September 30, 2025 Vol. 9 No. 1 E-ISSN 3026-8109 P-ISSN 3027-1657

International Journal of

BIOSCIENCE AND AGROLOGICAL RESEARCH (IJBAR)

www.harvardpublications.com

PHENOTYPIC CORRELATION BETWEEN EXERNAL AND INTERNAL EGG QUALITY TRAITS OF PANCAKE TORTOISE (*Malacochersus tornieri*)

KPEREGBEYI, J. I.; & AKAINE, F.

Department of Animal Production, Faculty of Agriculture (FOA), Southern Delta University (SDU), P. M. B. 5, Ozoro, Nigeria.

Corresponding Author: jameslovekperegbeyi2024@gmail.com

DOI: https://doi.org/10.70382/hijbar.v09i1.015

Abstract

Egg external and internal qualities are of major importance to egg industry worldwide. The objective of this study was to examine some issues such as external and internal quality traits of the pancake tortoise eggs in determining the phenotypic traits. A total of 180 eggs from pancake tortoise were collected over a period of 3 months was used for the study. The parameters measured include egg weight (EWT), shell weight (SWT), shell thickness (STH), egg length (ELT), and egg width (EWD) which was found respectively as 15.84

Keywords: Egg length, External egg quality, Egg weight, Yolk height, Shell thickness, Albumen height

INTRODUCTION

Phenotypic correlations between EEQTs and IEQTs in tortoises can vary, but generally, stronger positive correlations are observed between egg weight and internal components like yolk weight and albumen weight (Ewart *et al.*, 2022). Additionally, egg weight often shows a significant positive correlation with other external traits like shell weight. External egg quality traits include factors like egg weight (EWT), egg length (ELT), egg width (EWD), egg shape index (ESI), and shell weight (SWT). While internal egg quality traits are albumen weight (AWT), yolk weight (YWT), albumen height (AHT), yolk height (YHT), albumen index (AI), and yolk index (YI).

Harrington *et al.* (2021) reported that egg weight often has a strong positive correlation with YWT and AWT. Shell weight tends to be positively correlated with other internal egg components. Some studies have found an inverse

g, 0.52g, 0.32mm, 4.02cm, 2.79cm as external egg quality traits (EEQTs) and yolk weight (YWT), albumen weight (AWT), yolk colour (YC), yolk height (YHT), albumen height (AHT) and yolk diameter (YD) were found respectively as 7.48g, 7.84, 5.46cm, 1.34cm, 0.67cm and 4.28cm for internal egg quality traits (IEQTs). The research shows that positive and significant ($p<0.001$) correlations were found between EWT and ELT. EWT and SWT, EWD and YC, EWT and YWT. This implies that EWT had direct relationship with AWT, SWT and YWT. Negative significant correlations were also and only observed between EWD and AHT. There was statistically significant ($P<0.001$) but negative correlation (-0.24) obtained between the AHT and EWD, although a positive significant correlation exists ($P<0.001$) between YC and EWD, YWT and EWT. As a result of these observations, it was considered possible to use the EWT in determining SWT, AWT and YWT.

Correlation between shell weight and certain internal traits like albumen height and yolk index. There can also be negative correlations between shell thickness and albumen weight. Many of these correlations are statistically significant, meaning they are unlikely to have occurred by chance. The implication is that understanding these correlations is important for breeding programmes, as selecting for certain external traits (like larger eggs) can lead to improvements in internal egg quality. Egg external and internal qualities are of major importance to egg industry worldwide. These qualities traits of the eggs are significant in the tortoise breeding for their influence on the yield features of the future generation, breeding performance and quality growth of the hatchlings (Elliott *et al.*, 2019; Hanish *et al.*, 2020; Lee *et al.*, 2021; and Reinke *et al.*, 2022). It has been reported that the external and internal quality traits of the eggs in all species of tortoises (Kperegbeyi *et al.*, 2025) has significant effect on the hatchability of incubated and fertile eggs, weights and development of the laying tortoises. Approximately, 3-5% of the total amount of the eggs are damaged as a result of environmental factors. Thus, especially the amount of infertile eggs and damage embryo results in a serious economic problem both for the breeders and the hatchers (McHugh *et al.*, 2019; Rhodin *et al.*, 2021; Radu *et al.*, 2022; Kperegbeyi *et al.*, 2025a).

In the egg processing enterprises, the weight of egg shell, albumen and the yolk that form the egg as well as their rates affects the amounts and price of the produce (Segura *et al.*, 2020). During the investigation made on the quality trait of the egg, the researchers had focused on the studies related to the egg shell has a vital importance for the laying force, embryo growth and the hatchling quality (Kelley and Mendonca, 2020). In some other researchers, the egg weight is said to have a direct relation with egg shell quality which has a direct correlation with shell thickness (Goessling *et al.*, 2019; Hromada *et al.*, 2020; Segura *et al.*, 2021; Tiar-Saadi *et al.*, 2022) and the shell weight. Burgess *et al.* (2021) reported that the shell thickness has an effect on shell stiffness.

In Nigeria, especially in recent years, the decreasing number of laying breeding pancake tortoise activities is alarming. Therefore, the objective of this study was to examine some issues such as external and internal quality traits of the pancake tortoise eggs in determining the phenotypic traits.

MATERIALS AND METHODS

Experimental Site

The research was conducted at the Department of Animal Production Research Farm (DAPRF), Southern Delta University (SDU), Ozoro. Latitude 5^0 32^I N and Longitude 6^0 15^I E of Greenwich meridian place the center in mid-western Nigeria's rainforest. Humidity averages 2500-3000 mm per year and 27.4^0C and 85 % are the mean temperature and relative humidity (SDU, 2024).

Experimental Animal and Management Practices

A total of Sixty (60) mature pancake tortoises (54 females and 6 males) were obtained from different ecological zone in Delta State, Nigeria. Intensive housing system was used for this study. The dimension of the area is 12ft x 12ft. The house was ant proof to prevent ants not to invade the unit. A pen (ditched) was constructed measuring 8ft x 2ft. The tortoise was fed with concentrate diet (Top super feed) with the crude protein content of 30% and the energy content supplied 3500 kcal/kg ME. The feed was supplemented with fermented cassava (*Akpu*), cabbage and ripe palm fruits. Feeding was done twice (8:00 am and 5:00 pm) per day. The tortoises were given the same treatment throughout the experimental period under the same managerial conditions. The ditch was filled with enough water to reach the bridge where top shell (carapace) meets the bottom shell (plastron). Some routine preventive hygiene was done frequently such as providing fresh water, feeding, changing of water regularly at all times, observing the behaviour of the tortoises, signs or symptoms of any disease condition should be observed by physical examination. The tortoises were properly identified with an indelible mark on their back labeling T1, T2, T3, T4 and so on.

Egg collection

The experiment commenced when the female tortoises started laying eggs on a heap sharp sand in the month of May till July, 2025. The number of eggs per clutch was recorded. Eggs were collected in sequential weeks randomly from the nests and used for the study. **A total of 180 eggs from pancake tortoises were collected over a period of 3 months was used for the study.** The ELT (cm), EWD (cm) and YHT (cm) of each egg were measured by a digital caliper (150 cm +/- 0.02 cm) (Absolute AOS, Mitutoyo 500) and egg weight, shell weight, yolk weight and albumen weight of each egg were recorded in gram (g) by an electronic balance.

Data collection

The traits parameters collected are EWT (g), ELT (cm), EWD (cm), YWT (g), YHT (cm), YC, SWT (g), STH (mm), AHT (cm), AWT (g) and YD (cm).

Statistical Analysis

Data were computed using the Pearson correlation module according to IBM SPSS Statistics (2021) procedures.

RESULTS AND DISCUSSION

The descriptive statistics related to the quality traits of the examined eggs in the research is shown in Table 1. The values related to EWT, SWT, STH, ELT and EWD are found respectively as 15.84g, 0.52g, 0.32mm, 4.02cm, 2.79cm and the values for YWT, AWT, YC, YHT, AHT and YD are found respectively as 7.48g, 7.84, 5.46, 1.34cm, 0.67cm and 4.28cm. On the other hand, the phenotypic correlations values related to external and internal quality traits of the eggs are shown in Table 2, 3 and 4 respectively. In terms of EEQTs, shell thickness had the lowest standard deviation (0.08), indicating high consistency and stability. Egg weight showed the highest variability (1.46), while egg width (0.75) was moderately stable. The coefficient of variation confirmed that egg shell weight has the highest stability (6.83%), egg width the greatest variability (26.88%), and egg weight shows moderate consistency (9.23%). For IEQTs, the coefficient of variation confirmed these results, with yolk height being the most reliable (2.98%), yolk diameter moderately consistent (3.74%), and yolk colour the least stable (9.71%).

Table 1: Descriptive Statistics of Egg Quality Traits

EEQTs	**Min.**	**Max.**	**X ± SD**	**CV (%)**
EWT (g)	15.90	20.05	15.84 ± 1.46	9.23
ELT (cm)	3.96	4.06	4.02 ± 0.64	15.92
EWD (cm)	2.87	2.98	2.79 ± 0.75	26.88
SWT (g)	6.28	7.85	0.52 ± 0.49	6.83
STH (mm)	0.31	0.37	0.32 ± 0.08	25.00
IEQTs				
YWT (g)	6.67	8.75	7.48 ± 0.46	6.15
AWT (g)	6.98	8.68	7.84 ± 0.34	4.34
YC	5.15	6.05	5.46 ± 0.53	9.71
YHT (cm)	1.24	1.56	1.34 ± 0.04	2.98
AHT (cm)	0.45	0.87	0.67 ± 0.03	4.48
YD (cm)	3.97	4.64	4.28 ± 0.16	3.74

Table 2 shows the phenotypic correlations of EEQTs traits and indicates similarities with the findings of the Choi *et al.* (2021) but different for some traits (Walton *et al.*, 2019; Stanford, 2020; Agnolin, 2021). It was considered that the difference between the results might due to genetic structure, strain difference, health condition, feeding and management of the tortoises.

There was a correlation coefficient between EWT and ELT, SWT and egg weight and a low positive and significant difference (<0.001) and the egg weight has a direct relationship with STH of the egg, this conformity with the reports of (Brezina *et al.*, 2019; Scott *et al.*, 2020; Cilingir *et al.*, 2022; Kperegbeyi *et al.*,2025) who also reported that STH has a direct relations with the EWT and positive significant correlation with SWT. Cohen *et al.* (2022) reported a positive correlation value of 0.18 between the EWT and the STH. It has considered that egg shell quality would be determined by using the EWT value due to the positive and significant determined between the EWT and SWT (Averill-Murray *et al.*, 2020; Dutcher *et al.*, 2020; Blonder *et al.*, 2021; da Silva *et al.*, 2022) in Table 2.

Table 2: Phenotypic correlation of external egg quality traits

EEQTs	EWT (g)	ELT (cm)	EWD (cm)	SWT (g)	STH (mm)
EWT (g)	-				
ELT (cm)	0.29*	-			
EWD (cm)	-0.50	0.075	-		
SWT (g)	0.46*	0.38	-0.06	-	
STH (mm)	0.18	0.16	0.13	-0.13	-

*(P<0.01)

Table 3 shows the phenotypic correlations of IEQTs and there were no significant correlations between IEQTs of the egg since all values recorded were very low with some negative values.

Table 3: Phenotypic correlation of internal egg quality traits

Internal egg quality traits	YWT (g)	AWT (g)	YC	AHT (mm)	YHT (cm)	YD (cm)
YWT (g)	-					
AWT (g)	0.23	-				
YC	-0.25	0.53	-			
AHT (cm)	0.28	0.36	-0.36	-		
YHT (cm)	0.56	0.26	0.26	-0.42	-	
YD (cm)	0.42	0.62	0.31	0.46	0.37	-

Table 4 shows the phenotypic correlations between EEQTs and IEQTs, there was statistically significant (P<0.001) but negative correlation (-0.24) obtained between the AHT and EWD, although a positive significant correlation exists (P<0.001) between YC and EWD, YWT and EWT. This indicates a direct relationship between YC, EWD, YWT and EWT. This is in line with the findings of Cordero and Vlachos, (2021) that statistically important positive correlation was obtained in the IEQTs such as YWT.

Table 4: Phenotypic correlation between external and internal egg quality traits

IEQTs	EEQTs				
	STH (mm)	EWT (g)	ELT (cm)	EWD (cm)	SWT (g)
YC	0.36	0.23	0.16	0.46*	0.14
YHT (cm)	-0.27	-0.34	-0.36	-0.08	-0.06
AHT (cm)	-0.18	-0.08	-0.06	-0. 24*	0.36
YWT (g)	-0.21	0.41	0.26	0.04	0.44
YD (cm)	0.32	0.37	0.43	0.21	0.30

CONCLUSION

Based on the results of this study, it is considered that it is possible to use egg weight to determine the egg shell weight and shell thickness as in the case of EEQTs. In addition, EWT and YWT, EWD and YC, EWD and AHT were significantly correlated.

We hope that the results obtained in this study would contribute in this study of other researchers who will study these traits as well as the breeders who deal on tortoise breeding and improvement.

REFERENCES

Agnolin, F. L. (2021). A new tortoise from the Pleistocene of Argentina with comments on the extinction of Late Pleistocene tortoises and plant communities. *Paleontological Journal* 55: 913–922. DOI: 10.1134/s0031030121080037

Averill-Murray, R., C. H. Fleming, and J. D. Riedle. (2020). Reptile home ranges revisited: a case study of space use of Sonoran Desert Tortoises (*Gopherus morafkai*). *Herpetological Conservation and Biology* 15: 253–271. DOI: 10.2307/j.ctvfjcx1x.9

Blonder, B. I., K. J. Liedtke, and S.E. Stephens (2021). Changes in coastal gopher tortoise (*Gopherus polyphemus*) burrow characteristic and density following hurricane events in Northeast Florida, USA: implications for conservation planning. Global Ecology and Conservation 25:1-12. DOI: 10.1016/j.gecco, 2020.e01437.

Burgess, T.L., J. Braun, C. Witte, N. Lamberski, K. J. Field, L. J. Allison, R. C. Averill-Murray, K. K. Drake, K. E. Nussear, T. C. Esque, and B. A. Rideout, B.A. (2021). Assessment of disease risk associated with potential removal of anthropogenic barriers to Mojave Desert Tortoise (*Gopherus agassizii)* population connectivity. *Journal of Wildlife Diseases* 57: 579–589. DOI: 10.7589/jwd-d-20-00140

Brezina, J., A. Lujan, G. Calabkova and M. Ivanov. (2019). Revision on historical finding of the giant turtle from the Brno Sand (middle Miocene, lower Badenian). *Acta Mus. Moraviae, Sci. Geol.* 104:113–128. ISSN 1211–8796

Choi, S., N. Kim, H. Kim, J. J. Kweon, S. K. Lee, S. Zhang, and D. J. Varricchio, D.J. (2021). Preservation of aragonite in Late Cretaceous (Campanian) turtle eggshell. *Palaeogeography, Palaeoclimatology, Palaeoecology* 585: 110741. DOI: 10.1016/j.palaeo.2021.110741

Çilingir, F. G., L. A'Bear, D. R. Hansen, L. R. Davis, N. Bunbury, A. Ozgul, D. Croll, and C. Grossen. (2022). Chromosome-level genome assembly for the Aldabra giant tortoise enables insights into the genetic health of a threatened population. *GigaScience* 11. DOI: 10.1093/gigascience/giac090

Cohen, A. A., J. Deelen, and O. R. Jones. (2022). Editorial: Mechanisms and pathways contributing to the diversity of aging across the Tree of Life. *Frontiers in Cell and Developmental Biology,* 10. DOI: 10.3389/fcell.2022.854700

Cordero, G. A., and E. Vlachos. (2021). Reduction, reorganization and stasis in the evolution turtle shell elements. *Biological Journal of the Linnean Society* 134: 892–911. DOI: 10.1093/biolinnean/blab122

da Silva, R. D. A. Conde, A. Baudisch, and F. Colchero (2022). Slow and negligible senescence among testudines challenges evolutionary theories of senescence. *Science* 376: 1466–1470. DOI: 10.1126/science. abl7811

Dudgeon, T. W., M. C. H. Livius, N. Alfonso, S. Tessier, and J. C. Mallon. (2021). A new model of forelimb ecomorphology for predicting the ancient habitats of fossil turtles. *Ecology and Evolution* 11: 17071–17079. DOI: 10.1002/ece3.8345

Dutcher, K. E., A. G. Vandergast, T. C. Esque, and K. E. Nussear. (2020). Genes in space: what Mojave Desert Tortoise genetics can tell us about landscape connectivity. *Conservation Genetics* 21 289–303: DOI: 10.1007/s10592–020-01251 49

Elliott, T. F., D. S. Bower, and K. Vernes (2019). Reptilian mycophagy: a global review of mutually beneficial associations between reptiles and macrofungi. *Mycosphere* 10: 776– 797. DOI: 10.5943/mycosphere/10/1/18

Ewart, H. E., P. G. Trickle, W. I. Sellers, M. Lambertz, D. A. Crossley II, and J. R. Codd (2022). The metabolic cost of turning right side up in the Mediterranean spur-thighed tortoise (*Testudo graeca*). *Scientific Reports* 12:43–17. DOI: 10.1038/s41598-04273-w

Goessling J. M., C. Guyer, J. C. Godwin, S. M. Hermann, F, C. Sandmeier, L. L. Smith, and M. T. Mendonça. (2019). Upper respiratory tract disease and associated diagnostic tests of mycoplasmosis in Alabama populations of Gopher Tortoises, *Gopherus polyphemus*. *PLoS One*.14(4): e0214845. DOI: 10.1371/journal.pone.0214845.

Hanish, C. J., S. Velez, J. A. Moore, and C. D. Anderson. (2020). Endozoochory of *Chrysobalanus icao (Codoplum)* by *Gopherus polyphemus* (Gopher Tortoise) facilitates rapid gemination and colonization in a suburban nature preserve. *Annals of Botany Plants* 12(4): 1–12. DOI: 10.1093/aobpla/plaa024

Harrington, L. A., M. Auliya, H., Eckerman, A. P. Harrington, D. W. Macdonald, and N. D'Cruz. (2021). Live wild animal exports to supply the exotic pet trade: a case study from Togo using publicly available social media data. *Conservation Science and Practice* 3: e430. DOI: 10.1111/csp2.430

Hromada, S. J., T. C. Esque, A. G. Vandergast, K. E. Dutcher, C. I. Mitchell, M. E. Gray, T. Chang, B. G. Dickson, and K. E. Nussear. (2020). Using movement to inform conservation corridor design for Mojave Desert Tortoise. *Movement Ecology* 8: 1–18. DOI: 10.1186/s40462- 020-00224-8

Kelley, M. D. and M.T. Mendonça. (2020). Mental gland secretions as a social cue in gopher tortoises (*Gopherus polyphemus*): tortoise presence stimulates and maintains social behaviour with chemical cues. *Acta Ethologica* 24: 1–8. DOI:10.1007/s10211-020-00353-8

Kperegbeyi, J.I, Okhale, O.E, Onwumere-Idolor, O.S, Osunu, P.T, and Nwose, E. U. (2025). Changes in food-derived minerals and molecules during different growth phases of Freshwater Tortorise (*Geochelone Nigra*) under intensive management system: Implication for public health. *International Journal of Scientific Reports*, 11 (7): 238-243. DOI:10.18203/issn. 2454-2156.

Kperegbeyi, J.I, Onwumere-Idolor, O.S, Nwadiolu, R., Ewododhe, A.C.A.,and Meye, J.A. (2025a). Assessment of the phenotypic variation in colour among tortoise species from diverse ecological zones in Delta State, Nigeria. International Journal of modeling and Applied Science Research, 8(9). DOI: 10.70382/caijmasr.v8i9.023.

Lee, A. T. K., M. B. Macay, P. G. Ryan, and G. J. Alexander. (2021). Tortoise mortality along fence lines in the Karoo region of South Africa. *Journal for Nature Conservation* 59: 125945. DOI: 10.1016/j.inc.2020.125945

McHugh, S. W., K. N. White, B. B. Rothermel, T. D. Tuberville, and K R. Zamudio. (2019). Nesting and false nesting behaviors of Gopher Tortoises (*Gopherus polyphemus*). *Herpetological Review* 50(3): 453–459. Corpus ID: 209388037

Pudner, R. C., H. Waddle, S. P. Mersmann, J. S. Kush, C. Guyer, and S. M. Hermann. (2021). Changes in vegetation structure and gopher tortoise population structure after 17 years of restoration management. *Natural Areas Journal* 41: 273–282. DOI: 10.3375/21-3

Radu, V., M. Mărgărit, M., V. Voinea, A. Boroneanț, A., and I. Dulama. (2022). Processing the *Testudo* carapace in Prehistoric Romania (8th and 5th millennia BC). *Archaeological and Anthropological Sciences 14*: 60. DOI: 10.1007/s12520-022-01523-4

Reinke, B.A., H. Cayuela, H., F. J. Janzen, J. Lemaître, J., J. Gaillard, A. M. Lawing, J. B. Iverson, D. G. Christiansen, D.G., and 105 others. (2022). Diverse aging rates in ectothermic tetrapods provide insights for the evolution of aging and longevity. *Science* 376: 1459–1466. DOI: 10.1126/science. abm0151

Rhodin, A. G. J., J. B. Iverson, R. Bour, U. Fritz, A. Georges, H. B. Shaffer, and P. P. van Dijk. (2021). *Turtles of the World: Annotated Checklist and Atlas of Taxonomy, Synonymy, Distribution, and Conservation Status* (9th edition). *Chelonian Research Monographs* 8: 1–472. DOI: 10.3854/crm.8.checklist.atlas.v9.2021

Scott, P.A., L. J. Allison, K. J. Field, R. C. Averill-Murray, and H. B. Shaffer. (2020). Individual heterozygosity predicts translocation success in threatened desert tortoises. *Science* 370: 1086– 1089. DOI: 10.1126/science. abb0421

Segura, A., M. Delibes-Mateos, and Pelayo Acevedo. (2020). Implications for conservation of collection of Mediterranean Spur-thighed Tortoises as pets in Morocco: residents' perceptions, habits, and knowledge. *Animals* 10:265. DOI: 10.3390/ani10020265

Segura, A., R. C. Rodriguez-Caro, E. Garciá, and P. Acevedo. (2021). Differences in reproductive success in young and old females of a long-lived species. *Animals* 11, 467: 1–13. DOI: 103390/ani110120467

Southern Delta University Meteorological Station Report Zonal Office, Ozoro, 2024.

Stanford C.B. (2020). Turtles and Tortoises are in trouble. *Current Biology* 30. R721- R735 DOI: 10.1016/j.cub.2020.04.088 44.

Tiar-Saadi, M., G. Tiar, Z. Bouslama, and P. Siroky. (2022). Mechanisms determining body size and shape difference in Algerian Spur-thighed Tortoises (*Testudo graeca*). *Animals* 12: 1–21. DOI: 10.3390/ani12101330

Walton, R., R. Baxter, N. Bubury, D. Hansen, F. Fleischer-Dogley, S. Greenwood, and G. Schaepman-Strub. (2019). In the land of giants: habitat use and selection on Aldabra giant tortoise on Aldabra Atoll. *Biodiversity and Conservation* 28: 3183–3198. DOI: 10.1007/s10531-019-01813-9