Phenotypic Correlations among Various Egg Quality Traits in Pearl Grey, Lavender, Royal Purple, and White Varieties of Helmeted Guinea Fowl

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ABSTRACT

Guinea fowls are increasingly popular in Botswana since they not only provide an alternative to access protein in the form of eggs and meat but also become a good source of income for the peasants. There are different varieties of Guinea fowl in Botswana, including pearl grey, lavender, royal purple, and white. Indeed, there is a need to conduct more studies related to the phenotypic correlations among egg quality traits in different varieties of helmeted guinea fowl found in Botswana. Therefore, the present study was targeted toward the evaluation of both the external and internal quality characteristics of the four different varieties of the domesticated helmeted guinea fowl found in Botswana. In this regard, a total of 150 eggs were collected from the so-called varieties of domesticated helmeted guinea fowl. The egg weight was positively and significantly correlated with egg length, egg width, shell weight, egg surface area, and egg volume; however, the egg weight was negatively correlated with egg shape index. Of the four varieties of domesticated helmeted guinea fowl found in Botswana, the white variety had the strongest correlation coefficients with various external egg quality traits and different internal egg quality characteristics. The lavender variety had the highest correlation coefficients with internal and external egg quality traits. It seems that the selection for higher egg weight as is the case in the current egg grading system can lead to the greatest improvements in other egg quality characteristics in the white and lavender varieties, compared to the pearl grey and royal purple varieties. Therefore, the lavender and white varieties are the potential candidates for the possible selection of layer-type guinea fowl varieties.

Keywords: Botswana, Egg traits, Guinea fowl, Layer-type

INTRODUCTION

Guinea fowl production in Botswana is still at its early developmental stage and presents a viable alternative for the diversification of the country's poultry sector (Kgwatalala et al., 2013). Guinea fowl production has great potential because guinea fowl meat is an acceptable food product and its consumption is not restricted by any traditional or religious taboos (Alkan et al., 2013). Some challenges facing guinea fowl production in Botswana include poor management skills by farmers, insufficient technical and financial support from government extension services (Moreki and Seabo, 2012). Guinea fowl provide an alternative for the rural population in Botswana to access protein in the form of meat and eggs and have great potential for revenue generation through sales of live birds and eggs (Kgwatalala et al., 2013). Guinea fowl production could be a viable alternative to failed commercial chicken enterprises in rural areas of Botswana since guinea fowls are tolerant of poultry diseases compared to chickens (Moreki and Seabo, 2012). In Africa, guinea fowl production is practiced on a small scale due to the poor performance of native genotypes, and lack of information regarding genetic and phenotypic differences in traits of economic (Alkan et al., 2013). Apart from guinea fowl meat, guinea fowls also produce eggs which are often sold hard-boiled in local markets in many African countries (Adeyeye, 2012) or as fresh eggs for artificial incubation and hatching. Understanding the structure of the egg and its various components is essential for understanding egg quality, egg fertility, embryo

development, and diseases of poultry (Islam and Duta, 2010). Phenotypic correlations among various egg quality characteristics are useful in predicting the consequences of selection for a particular trait on other traits of economic importance. It seems that currently there is very limited work on phenotypic correlations among various egg quality characteristics in different varieties of helmeted guinea fowl found in Botswana. The purpose of the current study was therefore to compute correlations among various egg quality traits in pearl grey, royal purple, white, and lavender varieties of helmeted guinea fowl found in Botswana.

MATERIALS AND METHODS

Location and duration of the study

The study was conducted at the Botswana University of Agriculture and Natural Resources (BUAN), Content Farm, Sebele, Gaborone, in the Southern part of Botswana. BUAN is located at 25.94^0S, 24.58^0E at an altitude of 991 meters. The study commenced at the beginning of January 2018 and ended in the middle of March 2018.

Housing and management

The samples in this study were divided into 30 females and 5 males of pearl grey variety, 30 females and 5 males of royal purple variety, 30 females and 5 males of the white variety, and finally 30 females and 5 males of lavender variety. The four varieties of guinea fowl were raised under an intensive management system in four separate deep litter houses with concrete floors covered with wood shavings. The four deep litter houses were of similar dimensions and measured 9m x 4m. The guinea fowls were fed commercial broiler grower pellets and provided with water *ad libitum* throughout the study period. The guinea fowl were of the same age and the egg collection began when guinea fowl were 25 months of age and lasted for 7 days. The guinea fowl were raised under natural light (12hr light and 12hr dark periods) throughout the study phase.

Collection of eggs

A total of 150 eggs were collected from each variety of domesticated helmeted guinea fowl for the evaluation of both external and internal egg quality characteristics. The guinea fowl providing the eggs were of the same age (25 months) and were hatched on the same day via artificial incubation.

Measurements of egg quality traits

The investigated external egg quality characteristics included egg weight (g), egg length (cm), egg width (cm), egg surface area (cm^3), shell thickness (mm), and egg shape index (%). The examined internal egg quality characteristics entailed yolk weight (g), yolk width (cm), yolk height (cm), fresh albumin weight (g), albumin index (%), albumin (%), yolk (%), and yolk index (%). Egg weight was determined using an electronic balance, while egg length and egg width were determined using an electronic vernier caliper. Eggshell thickness was determined using a micrometer screw gauge calibrated in mm. The accuracy of shell thickness was ensured by measuring shell thickness at the broad end, a middle portion, and narrow end of the shell and taking the average of the three measurements.

Statistical analysis

The different external and internal egg characteristics of various varieties of the helmeted guinea fowl were evaluated using correlation procedures of the Statistical Analysis System (SAS Institute Inc., Cary, NC, USA, SAS, 2010). The correlations procedure of SAS automatically tested for a significant association between various pairs of traits at $P \leq 0.05$.

Ethical approval

The rearing of the research birds was approved by the Animal Research Ethics Committee of the Botswana University of Agriculture and Natural Resources (Approval No. 2020-10), which conforms to the guidelines and the use of research animals.

RESULTS AND DISCUSSION

Phenotypic correlations among external egg quality traits

Significant positive correlations were observed between egg weight and other external egg quality traits, such as egg length (r = 0.71, 0.74, 0.64, and 0.78), egg width (r = 0.79, 0.81, 0.83, and 0.87), and egg surface area (r = 0.95, 0.89, 0.92, and 0.97) in pearl grey, lavender, royal purple and white varieties of domesticated helmeted guinea fowl, respectively (Table 1). The correlation coefficients between egg weight and shell weight were both significant (p ≤ 0.05) and moderate (r = 0.42, 0.58, 0.35, and 0.69) in pearl grey, lavender, royal purple, and white varieties of domesticated helmeted guinea fowl, respectively. Moreover, significant positive correlations between egg weight, egg length, and egg width in different

varieties of guinea fowl were consistent with the obtained results of the studies conducted by Alkan et al. (2013) and Madibela et al. (2012). Regarding helmeted guinea fowl, egg weight, egg length, and egg width had higher correlation coefficients in this study were higher, compared to the obtained results of the same traits reported by Madibela et al. (2012). The white variety had the highest correlation coefficient of egg weight with

length, width, surface area, and shell weight of the four varieties of helmeted guinea fowl. Therefore, the selection for increased egg weight (current egg grading system based on egg weight) can lead to the greatest improvements in egg length, width, surface area, and shell weight in the white variety, compared to the other three varieties.

Table 1. Phenotypic correlations among egg quality traits in pearl grey, lavender, royal purple, and white varieties of domesticated helmeted guinea fowl

Varieties	TRAIT	EW	EL	EWD	ESI	AWT	YWT	EC	SWT	STH	ESA	EV
PG		1.000	0.713*	0.790*	-0.169	0.092	0.125	0.130	0.419*	-0.057	0.951*	0.967*
L	EW	1.000	0.744*	0.805*	-0.257*	0.040	0.344*	0.203	0.584*	0.045	0.892*	0.908*
RP		1.000	0.640*	0.830*	-0.099	0.018	-0.132	-0.060	0.345*	0.020	0.919*	0.968*
W		1.00	0.776*	0.870*	-0.086	-0.156	-0.194	-0.176	0.685*	0.275	0.972*	0.979*
PG			1.000	0.203*	-0.796*	0.013	0.078	0.047	0.191	-0.149	0.852*	0.685*
L	EL		1.000	0.487*	-0.779*	-0.080	0.206	0.046	0.446*	0.020	0.913*	0.818*
RP			1.000	0.173	-0.820*	0.055	-0.136	-0.035	0.376*	-0.056	0.864*	0.699*
W			1.00	0.467*	-0.680*	-0.161*	-0.209	-0.184	0.744*	0.299	0.867*	0.740*
PG				1.000	0.430*	0.104	0.129	0.141	0.262*	-0.026	0.685*	0.852*
L	EWD			1.000	0.186	0.175	0.357*	0.306*	0.442*	0.088	0.787*	0.890*
RP				1.000	0.414*	0.063	0.067	0.083	0.124	0.004	0.645*	0.824*
W				1.00	0.383*	-0.061	-0.141	-0.086	0.439*	0.198	0.813*	0.917*
PG					1.000	0.052	-0.001	0.039	-0.018	0.122	-0.363*	-0.106
L	ESI				1.000	0.215	0.037	0.174	-0.185	0.043	-0.458*	-0.280
RP					1.000	-0.025	0.111	0.043	-0.274*	0.063	-0.425*	-0.171
W					1.00	0.114	0.102	0.118	-0.408*	-0.159	-0.225	-0.013
PG						1.000	0.256*	0.890*	0.137	0.039	0.064	0.081
L	AWT					1.000	0.306*	0.877*	0.012	0.048	0.028	0.074
RP						1.000	0.211	0.841*	0.030	0.102	0.079	0.086
W						1.00	0.704*	0.986*	-0.121	-0.339	-0.152	-0.135
PG							1.000	0.669*	0.114	-.0.169	0.127	0.135
L	YWT						1.000	0.726*	0.249	-0.055	0.311*	0.338*
RP							1.000	0.707*	0.035	0.106	-0.089	-0.049
W							1.000	0.827*	-0.100	-0.141	-0.224	-0.208
PG								1.000	0.159	-0.500	0.109	0.126
L	EC							1.000	0.134	0.006	0.177	0.224
RP								1.000	0.041	0.132	0.007	0.035
W								1.000	-0.122	-0.306	-0.180	-0.163
PG									1.000	0.384*	0.280*	0.292*
L	SWT								1.000	0.133	0.517*	0.519*
RP									1.000	0.503*	0.359*	0.313*
W									1.000	0.522*	0.715*	0.646*
PG											1.000	0.965*
L	ESA										1.000	0.981*
RP											1.000	0.964*
W											1.000	0.977*

*: $P \leq 0.05$; PG: Pearl grey; L: Lavender; RP: Royal purple; W: White varieties; EW: Egg weight; EL: Egg length; EWD: Egg width; ESI: Egg shell index; AWT: Albumin weight; YWT: Yolk weight; EC: Egg content; SWT: Shell weight; STH: Shell thickness; ESA: Egg surface area; EV: Egg volume.

Negative correlations were recorded between egg weight and egg shape index in all the four varieties of helmeted guinea fowl and between egg weight and shell thickness in the pearl grey variety. Islam and Dutta (2010) also reported negative correlations between egg weight and shape index (r= -0.17, -0.21, -0.21, -0.49, 0.05) in indigenous, exotic, and crossbred chickens of Rajshahi, Bangladesh. A negative association between egg weight and egg shape index has also been reported in other poultry species (Dzungwe et al., 2018; Godson et al., 2020). Duman et al. (2016) however reported a significant positive association between egg shape index and egg weight implying that heavier eggs are rounder in shape than lighter eggs. A negative association between egg weight and eggshell thickness suggests that heavier eggs are more thin-shelled and therefore more prone to breakages than lighter eggs. Strong, significant, and positive correlation coefficients between egg weight and other egg quality parameters indicated that selection for higher egg weight in guinea fowls might lead to simultaneous positive improvements in egg length, egg width, and egg surface area. However, it might negatively affect eggshell thickness which would lead to large eggs that are more prone to breakages.

Egg length had a significant positive association with egg surface area (r = 0.85, 0.91, 0.86, 0.87), egg volume (r = 0.69, 0.82, 0.70, 0.74), and weak positive association with egg width (r = 0.20, 0.49, 0.17, 0.47) in the pearl grey, lavender, royal purple and white varieties of domesticated helmeted guinea fowl, respectively. Weak correlation coefficients between egg length and egg width in all the four varieties of domesticated helmeted guinea fowl found in the current study were consistent with a study performed by Madibela et al. (2012) who reported a weak positive correlation between egg length and width (r = 0.25) in guinea fowls. Yakubu et al. (2008) found a strong and positive association correlation between egg length and width (r=0.71) in Nigerian indigenous chickens. Alkan et al. (2013) also contented moderate and positive correlation coefficients between egg length and width in pearl grey and royal purple varieties of helmeted guinea fowl. Egg surface area was also observed to have a high, significant ($p \leq 0.05$) and positive correlation coefficient with egg volume (r = 0.97, 0.98, 0.96, 0.98). Of the four varieties, the lavender variety had the highest correlation coefficient. Significant correlation coefficients between egg length, width, and surface were due to the fact that egg length and width can determine the volume and holding capacity of an egg, which in turn gives an indication of egg surface area and egg weight (Alkan et al., 2013). This implies that direct selection for either egg length or width will result in simultaneous improvement in egg volume, surface area, and weight. A weak, positive, and non-significant correlation coefficient was observed between egg length and eggshell weight in the pearl grey variety (r=0.19) while other varieties had moderate and significantly positive correlation coefficients. Negative and non-significant correlation coefficients were observed between egg length and eggshell thickness in pearl grey and royal purple varieties (r=-0.15 and -0.06, respectively) while other varieties were of weak, positive, and non-significant correlation coefficients. Strong, positive, and significant correlation coefficients existed among egg width, surface area, and volume in all four varieties indicating that egg surface area and volume increase with the growth of egg width. Consequently, the direct selection for egg width will result in simultaneous improvement in egg surface area and volume. There was a weak to moderate and significant correlation coefficient between egg width and shell weight in all the varieties of helmeted guinea fowl except for the royal purple which had a weak non-significant correlation coefficient. Weak to moderate correlation coefficients between egg width and shell weight observed in the four varieties of guinea fowl were consistent with Yakubu et al. (2008) who reported a weak association between egg width and shell weight (r=0.19) in Nigerian indigenous chicken. A moderate, positive and significant correlation between egg width and egg shape index occurred in the pearl grey, royal purple, and white varieties (r=0.43, 0.41, and 0.38, respectively) while a weak, positive and non-significant correlation coefficient was observed between the two traits in the lavender variety. Negative, moderate, and significant correlations occurred between egg shape index and surface area in the different varieties of domesticated helmeted guinea fowl except for the white variety which showed a negative but non-significant correlation coefficient (r= -0.23). Ultimately, weak, positive and non-significant correlation coefficients were also observed between egg shape index and shell thickness in the different varieties of domesticated helmeted guinea fowl except white variety which indicated a negative but non-significant correlation coefficient (r=-0.16).

Phenotypic correlations among internal egg quality traits

Strong, positive, and significant correlations occurred between albumin weight and egg content (r = 0.89, 0.88, 0.84, and 0.99), and weak non-significant correlations were observed between albumin weight and

egg volume (r = 0.08, 0.07, 0.07, and -0.14) in the pearl grey, lavender, royal purple and white varieties of guinea fowl, respectively. Weak, positive, and significant correlations occurred between albumin weight and yolk weight (r = 0.26 and 0.31) in pearl grey and lavender variety**,** respectively. The correlation coefficients between albumin weight and yolk weight in pearl grey and lavender were consistent with Udoh et al. (2012) who also recorded a weak, positive, and significant correlation between albumin weight and yolk weight in naked neck local chickens (r = 0.28). Yolk weight was strongly, positively, and significantly correlated with egg content (r = 0.67, 0.73, 0.71, and 0.83) in the pearl grey, lavender, royal purple, and white varieties. However, negative, non-significant correlation coefficients were observed between yolk weight and egg volume in the pearl grey and white varieties (r = -0.14 and -0.05, respectively). In addition, a weak, positive, and significant correlation coefficient was observed between the two traits in the lavender variety. The most desirable egg should preferably have more albumin weight (more protein) and less yolk weight (less fat).

Phenotypic correlations between external and internal egg quality traits

There was a strong, positive, and significant correlation between egg weight and volume (r = 0.97, 0.91, 0.97 and 0.98), while egg weight showed weak, non-significant, both negative and positive correlations with other internal quality traits, such as albumin weight (r = 0.09, 0.04, 0.02 and -0.16), yolk weight (r = 0.13, 0.34, -0.13 and -0.19), and egg content (r = 0.13, 0.20,-0.06 and -0.18) in pearl grey, lavender, royal purple, and white varieties of guinea fowl, respectively. A strong correlation coefficient between egg weight and volume was observed in all the four varieties of guinea fowl that were consistent with the reported findings of Islam and Dutta (2010) who mentioned a strong positive correlation coefficient between egg weight and volume (r = 0.93) in the Sonali chicken breed of Bangladesh. The white variety had the highest correlation coefficient between egg weight and volume, while the pearl grey had the highest correlation coefficient between egg weight and albumin weight.

Strong, positive, and significant (p≤0.05) correlations existed between egg length and volume (r = 0.69, 0.82, 0.70, and 0.74) in the pearl grey, lavender, royal purple, and white varieties of guinea fowl, respectively. Weak and positive correlations (r = 0.05 and 0.05) were observed between egg length and content in pearl grey and lavender varieties, respectively, and

negative correlations (-0.04 and -0.18) were observed between egg length and egg content in royal purple and white varieties, respectively. All the correlation coefficients between egg length and egg content were non-significant in all the four varieties of helmeted guinea fowl. Weak, non-significant, positive correlations existed between egg width and albumin weight (r = 0.10, 0.18, 0.06 and -0.06), egg content (r = 0.14, 0.31, 0.08 and -0.09) and egg yolk weight (r = 0.13, 0.36, 0.07 and -0.14) while strong, positive and significant correlations were observed between egg width and egg volume (r = 0.85, 0.89, 0.82 and 0.92) in the pearl grey, lavender, royal purple and white varieties of helmeted guinea fowl, respectively. Weak, positive correlation coefficients between egg width and albumin weight observed in all the four varieties of guinea fowl were not in the same line with the obtained results of a study conducted by Yakubu et al. (2008) indicating a moderate, positive, and significant correlation coefficient between egg width and albumin weight (r = 0.57) in the free-range naked neck and full feathered chickens. Weak, non-significant positive correlation coefficients existed between egg surface area and albumin weight (r= 0.06, 0.03, 0.08, and -0.15), egg content (r=0.11, 0.18, 0.007, and -0.18) and yolk weight (r= 0.13, 0.31, -0.09, and -0.22) while strong, positive and significant correlations existed between egg surface area and volume (r = 0.97, 0.98, 0.96, and 0.98) in the pearl grey, lavender, royal purple and white varieties of helmeted of guinea fowl, respectively.

Egg volume was weakly and positively correlated with albumin weight (r = 0.08, 0.07, 0.07 and -0.14), egg content (0.13, 0.22, 0.04 and -0.16), and yolk weight (0.14, 0.34, -0.05 and -0.21) in the pearl grey, lavender, royal purple and white varieties of guinea fowl, respectively. Weak, negative, and non-significant correlations existed between egg shape index and egg volume (r = -0.11, -0.28, -0.17, and -0.01) while weak, positive, and non-significant correlations existed between egg shape index and egg content (0.04, 0.17, 0.04, and 0.12) in the pearl grey, lavender, royal purple and white varieties of helmeted guinea fowl, respectively. Egg shape index was weakly, positive to negative, and non-significantly correlated with albumin weight (r = 0.05, 0.22, -0.03 and 0.11) and yolk weight (r = - 0.001, 0.04, 0.11, and 0.10) in the pearl grey, lavender, royal purple and white varieties of domesticated helmeted guinea fowl, respectively. Weak, positive, and non-significant correlation coefficients between egg shape index and albumin weight were consistent with Islam and Dutta (2010) who also reported weak, positive, and non-

significant correlation coefficients between the two traits in five genetic groups of chicken in Rajshahi (r = 0.27, 0.10, -0.15, -0.44 and -0.13), respectively.

Weak, positive, and non-significant correlations existed between shell weight and albumin weight, yolk weight, and egg content in all the four varieties of helmeted guinea fowl. Weak and moderate, positive, and significant correlations were observed between shell weight and egg volume (r = 0.29, 0.52, 0.31, and 0.65) in the pearl grey, lavender, royal purple, and white guinea fowl varieties, respectively. Shell thickness was weakly and non-significantly correlated with egg content and yolk weight in all the varieties of helmeted guinea fowl.

The lavender variety had the highest correlation coefficient between various internal and external egg quality characteristics. It had the highest correlation coefficients with egg width and albumin weight, egg content, and yolk weight. The lavender variety also exhibited higher correlation coefficients between egg surface area and egg volume, egg content, and yolk weight as well as between egg volume and egg content and yolk weight. Improvements in external egg quality characteristics (egg weight, egg length, egg width) in guinea fowl are, therefore, likely to also lead to the greatest improvements in internal egg quality traits in lavender than other guinea fowl varieties.

CONCLUSION

Selection for higher egg weight in guinea fowl may lead to simultaneous improvements in egg length, width, shell weight, surface area, and volume. It might, however, negatively affect the egg shape index and shell thickness in all the four varieties of domesticated helmeted guinea fowl. Among the four varieties of helmeted guinea fowl, the white variety had the strongest correlation coefficients with various external egg quality traits and various internal egg quality characteristics. The lavender variety had the highest correlation coefficients with internal and external egg quality characteristics. The white and lavender guinea fowl varieties will therefore be more responsive than the pearl and royal purple varieties for selection of egg-type or layer type guinea fowl.

DECLARATIONS

Competing interests
The authors declare that they have no competing interest

Author's contributions
P Kgwatalala designed the research. F Manyeula and O Tumagole performed the research and wrote the manuscript. All authors read and approved the final version of the manuscript.

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