FATTY ACID PROFILE AND NUTRITIONAL INDICES/RATIOS OF THE YOLK IN FRESH MALLARD DUCK EGGS, BALUT, AND PENOY

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ABSTRACT

The nutritional value of the yolk from mallard duck eggs that are commonly consumed in the Philippines as salted eggs, balut, or penoy is important as consumers and health professionals become increasingly interested in functional foods that can prevent or ameliorate cardiovascular disease. This study compared fatty acids (FA) and related nutritional indices/ratios of yolk fats in fresh duck eggs, 15-day old balut (B15d), 18-day old balut (B18d), 1-wk old penoy (D1), and 2-wk old penoy (D2) produced in a government duck farm at Tiaong, Quezon. The major FAs with the highest proportion in the yolk of fresh eggs, balut, and penoy were oleic acid C18:1n-9 (41.9–44.9%), palmitic acid C16:0 (23.3–25.1%), linoleic acid C18:2n-6 (6.6–7.2%), and stearic acid C18:0 (3.8–4.8%). The yolk fats from both fresh eggs and D2 penoy had the highest polyunsaturated to saturated FA ratio (0.28). D2 penoy had the highest monounsaturated to saturated FA ratio (1.68: 1), lowest fat percentage (21.0%), lowest atherogenicity (0.49), lowest thrombogenicity (0.94), and highest health-promoting index (2.03). B18d balut had the lowest omega-6 to omega-3 FA ratio (9.53) and highest hypocholesterolemic/hypercholesterolemic ratio (2.07: 1). Yolk fats from D2 penoy and B18d balut may have greater benefits to human cardiovascular health.

Keywords: Balut, fatty acids, mallard eggs, nutritional indices, penoy

INTRODUCTION

In 2021, the duck egg industry in the Philippines produced 50.45 thousand metric tons of eggs, worth 5.44 billion pesos (PSA, 2022). Duck eggs are produced mainly from the Philippine mallard duck and sold in the market as fresh eggs (usually salted eggs or "*itlog na pula*/ *itlog na maalat*"), balut – with fertilized embryo at 15 days of incubation (B15d balut or "*balut mamatong*") or 18 days of incubation (B18d balut or "*balut sa puti*"), and penoy – with a very small dead embryo detected after one week of incubation (D1 penoy) or after two weeks of incubation (D2 penoy).

Duck eggs have been a popular food source for Filipinos largely because of our preference for the yolk that is present in salted eggs, balut, and penoy. Other than a source

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of protein in the human diet, the yolk also contains fats that may have different nutritional qualities and effects on human health. Yolk fats may be characterized by their fatty acid (FA) composition including saturated fatty acids (SFA), monounsaturated fatty acids (MUFA), and omega-3 and omega-6 polyunsaturated fatty acids (PUFA). The FA profile of the yolk can be used in assessing its nutritional and/or medicinal values (Chen and Liu, 2020) and could lead to its development as a functional food or nutraceutical.

While the technical characteristics and composition of fresh duck eggs (Bondoc *et al*., 2020a and 2020b) and balut (Bondoc *et al*., 2022) have recently been reported, there is no information yet on the measurement of the nutritional quality of yolk from fresh duck eggs, balut, and penoy that may impact on human cardiovascular health and disease. Such information may be used to update the local "Food Composition Tables" and "Food Exchange Lists". In this regard, this study aimed to evaluate the FA profile and compare the nutritional indices/ratios of the yolk in fresh duck eggs, B15d and B18d balut, and D1 and D2 penoy in relation to cardiovascular health.

MATERIALS AND METHODS

Data

A total of 527 eggs were randomly collected from Itik-Pinas (IP) mallard ducks (i.e., IP-Itim, IP-Khaki, and Kayumanggi-IP) at the National Swine and Poultry Research and Development Center (NSPRDC), Bureau of Animal Industry – Department of Agriculture (BAI-DA) in Tiaong, Quezon were used in the comparison of the yolk from fresh eggs, balut, and penoy.

Fresh duck eggs (N=155) were individually recorded for their egg weight, yolk weight, and albumen weight within 24 hours after their collection. Four (4) yolk samples from newly laid eggs collected on the same day and belonging to the same family or line were pooled and placed in 200 ml plastic bottles and immediately frozen at –20°C until further analysis. At least 4 pooled samples comprised of 16 eggs per family or line were analyzed for fat content and fatty acid composition.

Another set of duck eggs was collected in several batches and placed in an artificial incubator to produce balut (N=329) and penoy (N=41). Incubated eggs in each batch were candled at day 7 and 14 to separate the infertile eggs from the fertilized eggs. Penoy refer to fertilized eggs in which the developing embryo dies in the first week (i.e., D1 penoy) or second week (i.e., D2 penoy) of incubation. Balut, on the other hand, refer to fertilized eggs which were grown in the artificial incubator for 15 days (i.e., B15d balut) or 18 days old (i.e., B18d balut). Balut and penoy were cooked separately by boiling for 30 min and 15 min, respectively, and cooled prior to dissection and weighing the edible components of balut (i.e., embryo, yolk, albumen, and fluid portion) and penoy (yolk and albumen). The yolk samples from about 2–8 eggs belonging to the same family or line which were collected and incubated on the same day (batch) for the same type of balut or penoy were pooled and placed in 250 ml plastic bottles and immediately frozen at –20°C until analyzed for fat content and FA composition by gas chromatography. The yolk percentage in fresh duck eggs, balut, and penoy was calculated as: (yolk weight × 100) / egg weight. The yolk-albumen ratio was computed as: yolk weight / albumen weight.

Individual FAs were analyzed as a percentage (g/100 g) of total fatty acids including eight SFAs [i.e., lauric acid (C12:0), myristic acid (C14:0), pentadecylic acid (C15:0),

palmitic acid (C16:0), margaric acid (C17:0), stearic acid (C18:0), arachidic acid (C20:0), and behenic acid (C22:0)], six MUFAs [i.e., myristoleic acid (C14:1n-5), palmitoleic acid (C16:1n-7), oleic acid (C18:1n-9), trans-vaccenic acid (C18:1n-7), eicosenoic acid (C20:1n-11), and erucic acid (C22:1n-9)], and five PUFAs [i.e., conjugated linoleic acid or CLA (C18:2 c9tll), linoleic acid or LA (C18:2n-6), α-linolenic acid or ALA (C18:3n-3), arachidonic acid or AA (C20:4n-6), and docosahexaenoic acid or DHA (C22:6n-3)].

Six FA groups (i.e., SFA, MUFA, PUFA, unsaturated fatty acids or UFA, omega-3 FAs or n-6, and omega-6 FAs or n-3) were calculated, wherein UFA = MUFA + PUFA; omega-3 FA = C18:3n-3 + C22:6n-3; and omega-6 FA = C18:2n-6 + C20:4n-6. In addition, eight FA-based nutritional indices/ratios with health implications [i.e., PUFA/SFA ratio, MUFA/SFA ratio, n-6/n-3 ratio, LA/ALA ratio, atherogenicity index or IA, thrombogenicity index or IT, health-promoting index or HPI, and hypocholesterolemic / hypercholesterolemic (h/H) ratio] were estimated. The IA and IT values according to Ulbricht and Southgate (1991) were calculated as IA = [C12:0 + (4 × C14:0) + C16:0] / ΣUFA, while IT = (C14:0 + C16:0 + C18:0) / [(0.5 × MUFA) + (0.5 × n-6 PUFA) + (3 × n-3) + (n-3 / n-6)]. Following Chen *et al*. (2004), the HPI = UFA / [C12:0 + (4 × C14:0) + C16:0]. The h/H ratio = (C18:1n-9 + PUFA) / (C12:0 + C14:0 + C16:0), as used by Mierlita (2018).

The IP ducks were managed equally and fed with duck layer mash containing 3.84% crude fat and total FAs consisting of 22.74% SFA – C12:0 (0.66%), C14:0 (1.22%), C16:0 (16.65%), C18:0 (2.13%), C20:0 (1.79%), C22:0 (0.29%); 27.03% MUFA – C16:1n-7 (0.17%), C18:1n-9 (26.86%); and 39.31% PUFA – C18:2n-6 (38.95%), and C18:3n-3 (0.36%).

Fat content and fatty acid (FA) analysis

The fat content in the yolk of fresh duck eggs was determined using the Mojonnier method (AOAC Official Method 925.32: Fats in Eggs). The fat percentage in the yolk of balut and penoy was determined using the Soxhlet method (AOAC Official Method 960.39: Extraction of crude fat). Percent protein in the yolk was also determined using the Kjeldahl method (AOAC Official Method 932.08 Nitrogen (Water-Soluble and Crude Albumin) in Liquid Eggs).

The Folch *et al.* (1957) method was used in extracting yolk fat from fresh duck eggs, balut, and penoy. The fatty acid methyl esters (FAMEs) were prepared following the rapid methanolysis/methylation procedure of Ichihara and Fukubayashi (2010). The FAs were determined using a Shimadzu GC 2010 Plus - Capillary Gas Chromatograph System) that is equipped with Flame Ionization Detector (FID) and AOC-20i autosampler (Shimadzu Corporation, Kyoto, Japan. The FAs were separated and quantified based on the comparison of the retention times of individual FAMEs and the FAME standard mix purchased from Sigma Aldrich (i.e., Grain FAME Mix, arachidonic acid, docosahexaenoic acid, trans-vaccenic acid, and conjugated linoleic acid).

Statistical analysis

Differences in egg weight, yolk weight and percentage, albumen weight and percentage, and yolk composition among the yolk in fresh duck egg and B15d and B18d balut were initially determined using ANOVA (SAS Ver. 9.2, 2009). Since the production of penoy is limited in each batch of incubated eggs, the simple unadjusted mean and standard deviation were calculated for yolk characteristics and FA composition in D1 and D2 penoy.

Each FA in the yolk of fresh duck eggs or balut was analyzed using the general least squares procedures for unbalanced data. Statistical significance was set at P value <0.05. The mathematical models used separately for fresh eggs and balut were as follows: (1) for fresh eggs, $y_{ijkl} = \mu + Age_i + YolkWt_j + PFat_k + e_{ijkl}$, and (2) for balut, $y_{ijklm} = \mu + BType_i + Age_j + EggWt_k + YolkWt_l + e_{ijklm}$, where y_{ijklm} is the proportion of FA (g/100 g of total identified fatty acids), μ is overall mean, $BType_i$ is effect of the i^{th} type of balut (B15d and B18d), Age_j is the j^{th} covariate effect of hen's age at lay (years), $EggWt_k$ is the k^{th} covariate effect of egg weight (g), $YolkWt_l$ is the l^{th} covariate effect of yolk weight (g), and e_{ijklm} is the error term.

The least-square mean for each FA in the yolk of fresh duck eggs and balut and the unadjusted mean for each FA in the yolk of penoy were used to estimate the nutritional indices/ratios.

RESULTS AND DISCUSSION

The yolk weight was highest in D1 penoy (35.2 g), followed by D2 penoy (33.7 g), fresh eggs (22.4 g), B15d balut (21.7 g), and lowest in B18d balut (19.7 g), see Table 1. Percent yolk, however, was highest in D1 penoy (55.3%) and D2 penoy (55.4%) – which were significantly higher than B15d balut (34.3%), B18d balut (31.7%), and fresh eggs (30.59%). The yolk in balut is rich in lipids, fats, and energy that is used for tissue growth during embryonic development (Speake *et al*., 1998). The decrease in yolk size is due to the release of water into the allantois (Li *et al.,* 2019). On the other hand, percent albumen was highest in fresh eggs (45.8%), which was significantly higher than D1 penoy (30.9%), D2 penoy (29.1%), B15d balut (21.8%), and B18d balut (10.2%). Albumen in balut consists of 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 major source of water and proteins required for tissue synthesis in the developing embryo (Willems *et al*., 2014). The reduction in the volume of albumen is due to the continuous removal of water as the albumen is rapidly dehydrated when water flows into the yolk to form sub-embryonic fluid (Freeman and Vince, 2011). In this regard, the yolk-albumen ratio was highest in B18d balut (1: 3.05), followed by D1 penoy (1: 1.96), D2 penoy (1: 1.94), B15d balut (1: 1.56), and lowest in fresh egg (1: 0.66).

The differences in yolk-albumen ratio and consequently the fat content and FA composition of yolk in fresh duck eggs, balut, and penoy may be attributed to the presence or absence of the developing embryo at different stages of incubation. Without an embryo, the yolk in fresh duck egg had the lowest yolk-albumen ratio (1: 0.66). In B15d and B18d balut, there is a proportionate loss in yolk and albumen weight (and an increase in embryo weight) as the growing embryo absorbs the yolk and albumen. Since the loss in yolk weight was lower than the loss in albumen weight, the yolk-albumen ratio was much lower in B15d balut (1: 1.56) than in B18d balut (1: 3.05). The yolk-albumen ratio was similar in D1 (1: 1.96) and D2 penoy (1: 1.94). Penoy produced from 1–2 week old incubated duck eggs contains a very small dead embryo. Penoy had a higher yolk weight, albumen weight, and yolk-albumen ratio compared to B15d balut which was incubated for 15 days.

Table 2 shows that the yolk in fresh mallard eggs, balut, and penoy is composed mainly of moisture (49.5–55.8%), followed by fat (29.0–31.5%) and protein (14.2–15.8%). Moisture content in the yolk of D1 penoy (65.2%), D2 penoy (65.8%), B15d balut (55.8%), and B18d balut (53.2%), were higher than that in fresh eggs (49.5%). Fat content was

Table 1. Number of eggs and the weight of egg components used in the evaluation of fresh mallard duck eggs, balut, and penoy.

	Fresh eggs	B15d balut	B18d balut	D1 Penoy	D2 Penoy
No. of eggs	155	154	175	28	13
Egg weight, g	73.15 ± 0.93^{a}	63.78 ± 0.27^{b}	62.40 ± 0.25^{c}	63.05 ± 1.32^{b}	63.00 ± 1.88^{b}
Yolk weight, g	22.40 ± 0.61^{b}	21.74 ± 0.30^{b}	19.66 ± 0.28^{c}	35.23 ± 1.64^{a}	33.67 ± 2.72^{a}
Albumen weight, g	33.53 ± 0.97^{a}	13.90 ± 0.30^{c}	6.45 ± 0.28^{d}	17.91 ± 1.46^{b}	17.38 ± 2.42^{b}
Embryo weight, g	N/A	8.21 ± 0.30^{b}	21.40 ± 0.28^{c}	N/A	N/A
% Yolk	30.59 ± 0.23^{d}	34.27 ± 0.34^{b}	31.74 ± 0.32^{c}	55.31 ± 2.63^{a}	53.36 ± 3.76^{a}
% Albumen	45.79 ± 0.36^{a}	21.84 ± 0.35^{c}	10.23 ± 0.32^{d}	30.86 ± 8.35^{b}	29.06 ± 12.77^{b}
Yolk-Albumen ratio	1: 0.66	1: 1.56	1: 3.05	1: 1.96	1: 1.94

Note: N/A - Not applicable.
Least-squares means with different superscript letters within a row are significantly different ($P<0.05$).

Table 2. Yolk composition and proportion of fatty acid (g/100 g of total identified fatty acids) in fresh mallard duck eggs, balut, and penoy.

	Fresh eggs	B15d balut	B18d balut	D1 Penoy	D2 Penoy
% Moisture	49.46 ± 0.13^{c}	55.85 ± 3.35^{b}	53.24 ± 1.96^{b}	65.22 ± 6.68^{a}	65.76 ± 5.42^{a}
Protein content, %	15.81 ± 0.04^{a}	11.69 ± 1.05^{c}	14.17 ± 1.25^{b}	10.11 ± 1.72^{bc}	10.57 ± 2.22^{bc}
Fat content, %	31.49 ± 0.13^{a}	29.08 ± 1.95^{b}	28.97 ± 1.65^{b}	21.86 ± 4.48^{c}	20.96 ± 3.16^{c}
Saturated FAs					
C12:0	0.17 ± 0.00^{a}	0.11 ± 0.01^{b}	0.12 ± 0.00^{b}	0.16 ± 0.01^{a}	0.17 ± 0.02^{a}

Table 2. Continuation....

	Fresh eggs	B15d balut	B18d balut	D1 Penoy	D2 Penoy
Saturated FAs					
C14:0	1.07 ± 0.03^{a}	0.81 ± 0.03^{b}	0.84 ± 0.03^{b}	1.01 ± 0.06^{a}	1.04 ± 0.10^{a}
C15:0	0.03 ± 0.00	0.03 ± 0.00	0.03 ± 0.00	0.03 ± 0.00	0.05 ± 0.01
C16:0	23.27± 0.22^{b}	24.34 ± 0.55^{ab}	24.60 ± 0.48^{ab}	25.14 ± 0.49^{a}	23.71 ± 0.79^{b}
C17:0	0.09 ± 0.01^{b}	0.08 ± 0.01^{b}	0.08 ± 0.00^{b}	0.16 ± 0.01^{a}	0.12 ± 0.02^{b}
C18:0	4.25 ± 0.11^{b}	4.84 ± 0.20^{a}	4.24 ± 0.18^{b}	4.24 ± 0.19^{b}	3.75 ± 0.30^{b}
C20:0	0.19 ± 0.00	0.17 ± 0.02	0.18 ± 0.01	0.18 ± 0.01	0.18 ± 0.01
C22:0	0.07 ± 0.01^{a}	0.04 ± 0.00^{b}	0.02 ± 0.00^{c}	0.03 ± 0.00^{bc}	0.02 ± 0.00^{c}
Monounsaturated FAs					
C14:1n-5	0.11 ± 0.01^{b}	0.08 ± 0.00^{c}	0.08 ± 0.00^{c}	0.10 ± 0.01^{bc}	0.15 ± 0.02^{a}
C16:1n-7	2.91 ± 0.08^{a}	2.47 ± 0.06^{b}	1.18 ± 0.06^{c}	2.75 ± 0.14^{a}	3.03 ± 0.23^{a}
C18:1n-9	41.93 ±0.33^{b}	42.70 ± 0.94^{b}	44.94 ± 0.81^{a}	44.66 ± 0.75^{a}	41.52 ± 1.20^{b}
C18:1n-7	0.38 ± 0.04^{b}	ND	ND	2.88 ± 1.06^{a}	4.11 ± 1.70^{a}
C20:1n-11	0.09 ± 0.01^{a}	0.04 ± 0.01^{b}	0.02 ± 0.01^{b}	0.02 ± 0.00^{b}	0.03 ± 0.00^{b}
C22:1n-9	0.07 ± 0.01^{b}	0.03 ± 0.01^{c}	0.01 ± 0.01^{c}	0.27 ± 0.03^{a}	0.05 ± 0.00^{b}
Polyunsaturated FAs					
C18:2c9t11, CLA	0.23 ± 0.01	ND	ND	ND	ND
C18:2n-6, LA	6.92 ± 0.36^{ab}	6.63 ± 0.14^{b}	7.16 ± 0.13^{a}	6.82 ± 0.15^{ab}	7.24 ± 0.24^{a}
C18:3n-3, ALA	0.36 ± 0.01^{b}	0.36 ± 0.01^{b}	0.38 ± 0.00^{a}	0.35 ± 0.01^{b}	0.35 ± 0.02^{b}
C20:4n-6, AA	0.46 ± 0.05^{a}	ND	ND	0.27 ± 0.03^{b}	0.18 ± 0.02^{c}
C22:6n-3, DHA	0.32 ± 0.03^{b}	0.32 ± 0.01^{b}	0.38 ± 0.01^{a}	0.32 ± 0.01^{b}	0.36 ± 0.04^{ab}

Note: ND - Not detected.
Least-squares means with different superscript letters within a row are significantly different (P<0.05).

highest in fresh eggs (31.5%), followed by B15d balut (29.1%) and B18d balut (29.0%), and lowest in D1 penoy (21.9%), D2 penoy (21.0%). Protein content was also highest in the yolk of fresh eggs (15.8%), followed by B18d balut (14.2%), B15d balut (11.7%), D1 penoy (10.1%), and D2 penoy (10.6%).

Major FAs in the yolk from fresh mallard eggs, balut, and penoy

The major FAs with the highest proportion in the yolk of fresh mallard eggs, balut, and penoy were oleic acid C18:1n-9 (41.9–44.9%), palmitic acid C16:0 (23.3–24.6%), linoleic acid C18:2n-6 (6.6–7.2%), and stearic acid C18:0 (4.2–4.8%), see Table 2. In particular, the egg yolk from B18d balut had the highest oleic acid (44.9%); D1 penoy had the highest palmitic acid (25.1%); D2 penoy had the highest linoleic acid (7.2%); and B15d balut had the highest stearic acid (4.8%).

Fatty acid - based nutritional indices/ratios for the yolk from fresh eggs, balut, and penoy

The differences in nutritional indices/ratios of the yolk from fresh mallard eggs, balut, and penoy are presented in Table 3.

PUFA/SFA ratio. The PUFA/SFA ratio measures all PUFAs that are known to reduce low-density lipoprotein cholesterol and depress the levels of serum cholesterol, in relation to all SFAs that may add to high levels of serum cholesterol (Chen and Liu, 2020). A higher PUFA/SFA ratio implies a favorable effect in protecting the cardiovascular system from the detrimental effects of atherosclerotic lesions (Naeini *et al.,* 2020). The PUFA/SFA ratio in dietary fats from meat and milk ranged from 0.11–1.29 and 0.06–0.18, respectively (Chen and Liu, 2020). By contrast, the current study showed that the PUFA/SFA ratio for yolk from fresh mallard eggs, B15d and B18d balut, D1 and D2 penoy was 0.28, 0.24, 0.26, 0.25, and 0.28, respectively, which was comparable to that of meat but higher (more beneficial to human health) than that of milk.

MUFA/SFA ratio. The MUFAs, especially oleic acid, are known to increase the activity of low-density lipoprotein receptors (LDLRs) and decrease the cholesterol concentration in serum (Dietschy, 1998). A higher MUFA/SFA ratio can thus have beneficial effects on human health. In this study, the MUFA/SFA ratio value for yolk from fresh mallard eggs, B15d and B18d balut, D1 and D1 penoy was 1.56, 1.49, 1.54, 1.64, and 1.68, respectively.

LA/ALA ratio. The linoleic acid to α-linolenic acid (LA/ALA) ratio describes the balance between LA and ALA, both of which cannot be synthesized by humans. It was developed as a guide to improve the nutritional value of baby food or infant formula (milk), with a minimum reference value usually set within 5–15: 1 (Chen and Liu, 2020). A higher LA/ALA ratio implies faster rates of synthesis of ALA. The LA/ALA ratio in cow's milk fat ranged from 2.46–3.45 (Chen and Liu, 2020). By comparison, this study showed a substantially higher PUFA/SFA ratio for yolk from fresh mallard eggs, B15d balut, B18d balut, D1 penoy, and D1 penoy at 19.02, 18.39, 19.03, 19.47, and 20.93, respectively.

n-6/n-3 ratio. The omega-6 FAs to omega-3 FAs (n-6/n-3) ratio is a measure of the dietary contribution of omega-6 FAs (i.e., LA and AA) that are generally pro-inflammatory, in relation to omega-3 FAs (i.e., ALA and DHA) that are anti-inflammatory. The increased dietary intake of n-6 PUFA and decreased dietary intake of n-3 PUFA changes the production of important mediators and regulators of inflammation and immune responses towards a

Table 3. Fatty acid groups and FA-based nutritional indices/ratios for the yolk in fresh mallard duck eggs, balut, and penoy.

	Fresh eggs	B15d balut	B18d balut	D1 Penoy	D2 Penoy
FA groups					
SFA	29.20	30.41	30.11	30.95	29.03
UFA	53.78	52.63	54.15	58.44	57.00
MUFA	45.49	45.33	46.24	50.69	48.88
PUFA	8.30	7.30	7.91	7.76	8.12
n-3 (ALA + DHA)	0.68	0.68	0.75	0.67	0.70
n-6 (LA + AA)	7.39	6.63	7.16	7.09	7.42
FA-based nutritional indices/ratios					
PUFA/SFA ratio	0.28	0.24	0.26	0.25	0.28
MUFA/SFA ratio	1.56	1.49	1.54	1.64	1.68
LA/ALA ratio	19.02	18.39	19.03	19.47	20.93
n-6/n-3 ratio	10.80	9.81	9.53	10.66	10.57
Atherogenicity index	0.52	0.53	0.52	0.50	0.49
Thrombogenicity index	1.00	1.07	1.02	0.98	0.94
Health-promoting index	1.94	1.90	1.93	1.99	2.03
h/H ratio	2.05	1.98	2.07	1.99	1.99

Abbreviations: [SFA] saturated fatty acids; [UFA] unsaturated fatty acids; [MUFA] monounsaturated fatty acids; [PUFA] polyunsaturated fatty acids; [LA] linoleic acid (C18:2n-6); [ALA] α-linolenic acid (C18:3n-3); [AA] arachidonic acid (C20:4n-6); [DHA] docosahexaenoic acid (C22:6n-3); [n-3] omega-3 fatty acids; [n-6] omega-6 fatty acids, [h/H ratio] hypocholesterolemic/ hypercholesterolemic ratio

proinflammatory profile associated with chronic inflammatory diseases (Patterson *et al.,* 2012). Hence, a lower n-6/n-3 ratio (1–2: 1) indicates a favorable effect to alleviate the effects of inflammatory diseases and reduce the risk of many chronic diseases such as nonalcoholic fatty liver disease, cardiovascular disease, obesity, inflammatory bowel disease, rheumatoid arthritis, and Alzheimer's disease. In this study, the n-6/n-3 ratio was lowest for B18d balut (9.63: 1), followed by B15d balut (9.81: 1), D2 penoy (10.57: 1), D1 penoy (10.66: 1), and highest for fresh eggs (10.80: 1).

Atherogenicity index. The index of atherogenicity (IA) measures the dietary contribution of some SFAs that are pro-atherogenic (i.e., lauric acid, myristic acid, and palmitic acid, except stearic acid), in relation to total MUFA and PUFA that are anti-atherogenic (Ulbricht and Southgate, 1991). The adhesion of lipids to cells of the circulatory and immunological systems is favored by the pro-atherogenic FAs, while the accumulation of fatty plaque and higher levels of phospholipids, cholesterol, and esterified FAs is inhibited by the anti-atherogenic FAs. Hence, a lower IA suggests lower tendency to build fatty plaques in the arteries (Chen and Liu, 2020). While the IA values in dietary fats from meat and milk ranged from 0.27–1.32 and 1.42–5.13, respectively (Chen and Liu, 2020), this study shows comparable IA values for the yolk from fresh mallard eggs, B15d balut, B18d balut, D1 penoy, and D1 penoy at 1.00, 1.07, 1.02, 0.98, and 0.94, respectively.

Thrombogenicity index. The index of thrombogenicity (IT) measures the dietary contribution of prothrombogenic SFAs (i.e., lauric acid, myristic acid, and palmitic acid) in relation to total MUFA and PUFA that are anti-thrombogenic (Ulbricht and Southgate, 1991). A lower IT value indicates lower tendency to produce clots in blood vessels. The IT values in dietary fats from meat and milk ranged from 0.29–1.69 and 1.00–5.04, respectively (Chen and Liu, 2020). By comparison, this study reveals a generally lower IT value for yolk from fresh mallard eggs, B15d balut, B18d balut, D1 penoy, and D1 penoy at 0.52, 0.53, 0.52, 0.50, and 0.49, respectively.

Health-promoting index. The health-promoting index (HPI) is the inverse of the atherogenicity index (Chen *et al*., 2004), with a higher HPI value suggesting more benefits for human health. While the HPI values ranged from 0.16–0.68 in dairy products such as milk and cheese (Chen and Liu, 2020), this study reveals a higher HPI value for the yolk in fresh mallard eggs, B15d balut, B18d balut, D1 penoy, and D1 penoy at 1.94, 1.90, 1.93, 1.99, and 2.03, respectively.

h/H ratio. The hypocholesterolemic/hypercholesterolemic (h/H) ratio shows the correlation between hypocholesterolemic FAs (i.e., oleic acid and PUFAs) and hypercholesterolemic FAs (lauric acid, myristic acid, and palmitic acid). A higher h/H value suggests lower levels of cholesterol that may contribute to a decrease in the incidence of cardiovascular disease (Mierlita, 2018). The h/H ratio in dietary fats from meat and dairy products ranged from 1.27–2.79 and 0.32–1.29, respectively (Chen and Liu 2020). In contrast, this study reports a higher h/H ratio (i.e., more beneficial) for yolk in fresh mallard eggs, B15d balut, B18d balut, D1 penoy, and D1 penoy at 2.05, 1.98, 2.07, 1.99, and 1.99, respectively.

CONCLUSION

The yolk from fresh mallard eggs had the lowest moisture content and highest protein and fat content compared to that of balut and penoy. However, the yolk from D2

penoy had the highest FA-based nutritional value (i.e., lowest fat percentage, atherogenicity, and thrombogenicity; and higher HPI). The yolk fats from B18d balut appear to be more beneficial for human cardiovascular health (i.e., lowest n-6/n-3 ratio and highest h/H ratio). Overall, the yolk from fresh mallard eggs, balut, and penoy may be considered healthy food for Filipinos produced by the local duck egg industry.

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