells[29]. Shell thickness of balut is especially important to avoid breakage while cooking and when transporting balut in bamboo-woven baskets as is commonly practiced by street vendors peddling during the night time. Any breakage in balut decreases its value as food contaminated by microorganisms can cause spoilage.

Shell thickness at the tip, middle and butt portions of balut were negatively correlated (p<0.01) with embryo weight (r = -0.16 to -0.24) and yolk weight (r= -0.17 to -0.20) but positively correlated with albumen weight (r = 0.11 to 0.17) and fluid weight (r = 0.22 to 0.27). The average shell thickness of balut was slightly affected by the type of balut (p<0.05) but not affected by the "breed×balut type" interaction (p>0.05). Shell thickness at the tip, middle and butt portions were similar in B15d (0.36 mm) and B18d balut (0.35 mm). Average shell thickness ranged from 0.35-0.36 mm in B15d balut and 0.34-0.36 in B18d balut across the IP duck breeds.

Egg shape dimensions: Both short circumference (~width) and long circumference (~length) of balut were lowly correlated (p<0.01) with embryo weight and fluid weight, ranging from r= 0.13 to 0.24. The moderate correlations between yolk weight and short circumference (r= 0.40) and between yolk weight and long circumference (r= 0.50), however, may imply that stouter and longer balut eggs may contain more yolk. Both measures of short and long circumference were not significantly affected by the type of balut and "breed×balut type" interaction (p>0.05). The range of short circumference of balut from the IP-Itim, IP-Khaki and Kayumanggi-IP was 14.14-14.19 cm, 14.27–14.35 cm and 14.08-14.17 cm, respectively. The range of long circumference of balut from the IP-Itim, IP-Khaki and Kayumanggi-IP was 16.29-16.36 cm, 16.32–16.43 cm and 16.26-16.42 cm, respectively.

The long-short circumference ratio which measures the elongated shape of balut was lowly correlated (p<0.05) with yolk weight (r = 0.14) and not correlated with weight and proportion of embryo, albumen, fluid and shell (p>0.05).

Long-short circumference ratio of balut was not affected by balut type and "breed×balut type" interaction ($p>0.05$). The long-short circumference ratio ranged from 1.14-1.17 in B15d balut and 1.14-1.15 in B18d balut across the IP duck breeds.

Implications on the choice of breed for balut production: The choice of breed to be used in balut production will depend on breed differences in fertility rates of incubated duck eggs and ultimately on consumer preferences.

A high fertility rate in the breeding flock will be required to produce more balut consistently. This means that less by-products (infertile eggs and penoy) are produced in balut production. Depending on the farm capacity and a higher consumer demand for B15d balut, only a smaller portion of the same batch of incubated eggs may be retained in the incubator for 3 more days to produce B18d balut. In many cases, however, the incubation process for a batch of eggs involves a mixture of eggs that were collected within a 4-5 days period. Hence, the exact age of balut is not really known except when determined by candling before boiling them.

Local consumers often prefer balut with smaller embryos, higher percentage of yolk and lower albumen content. The albumen is less palatable because of its hard solid texture when boiled. In this regard, IP-Itim had the lowest weight and proportion of embryo (6.6 g and 10.60%) and highest weight and proportion of yolk (22.3 g and 35.31%) in B15d balut. Kayumanggi-IP breed had the lowest weight and proportion of albumen (13.7 g and 20.86%) in B15d balut and lowest weight and proportion of embryo (20.3 g and 32.86%) in B18d balut. The weight and proportion of albumen and yolk in B18 balut were not significantly different among the IP duck breeds.

CONCLUSION

The technical characteristics of B15d and B18d balut may be considered in the choice of breed to be used in balut production according to consumer preferences. The IP-Itim and IP-Khaki breeds should be preserved and improved in nucleus flocks. These breeds should be used in the commercial production of Kayumanggi-IP ducks by multiplier farms. Further studies on the nutritive values of balut components, however, will be needed to anticipate changes in consumer preferences for a healthy lifestyle.

SIGNIFICANCE STATEMENT

This study contributes to the limited information available on the technical characteristics of balut from mallard duck eggs. Such information can be used in the development of a Philippine national grading standard and pricing scheme for balut. This will benefit all stakeholders in the local balut industry-duck egg producers, breeders, researchers, dealers/vendors and consumers, from a better understanding of the characteristics of balut. They can use this information in local breeding programs that aim to conserve and improve adapted egg-type ducks.

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