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The metric and color profiling of eggs produced by F_2 Mahkota Arab chickens

Angga Bintang Narzassi[1], Budi Setiadi Daryono[1*]
[1]Laboratory of Genetics and Breeding, Faculty of Biology, Universitas Gadjah Mada
Jl. Teknika Selatan, Sekip Utara, Sleman, D.I.Yogyakarta, Indonesia. 55281
*Email: bs_daryono@mail.ugm.ac.id

ABSTRACT. Genetic quality improvement in local chickens can be achieved through crossbreeding, which has enhanced productivity and egg quality, satisfying consumer demand. To improve the quality of livestock products, it is crucial to assess the egg quality of chickens. This study evaluated the quality of eggs produced by F_2 Mahkota Arab chickens bred from crossbreeding with F_1 Mahkota Arab chickens. The research comprised several stages: chicken rearing, tests for egg shape index calculation, yolk index, albumin index, Haugh unit, and eggshell colour observation. The obtained results were compared with those of F_1 Mahkota Arab chicken, Arab chicken, and Layer chicken. According to the study's findings, the F_2 Mahkota Arab had an egg with a standard egg shape of 70% as per the egg shape index. The F_2 Mahkota Arab chicken had a mean yolk index of 0.37±0.00, a mean albumin index of 0.121±0.005, and a mean Haugh unit of 91.99±1.13. The shell colour of their eggs belongs to the orange-white group, and the egg quality, including egg shape index, albumin index and Haugh unit, is higher than other chicken groups. Furthermore, the shell colour of F_2 Mahkota Arab chicken eggs is whiter than other chicken groups.

Keywords: albumin index; egg shape index; F_2 Mahkota Arab chicken; shell color; yolk index

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INTRODUCTION

Chicken eggs constitute a nutritionally dense and economically viable food compared to other ingredients with a high-quality protein content and a comprehensive amino acid profile (Donadelli *et al*., 2019; Ramadhani *et al*., 2019; Pal & Molnár, 2021). The demand for egg consumption in Indonesia has been growing, as evidenced by the rise in per capita egg production. In 2015, purebred and local chickens' average per capita egg consumption reached 97968 and 3754, respectively. Egg consumption grew continuously until 2018, reaching 108399 eggs for purebred chickens and 3806 for local chickens (KEMENTAN, 2020).

Generally, chicken eggs are classified into purebred chicken eggs and local (Kampong) chicken eggs (BPS, 2016). However, consumers still place a higher value on local chicken eggs than on purebred ones. A growing consumer preference for local chicken eggs in Indonesia is evident, driven by perceived health benefits including reduced cholesterol, increased protein content, purported wound healing properties, and perceived lower allergenicity compared to purebred chicken eggs (Marlya *et al*., 2018; Ramadhani *et al*., 2019; Hastuti *et al*., 2022). Furthermore, the development of local chickens to meet the demand for animal feed is suboptimal due to low egg productivity. To address this issue, it is imperative to enhance the genetic quality of local chickens via selection and crossbreeding (Lapihu *et al*., 2019). Crossbreeding aims to increase productivity and better egg quality than the parents to meet consumer demand (Soliman *et al*., 2020; Sungkhapreecha *et al*., 2022; Wang *et al*., 2022).

The Gama Ayam Team is a leading research team that breeds local Indonesian chickens. In 2011, a successful crossbreeding of a Layer hen and a Pelung rooster resulted in the development of the Kamper chicken, a breed capable of producing an average of 140.37 eggs within a 49-week period (Mahardhika *et al*., 2020). Nonetheless, the eggs remain similar in characteristics to those laid by Layer chickens (Ernanto & Daryono, 2017). The Gama Ayam team bred a Crown Hybrid (Hibrida Mahkota) chicken by crossing a BC_3 Golden Kamper with a Crown chicken. Crown Hybrid (Hibrida Mahkota) chicken has a crest and frizzled feathers and exhibits egg productivity and characteristics similar to that of local (Kampong) chicken. However, its development is suboptimal (Riswanta &

Daryono, 2021; Hidayat & Daryono, 2022). To improve its egg productivity and quality, the team innovatively crossbred it with Arab chickens. Arab chickens are a source of locally superior laying eggs due to their high egg productivity and characteristics, similar to those of local chickens (Hartawan & Dharmayanti, 2016; Tamzil & Indarsih, 2022). The cross between the crown hybrid chicken and the Arab chicken was named the Mahkota Arab chicken.

Evaluation of chicken egg quality is imperative for advancing livestock production standards (Ahammed *et al*., 2014; Preisinger, 2018). As a key determinant of commercial value, egg quality, encompassing both internal such as yolk and albumin indices, yolk color, and Haugh units, and external attributes such as shell colour, shape index, thickness, and weight, warrants comprehensive investigation (Duman *et al*., 2016; Qurniawan *et al*., 2022; Damte *et al*., 2024). Market value is significantly impacted by egg condition, with damaged eggs commanding lower prices compared to those of superior quality (Eke *et al*., 2013; Zaheer, 2015; Dikmen *et al*., 2016; Tobaol *et al*., 2018). This study aimed to evaluate the egg quality in terms of egg shape index, yolk index, albumen index and shell colour between F_2 Mahkota Arab and their F_1 Mahkota Arab, Arab, and layers. The results of this study are expected to disseminate knowledge regarding the potential of chicken crossbreeding to augment egg quality, and to serve as a foundation for future research aimed at identifying superior chicken crossbreeds capable of further enhancing egg quality parameters.

MATERIALS AND METHODS

The study was conducted at Inovation and Agrotechnology Centre, Universitas Gadjah Mada (UGM) in Berbah, D.I.Yogyakarta. Egg incubation took place at HTN egg hatching Yogyakarta. The F_2 Mahkota Arab chickens used in this study were produced by inbreeding ♀F_1 Mahkota Arab and ♂F_1 Mahkota Arab chickens. The F_1 Mahkota Arab chicken is a hybrid of a Crown Hybrid chicken and Arab Silver chicken. All the procedures have been conducted according to the guidelines the Institutional Ethics Committee laid down.

F_1 Mahkota Arab breeding individuals were housed in semi-intensive cages (2 × 2 × 3 m) and comprised one male and one female, each aged one year. Day-old chicks (DOC) were F_2 Mahkota Arab hatchlings reared in intensive cages (1 × 1 × 0.5 m) with an incandescent lamp as a heat source. DOC F_2 Mahkota Arab were fed BR-1 (PT. Japfa Comfeed, Indonesia) for four weeks. The vitamin supplement Vitachick® was continued until the DOC was seven weeks old. After seven weeks, they were transferred to a semi-intensive rearing cage and given AD-II standard feed from PT. Japfa Comfeed, Indonesia. Adult chickens, aged between 5-6 months, were provided with mixed feed containing KLK Concentrate (PT. Japfa Comfeed, Indonesia) with a composition of 2 parts corn to 2 parts bran to 1 part Egg Stimulant® and addition of Mineral B-12, ad libitum. Comparable data was collected from F_1 Mahkota Arab chickens, Arab chickens, and Layer chickens. All fed the same mixed feed.

Egg shape index. The egg's shape index was determined by obtaining the length (L) and width (W) measurements using a vernier calliper (Trickle Brand). The results of the calculation of the egg's shape index will determine whether it has a standard egg shape (SI=72-76), a round shape (SI>76), or a sharp shape (SI<72). The formula for calculating the egg's shape index is as follows (Narushin & Romanov, 2002):

$$\mathrm{EI} = \left(\frac{\mathrm{W}}{\mathrm{L}}\right) \times 100$$

Egg yolk index. The Egg yolk index was measured by breaking the egg and pouring the contents into a petri dish. The yolk's height and diameter were then measured using a Tricle Brand vernier calliper. Ten eggs were used for each chicken group. The Yolk Index was calculated using the formula (Sharp & Powell, 1930):

$$\text{Egg Yolk Index} = \frac{\text{Yolk height (mm)}}{\text{Yolk diameter (mm)}}$$

Albumin index. Break an egg onto a flat surface, such as a petri dish, to measure the albumin index. Next, use the vernier calliper (Trickle Brand) to measure the diameter and height of the viscous egg white. Ten eggs were used for each chicken group. The formula is then used to calculate the albumin index (Wilhelm & Heiman, 1936; Haugh, 1937).

$$\text{Albumin index} = \frac{\text{Albumin height (mm)}}{\text{Diameter of albumin (mm)}}$$

Haugh units. The Haugh unit measurement process entails weighing the eggs with digital analytics (KrisChef EK9350H) and recording the weight. The egg is then broken on a flat surface, such as a petri dish, and the height is measured at three different points. The resulting average determines the Haugh unit value (Haugh, 1937).

$$\text{HU} = \log 100(\text{H} + 7{,}57 - 1{,}7\,\text{E}^{0{,}37})$$

Note:
H= Egg white height (mm)
E = Egg weight (grams)

Eggshell color. Eggshell color was observed using the Royal Horticultural Society (RHS) color chart.

Data analysis. The data were analyzed using ANOVA and Tukey significant differences in the SPSS ver. 23, and the results were statistically significant.

RESULTS AND DISCUSSION

Egg shape index. Table 1 reveals that layer hens exhibit the roundest shape with 22 eggs, F_2 Mahkota Arab hens have the most normal shape with 21 eggs, while Arab hens have the sharpest shape with three eggs. In addition, F_2 Mahkota Arab hens have 70% normal-shaped eggs, followed by Arab hens with 63.33%, F_1 Mahkota Arab with 26.66% and Layer hens with 26.66%. The study revealed that F_2 Mahkota Arab chickens' eggs were predominantly oval-shaped, conforming to the standard egg shape.

Table 1. Statistical description of the egg shape index (ESI)

Chicken type	Egg shape index (ESI)							
	N*	R	N	S	Min*	Max*	Mean*	SEM*
F_1 Mahkota Arab	30	21	8	1	71.43	86.57	78.47	0.65
F_2 Mahkota Arab	30	9	21	0	72.08	96.69	76.64	0.99
Layer	30	22	8	0	73.68	81.63	77.25	0.38
Arab	30	8	19	3	65.09	80.49	74.74	0.584

Notes: Number of eggs (*N), Round (R), Normal (N), Sharp (S), Min* (Lowest shape index value), Max* (Highest shape index value), Mean (Average shape index value), SEM (Standard error of the average shape index)

The egg shape index, calculated by dividing an egg's width by its length, is a crucial factor in assessing egg quality (Alkan & Türker, 2021). This index allows for the identification of the ideal egg shape (Dirgahayu *et al*., 2016). Duman *et al*. (2016) have classified eggs into three shapes: round (EI > 76), sharp (EI < 72), and standard (EI = 72-76). In addition, eggs are graded into three categories based on their quality: AA (perfect/standard), A/B (nearly perfect/sharp), and AB (round) (Duman *et al*., 2016; Ikegwu *et al*., 2016). The shape of chicken eggs can be biconical (oval), spherical (almost round), or oval (ideal shape). In addition, eggs are categorized into three grades based on their quality: Eggs with an oval shape are considered suitable due to their durability during transportation and storage in egg trays (Alkan & Türker, 2021). Genetics has a marked influence on egg shape, and no correlation exists between egg shape and the rearing system temperature (Mahardhika *et al*., 2022).

Yolk index. The yolk index means of F_1 Mahkota Arab chicken, F_2 Mahkota Arab chicken, Arab chicken and Layer chicken were 0.37±0.007, 0.37±0.006, 0.29±0.016, and 0.42±0.012, respectively. The mean yolk index of F_2 Mahkota Arab chicken (0.37±0.006) is the same as that of F_1 Mahkota Arab chicken but 0.08 higher than the egg yolk index of the Arab chicken (0.29±0.016). In addition,

F_2 Mahkota Arab chicken's average egg yolk index (0.37±0.006) was 0.05 lower than Layer chicken's egg yolk index. Several chicken groups identified Significant differences in the mean egg yolk index. The average egg yolk index of F_1 and F_2 Mahkota Arab chickens showed a significant difference from Arab and Layer chickens as follows in Table 2.

Table 2. Quality of F_1 Mahkota Arab chicken eggs, F_2 Mahkota Arab chicken eggs, Arab chicken eggs, and Layer chicken eggs

Chicken Type	Parameters		
	Yolk index	Albumin index	Haugh unit
F_1 Mahkota Arab	$0.37±0.007^{b}$	$0.087±0.006^{b}$	$83.05±2.58^{ab}$
F_2 Mahkota Arab	$0.37± 0.006^{b}$	$0.121±0.005^{a}$	$91.99±1.13^{a}$
Arab	$0.29±0.016^{a}$	$0.047±0.005^{c}$	$60.25±3.75^{c}$
Layer	$0.42±0.012^{c}$	$0.078±0.004^{b}$	$77.31±1.41^{b}$

Notes: Different superscript letter notations a,b,c,d between chicken breeds indicate significant differences (P<0.05)

The yolk index, calculated as the ratio of yolk height to diameter, serves as a reliable indicator of egg freshness, with a decreasing value correlating to egg age due to yolk expansion resulting from water loss (Popoola *et al*., 2015; Stępińska *et al*., 2017; Wang *et al*., 2021; Fu *et al*., 2023). Egg age significantly influences the vitelline membrane's structural integrity, leading to yolk weakening and diameter expansion due to the osmotic gradient between the yolk and albumen, facilitating water translocation from the albumen into the yolk (Nasri *et al*., 2020; Zhou *et al*., 2020). A direct correlation exists between yolk height and yolk index, with increased yolk size resulting in a higher yolk index value (Duman *et al*., 2016; Aryee *et al*., 2020). SNI 3926:2008 defines the egg yolk index into three quality ranges: quality I (0.458-0.521), quality II (0.394-0.457), and quality III (0.330-0.393) (BSN, 2008). Furthermore, DSM (2022) categorizes egg quality according to the yolk index value into three distinct groups: regular egg (>28), fresh egg (0.29-0.38), and extra fresh egg (>0.38). The egg yolk index of the F_1 and F_2 Mahkota Arab chickens was measured at 0.37 ± 0.007 and 0.37 ± 0.006, respectively. This places their egg yolk index in category III (fresh egg) on the quality scale. The egg yolk index for layer chickens with a mean of 0.42 ± 0.012 is categorized as quality II (extra fresh egg). Arab chickens are not classified in quality I, II, or III.

Albumin index. The albumin index means for F_1 Mahkota Arab, F_2 Mahkota Arab, Arab, and Layer chickens were 0.087±0.006, 0.121±0.005, 0.047±0.005, and 0.078±0.004, respectively. The mean egg white index of F_2 Mahkota Arab chickens (0.121±0.005) was 0.034 higher than F_1 Mahkota Arab chickens (0.087±0.006), 0.047 higher than Arab chickens (0.047±0.005), and 0.043 higher than Layer chickens' (0.078±0.004) value. The average egg white index indicates a considerable difference between the groups. The albumin index of F_2 Mahkota Arab chickens did not significantly differ from that of Layer chickens, but it was substantially different from that of F_1 Mahkota Arab and Arab chickens.

Table 1 displays the albumin index values, which indicate that the average albumin index value was the highest for F_2 Mahkota Arab chickens at 0.121±0.005. The albumin index's average value falls under quality category II, which is 0.092-0.133 according to the standards set by SNI 3926: 2008 (BSN, 2008). This suggests that the eggs from F_2 Mahkota Arab chickens are of good quality and comparatively fresh compared to other chicken groups. The F_2 Mahkota Arab chickens' high albumin index is attributable to the thickness of the egg white. Ovomucin, a glycoprotein, forms a gel-like structure within the egg white by binding to the liquid components (Offengenden & Wu, 2013; Dong & Zhang, 2021). The albumin index, a ratio of albumen height to thick diameter, serves as an indicator of egg freshness, with higher values correlating to superior quality (Padhi *et al*., 2013; Quan *et al*., 2021). Factors including temperature, storage duration, carbon dioxide loss, and pH elevation negatively impact this index (Khan *et al*., 2013; Abioja *et al*., 2021). Prolonged storage degrades ovomucin, thins the albumen, and facilitates carbon dioxide evaporation and pH increase, leading to ovomucin-lysozyme binding, water release, and subsequent weakening of the vitelline membrane (Li *et al*., 2018; Liu *et al*., 2018; Hagan *et al*., 2019). The albumin index value is stratified into three

different qualities, which quality I ranges from 0.134-0.175, quality II from 0.092-0.133 and quality III from 0.050-0.091 (BSN, 2008).

Haugh Unit (HU). The mean HU for F_1 Mahkota Arab, F_2 Mahkota Arab, Arab and layer hens were 83.05±2.58, 91.99±1.13, 60.25±3.75 and 77.31±1.41, respectively. The HU values indicated that the F_2 Mahkota Arab breed had a higher HU (91.99±1.13) than the F_1 Mahkota Arab breed (83.05±2.58) by 8.94 and 14.68 higher than the layer breed (77.31±1.41). Although the average HU of F_2 Mahkota Arab chickens was not significantly different from that of the F1 Mahkota Arab chickens, it was substantially different from that of the Arab and Layer chickens. HU serves as a quantitative measure of albumen quality and, consequently, overall egg quality (Ding *et al*., 2020; Obianwuna *et al*., 2022). Calculated based on egg weight and albumen height, HU values increase with albumen height. Additionally, hen age influences HU values due to physiological function of their reproductive organs (Khaleel, 2019; Dilawar *et al*., 2021; Gu *et al*., 2021). HU quality assessment is divided into four groups: AA with a value > 72, A with a value of 60-72, B with a value 31-60 and C with a value <31 (Mountney, 1976).

Eggshell colour. This study examined eggshell colour using the RHS (Royal Horticultural Society) colour chart. As depicted in Fig. 1, the F_1 Mahkota Arab chicken eggs show a shell colour in the orange-white group-159B, classified as pale orange-yellow. The F_2 Mahkota Arab chicken has an eggshell colour of orange white group-159C-pale orange yellow and orange white group-159D-pale yellowish pink. The Arab chicken has an eggshell colour of orange, white group-159D-light yellowish pink. In comparison, the Layer chicken has an eggshell colour of greyed-orange oroup-165C-moderate orange yellow. The difference in shell pigmentation is responsible for the varied colouration seen in different types of chicken. protoporphyrin, a pigment present in the shell during formation, is responsible for the brown tone observed in some eggs. Furthermore, the laying season, vitamins, medication, illnesses, feed and upkeep can affect the colour of eggshells.

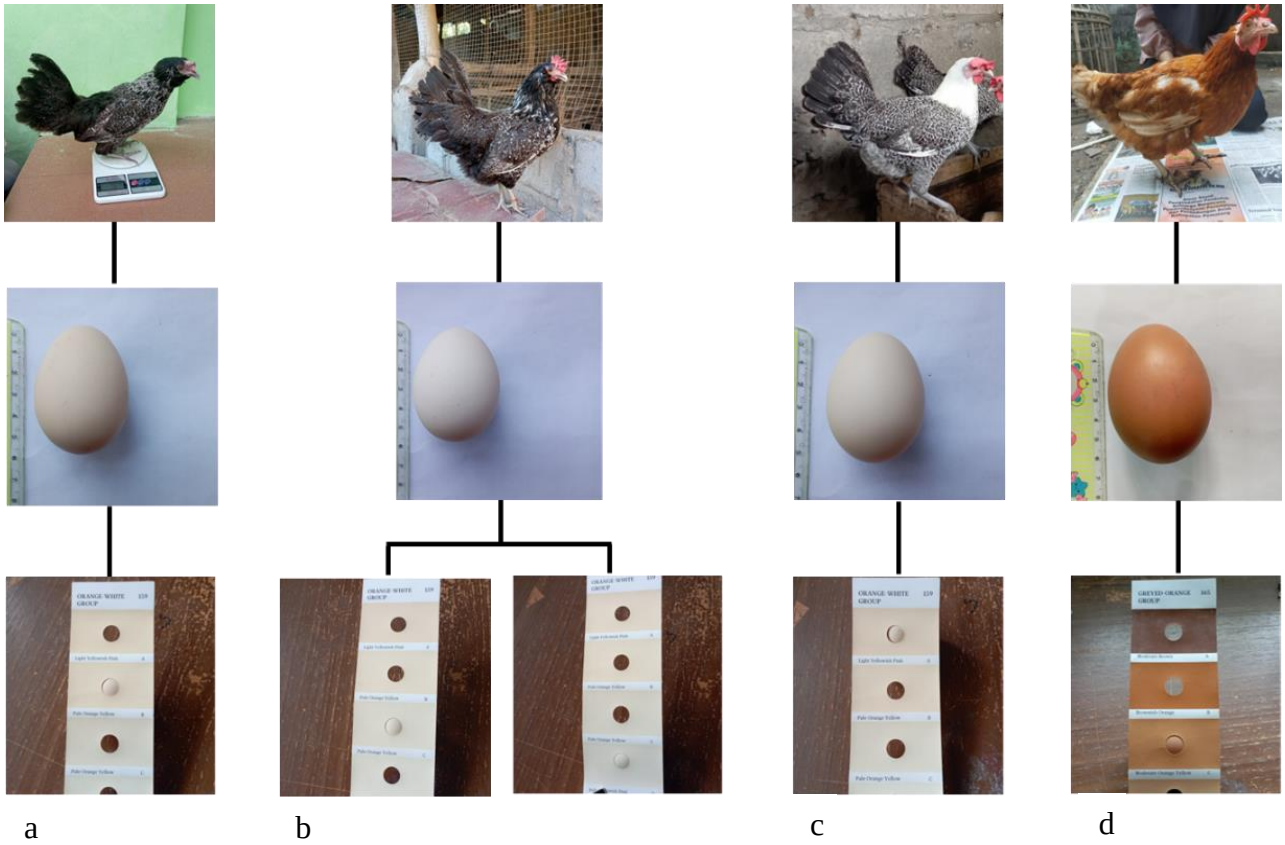

Fig. 1. Egg shell color: a. F_1 Mahkota Arab; b. F_2 Mahkota Arab; c. Arab chicken; d. Layer chicken

Based on the observed eggshell colours, it is evident that F_1 Mahkota Arab chickens, F_2 Mahkota Arab chickens, and Arab chickens possess eggshells that are categorized as white (orange-white group). On the other hand, Layer chickens possess eggshells that fall under the orange or brown colour category (greyed-orange group). These findings suggest that the Mahkota Arab chicken's eggshells resemble the local (kampong) chicken eggshells regarding their whiteness. These findings indicate that the eggshells of Mahkota Arab chickens resemble the eggshells of local (kampong) chickens in terms of their whiteness. In this case, the color of the eggshell certainly affects the expression of genes in the tissue, pigments, and structure of the eggshell which requires further research. Our research on genetic improvement of local chickens through crossing F_2 Mahkota Arab chickens holds significant potential for the poultry industry.

CONCLUSION

This study concluded that the egg shape index of F_2 Mahkota Arab chicken was 70%, Arab chicken was 63.33%, F_1 Mahkota Arab was 26.66%, and Layer chicken was 26.66%. The mean yolk index of F_2 Mahkota Arab chickens was 0.37±0.007 higher than that of Arab chickens but lower than that of Layer chickens. Furthermore, the mean albumin index and Haugh unit of F_2 Mahkota Arab chickens were higher than the other three chicken groups. The shell colour of F_2 Mahkota Arab chickens falls within the orange-white group, classifying them as a local chicken variety**.**

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