International Journal of Agricultural Technology 2024 Vol. 20(2):535-550
Available online http://www.ijat-aatsea.com
ISSN 2630-0192 (Online)

Heat stress mitigation strategies employed by small-scale poultry farmers in Greater Gaborone, Botswana

Chiwaya, L. and Moreki, J. C.*

Department of Animal Science, Faculty of Animal and Veterinary Sciences, Botswana University of Agriculture and Natural Resources, Gaborone, Botswana.

Chiwaya, L. and Moreki, J. C. (2024). Heat stress mitigation strategies employed by small-scale poultry farmers in Greater Gaborone, Botswana. International Journal of Agricultural Technology 20(2):535-550.

Abstract Heat stress is a major challenge in poultry production in Botswana as temperatures of 35 ºC and above are common phenomena in summer. A survey was carried out from April 2023 to May 2023 in Metsimotlhabe, Gabane, Tlokweng, Oodi, and Matebeleng to investigate the strategies employed by small-scale poultry farmers and their effectiveness in mitigating heat stress. Structured and semi-structured questionnaires and interviews were used to collect data from 48 small-scale poultry farmers in the study area. Data were subjected to descriptive and inferential statistics for analyses using the R software package 4.2.2. Results showed that 58.4% and 41.6% of poultry farmers were females and males, respectively. Preferences in chicken farming systems were evident, with 37.50% favoring battery cages for layer chickens, 56.25% using deep litter systems for broiler chickens, and 6.25% opting for free-range *Tswana* chickens. Feeding practices varied, with 2.10%, 47.90%, and 50% of the respondents employing once-a-day, twice-a-day, and *ad libitum* feeding, respectively. Heat stress posed substantial economic challenges, primarily affecting broiler projects (56.3%) and layer projects (29.2), while *Tswana* chickens remained unaffected. A variety of heat stress mitigating techniques including regulated feeding, the use of an electric fan, *Aloe vera*, electrolytes (i.e., Phoenix stress pack), adequate ventilation, and the administration of cool water were used. Cost-effectiveness analysis revealed no significant correlation between heat stress management strategies and poultry types. In conclusion, the management strategies employed by poultry farmers in Greater Gaborone appeared to be ineffective in mitigating heat stress; hence a need for cheaper alternatives.

Keywords: Effectiveness, Heat stress, Management strategies, Small-scale poultry farmers

Introduction

In Botswana, the summer months are characterized by high temperatures ranging from 30 to 40 °C, coupled with low humidity and high solar radiation (World Bank, 2020). These environmental conditions harm the production and health of poultry. Heat stress in poultry production can lead to reduced feed intake, slow growth rate, decreased egg production, poor egg quality, and increased mortality rates (Abidin and Khatoon, 2013; Bhawa *et al.*, 2023). This

***Corresponding Author:** Moreki, J. C.; **Email:** jmoreki@buan.ac.bw

can contribute to significant economic losses for poultry farmers, who depend on the sale of poultry for income generation. In addition, heat stress can affect the welfare of the birds, leading to increased stress levels, dehydration, and heat exhaustion (He *et al.*, 2018). To mitigate the effect of heat stress in poultry production, various strategies are used worldwide including the provision of shade, adequate ventilation, misting, and the provision of cool water; using reflective roofing and surfaces to minimize solar radiation; and selecting heat-tolerant poultry breeds (Wasti *et al.*, 2020). Additionally, farmers should adjust their feeding practices during the summer months to reduce the impact of heat stress as the body temperature of birds rises during digestion.

The poultry subsector in Botswana is dominated by small-scale farmers who lack the resources to employ sophisticated mitigation strategies such as misting, floor cooling, pad cooling, fans, and the construction of climate-conditioned houses. Therefore, the aim of this study was to investigate the heat stress mitigation strategies employed by small-scale poultry farmers in Greater Gaborone, Botswana.

Materials and methods

Experimental site

The survey was conducted in five areas of Greater Gaborone, a metropolitan area including Gaborone city, and the surrounding villages located in three districts (i.e., Kgatleng, Kweneng, and Tlokweng). The study focused on small-scale commercial poultry enterprises from April 2023 to May 2023 in Metsimotlhabe, Gabane, Tlokweng, Oodi, and Matebeleng (Figure 1).

Greater Gaborone is located at coordinates -24.6º S and 25.9º E, with summer temperatures ranging between 27 ºC and 35 ºC, with occasional heat waves with temperatures rising to 40 ºC and above in some areas. According to Statistics Botswana (2022), Greater Gaborone has a human population of approximately 464,985. Small-scale poultry farming in Greater Gaborone is a growing enterprise due to the increasing population, demand for relatively cheap animal protein sources, and high unemployment rates.

Selection of study respondents

The multistage sampling technique was used to draw the sample of respondents. The list of poultry farmers from Kweneng, Kgatleng, and Southeast Districts was sourced from the Department of Animal Production in the Ministry of Agriculture. A simple random sampling method was used to select 50 farmers from Metsimotlhabe, Gabane, Tlokweng, Oodi, and Matebeleng. The respondents were contacted by telephone to arrange suitable times for the interviews. Only small-scale commercial operations were surveyed.

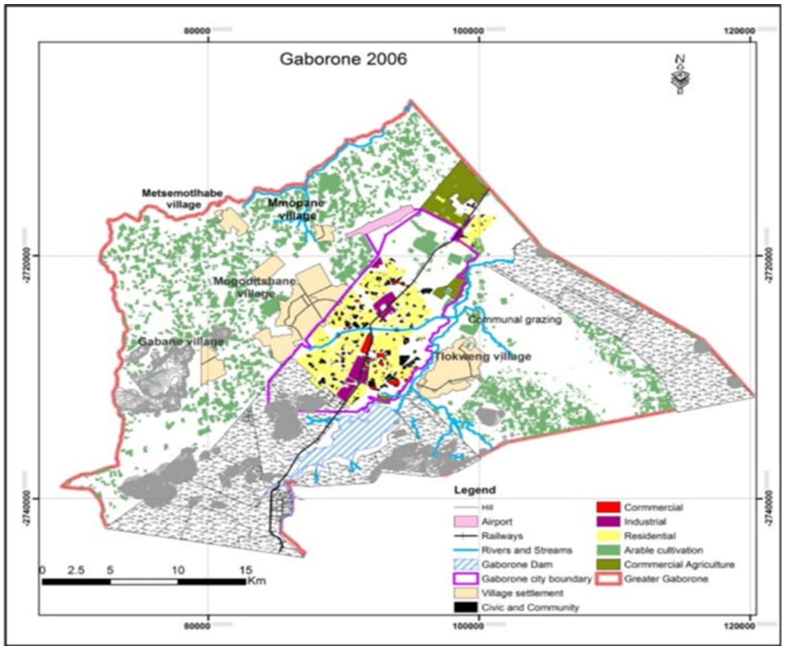

Figure 1. Map of Greater Gaborone (Sebego and Gwebu, 2013)

Ethical considerations

The respondents were informed that participation would be anonymous and treated with strict confidentiality, and the results would be published as a collective analysis without a mention of a single individual or organization. Permission to record the interviews was sought at the beginning of each interview, as it was considered a vital component of the qualitative interview process.

Data collection

Data were collected using structured and semi-structured questionnaires to ensure key areas were covered in each interview. The interviews were non-leading, and the questions were phrased in a manner that encouraged participants to communicate their personal views about managing heat stress. The design of the questionnaire was clustered around three sections. Section A considered the demographic characteristics of respondents, including age, sex, marital status, farming experience, educational level, and membership in social organizations. Section B comprised possible poultry management strategies, whereas Section C consisted of heat stress mitigation strategies applied to poultry production in the study area.

A pilot pre-testing of the questionnaires was done prior to the collection of data using both official languages, i.e., English and Setswana. The questionnaire was pre-tested on 10 respondents in Oodi village to see if they would be able to complete the entire data collection procedure, and changes were made where necessary. On average the administration of the questionnaire took 25 minutes to complete.

Statistical analysis

Data were captured using Microsoft Excel, and the R software package (R core team, 2022) was used for statistical analysis. Descriptive statistics and inferential statistics (Chi-square) were used to analyze the quantitative data on heat stress mitigation strategies employed by poultry farmers. Tables and figures were used to present summary statistics such as frequencies and percentages.

Results

Socio-economic characteristics of respondents

Females accounted for 58.4% and males 41.6% (Table 1). A majority (43.85%) of the respondents were aged 26-35 years, followed by 36-45 years (37.5%), 46-55 years (14.5%), and 55 and older (4.2%), indicating that small-scale poultry production is done by people of all ages. According to the observed age distribution among respondents, small-scale poultry farming has absorbed 81.3% of the millennials, who constitute the majority (64.6%) of Botswana's economically active population and comprise the potential workforce in agricultural production. Fifty percent of the participants were married, 41.6% were single, 6.4% were widowed and 2.0% were divorced.

All the respondents in this study were literate with 52.1% of them having tertiary education while 47.7% had high school education, i.e., the Botswana General Certificate of Secondary Education (BGCSE) (Table 1). Although most of the respondents had tertiary education, only 41.6% of them were employed. In addition, 54.2% of the respondents were members of the Botswana Poultry Association (BPA) while the remainder was not. Based on this analysis, it was apparent that there was a relatively higher proportion of individuals with a tertiary education level who are members of the BPA compared to those with a BGCSE education level.

Table 1. Socioeconomic data of the respondents in the study area

Variable	**Category**	**Frequency (n=48)**	***Per cent***
Gender	Male	20	41.6
	Female	28	58.4
Age group	26-35	21	43.8
	36-45	18	37.5
	46-55	7	14.5
	Above 55	2	4.2
Marital status	Single	20	41.6
	Married	24	50
	Divorced	1	2.0
	Widowed	3	6.4
Education level	BGCSE	23	47.9
	Tertiary	25	52.1
Employment	Yes	20	41.6
	No`	28	58.4
Membership to the Poultry Association	Yes	26	54.2
	No	22	45.8

BGCSE = Botswana General Certificate of Secondary Education

Rearing systems

It is indicated that 37.50% of respondents used the battery cage system for layer chicken production, while 56.25% and 6.25% used the deep litter system for broiler chicken production and the free-range for *Tswana* chicken production, respectively (Table 2).

Table 2. The frequencies of rearing systems employed by respondents

Farming System	**Layers**	**Broilers**	***Tswana***	**Per cent**
Battery cage	18	0	0	37.50
Deep litter	0	27	0	56.25
Free range	0	0	3	6.25
Total				**100**

Feeding

The frequency distribution of feeding practices employed by the respondents in the study area is presented in (Table 3). The three feeding practices identified were once a day, twice a day, and *ad libitum* feeding.

According to Table 3, 2.10% of respondents fed their chickens once a day, 47.90% twice a day, whereas 50% of respondents practiced *ad libitum* feeding. The results show that the once-a-day feeding practice was used for *Tswana* chickens, which may be attributed to the extensive free-range management system where chickens depended on scavenging with minimal or occasional supplementation.

Table 3. Analysis of feeding practices employed by respondents

Feeding practice	**Layers**	**Broilers**	***Tswana***	***Per cent***
Once a day	0	0	1	2.10
Twice a day	14	7	2	47.90
Ad libitum	4	20	0	50
Total				**100**

Litter management in the summer

The results in Table 4 showed that all the broiler chicken farmers in the study used litter in broiler houses to absorb moisture from fecal material and provide insulation and cushion between the birds and the floor. It is indicated that 54.16% of the respondents were broiler chicken farmers who used the same thickness of litter on the floor during both the summer and winter seasons, whereas 2.09% reduced litter thickness during the summer season (Table 4). In addition, 43.75% of layer and *Tswana* chicken farmers did not use any litter in their poultry houses. All the laying hens in this study were caged.

Table 4. The analysis of litter usage during summer by respondents

Litter Usage	**Layers**	**Broilers**	***Tswana***	**Total**
Same thickness as winter	0	26	0	54.16
Reduced thickness	0	1	0	2.09
No litter used	18	0	3	43.75
Total				**100**

Impact of heat stress on enterprises

Results showed that the broiler projects experienced the highest frequency of profit loss due to mortality (56.3%) caused by heat stress, followed by layer projects (29.2%), whereas there were no losses on *Tswana* chicken projects, indicating a significant economic impact on layer and broiler chicken enterprises (Figure 2).

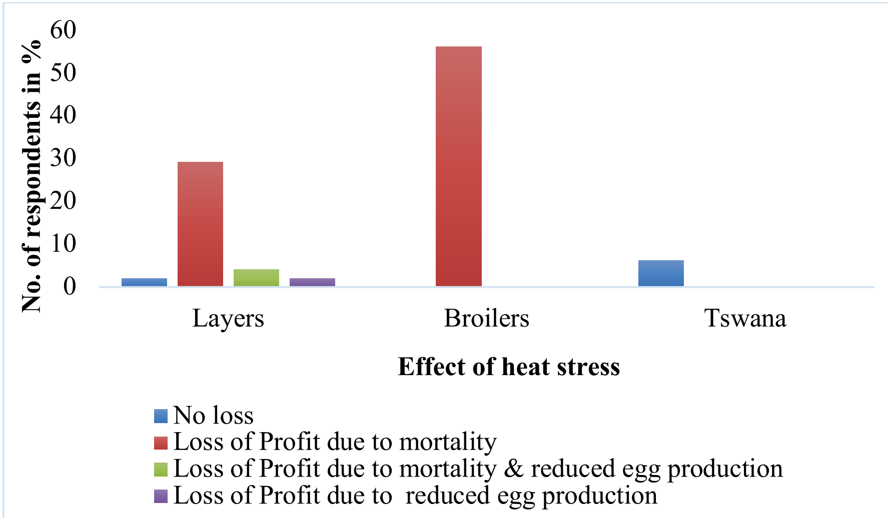

Figure 2. Effect of heat stress on poultry enterprises

Observed signs of heat stress in different types of poultry

The observed signs of heat stress provided valuable insights into the manifestation and severity of heat stress symptoms in poultry. Broilers were more susceptible to heat stress, as they exhibited heat stress signs such as increased panting, increased water intake, restricted movement, and decreased feed intake than laying hens and *Tswana* chickens (Figure 3). Laying hens also showed relatively high counts of panting, increased water intake, restricted movement, decreased feed intake, and low egg production compared to *Tswana* chickens.

Heat stress management strategies employed and their effectiveness

Data on heat stress management strategies was employed by poultry farmers in the study area (Table 5). The chi-square (χ^2) test of independence was employed as a hypothesis test within contingency tables constructed using variable values from various treatments and groups. Consequently, χ^2 was used to either accept or reject the null hypothesis (H0) concerning the independence of these variables. The computed χ^2 value was 7.176, yielding a corresponding p-value of 0.8458 (which is greater than 0.05). As a result, we failed to reject the null hypothesis H0 at a significance level of less than 0.05, thereby eliminating the possibility of a significant relationship between the variables related to heat stress management strategies and the type of poultry.

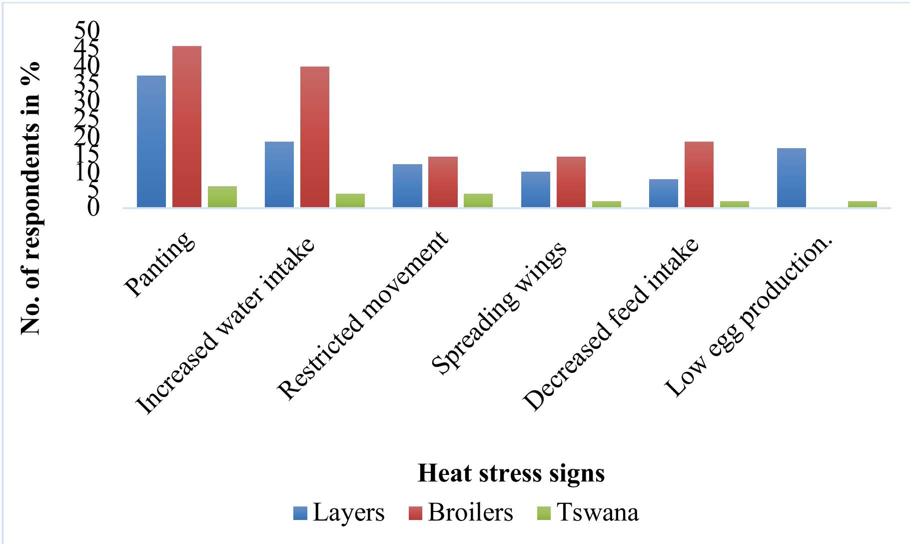

Figure 3. Observed behavioral changes shown by heat-stressed chickens

Table 5. Standardised Pearson residuals and chi-square test of goodness of fit between the observed and expected frequencies of heat stress management strategies

Poultry	Calculations	Cool Water	Stress Pack	Ventilation	*Aloe vera*	Sugar Water	Electric Fan	Controlled Feeding	Total
Layers	Observed	10	14	9	1	1	0	3	38
	Expected	10.64	13.68	8.36	1.52	0.38	0.38	3.04	38
	SPR	-0.20	+0.09	+0.22	-0.42	+1.01	-0.62	-0.02	
Broilers	Observed	16	20	13	2	0	1	4	56
	Expected	15.68	20.16	12.32	2.24	0.56	0.56	4.48	56
	SPR	+0.08	-0.04	+0.19	-0.16	-0.75	+0.59	-0.23	
Tswana	Observed	2	2	0	1	0	0	1	6
	Expected	1.68	2.16	1.32	0.24	0.06	0.06	0.48	6
	SPR	+0.25	-0.11	-1.15	+1.15	-0.24	-0.24	+0.75	
Total	Observed	28	36	22	4	1	1	8	100
	Expected	28	36	22	4	1	1	8	100
X^2 = 7.176			**α = 0.05**						
P-Value = 0.8458				**df = 12**					

Note: X^2 – Pearson's Chi-square, SPR- Standardised Pearson Residuals

Further analysis was done to assess the effectiveness of the management strategies implemented by the respondents to mitigate the impact of heat stress on poultry. The study assessed the cost-effectiness of the strategies employed in reducing the effects of heat stress in poultry. The calculated χ^2 value (6.2654) was less than the critical value (9.488) at a 0.05 significance level as shown in Table 6. The results showed that there was no statistically significant association between heat stress management strategies employed by farmers and the type of poultry enterprises. It is therefore concluded that the heat management strategies employed by poultry farmers in Greater Gaborone were not effective.

Table 6. Chi-square analysis of the effectiveness of the heat management strategies used by the respondents

Type of Poultry	Calculations	Cost-effective	Reduce the effect of HS	Both	χ2
Layers	Observed	1	3	14	1.5730
	Expected	2.47	4.11	11.42	
Broilers	Observed	0	8	19	3.9937
	Expected	3.94	6.56	18.50	
Tswana	Observed	0	1	2	0.6987
	Expected	0.59	0.98	2.76	
χ²_total = χ²_Layers + χ²_Broilers + χ²_*Tswana* = **6.2654**					
df = 4 **α** = 0.05					

Note: X^2 – Pearson's Chi-square; HS = heat stress

Discussion

The finding on the respondents' age in the present study is consistent with Baliyan and Masuku (2017) who reported a predominance of medium-aged people among the farming population. As indicated earlier, all the respondents in this study were literate. This according to Moreki *et al.* (2019) implies that the respondents could comprehend technical messages from extension services resulting in the adoption of technologies. The present results show that a higher proportion of individuals with a tertiary education level are members of the BPA compared to those with a BGCSE education level.

When considering poultry production, the choice of rearing system plays a role in determining not only the efficiency and sustainability of the operation but also its impact on animal welfare and product quality. The use of deep litter and battery cage systems in broiler and layer production in this study is consistent with Swain *et al.* (2002) and Bari *et al.* (2019) who reported that intensive farming systems are preferred for layer and broiler chickens as they are widely adopted in commercial egg and meat production due to their economic advantages, and biosecurity control. Riber *et al.* (2018) reported that deep litter systems are mostly suitable in commercial broiler chicken production because they promote better footpad health and reduce the incidences of lameness compared to broilers raised in slatted floor systems. The preference for a free-range system for *Tswana* chickens in this study is consistent with Dabbou *et al.* (2016) who stated that the free-range system is often preferred for rearing indigenous breeds due to their adaptability to local conditions and potential benefits for sustainable agriculture. These rearing systems reflect poultry farmers' varying needs and considerations, encompassing factors such as bird welfare, product quality, and market demands.

In agreement with the finding on feeding, Badubi *et al.* (2006) reported that indigenous chickens rely on unbalanced grain feed offered once a day and foraging. The twice-a-day feeding practice was used for all types of chickens in the study area, particularly layer chickens. Liu *et al.* (2020) stated that the twice-a-day feeding practice is widely adopted by many layer farmers because feeding the birds in the mornings and evenings allows for better nutrient absorption, adequate growth, and productivity. The most prevalent feeding practice reported in this study was *ad libitum* feeding, which was mostly used for broiler chickens to aid maximum growth rates in a short period. The current results agree with Liu *et al.* (2020) who stated that *ad libitum* feeding practice is common in broiler production, where rapid growth and efficient feed conversion rates are desired. The present findings suggest that feeding practices are influenced by various factors, including bird type, nutritional requirements, metabolic rate, the availability of feed resources, and farmer preferences.

Litter management plays a vital role in mitigating heat stress, as it serves as a medium for heat transfer. Garcês *et al.* (2017) stated that broilers require a suitable litter environment to perform optimally, reinforcing that broiler farmers must maintain constant litter usage during the summer as in winter. According to Durmuş *et al.* (2023), during summer proper litter management, including the reduction or removal of litter is crucial to alleviate heat stress and improve bird comfort during hot weather conditions. The reduced litter thickness is commonly adopted as it allows for better air circulation and heat dissipation, which can help alleviate heat stress and promote optimal performance (Kpomasse *et al.*, 2021). It is noteworthy that 43.75% of respondents (layer chicken and *Tswana* chicken farmers) in this study did not use any litter as bedding in their poultry houses. This finding is consistent with Abougabal and Taboosha (2023) who reported that the farming system used for layers and indigenous chicken houses does not require the use of floor bedding. Litter usage can be influenced by various factors such as bird type, environmental conditions, and farmer preferences (Toghyani *et al.*, 2010). Furthermore, understanding the factors that influence litter management practices can inform the development of optimal strategies for maintaining a suitable rearing environment for different types of poultry during the summer season.

Heat stress deleteriously affects the performance of poultry. The broiler projects experienced higher mortality rates due to heat stress compared to other enterprises. The frequencies of profit loss due to mortality for broilers, and layers were 56.3% and 29.2%, respectively, whereas no losses were reported for *Tswana* chicken projects, indicating a significant economic impact on layer chicken and broiler chicken enterprises. The present findings agree with Arjona *et al.* (1988) who reported that heat stress-related mortality leads to financial losses for commercial poultry producers because as birds die prematurely, there is a direct loss of potential revenue and the cost of feeds, housing, and other inputs invested in those birds become unrecoverable. Our results show that 4.2% of layer projects suffered a loss of profit due to high mortality rates and reduced egg production, while 2.1% reported a loss due to a reduction in egg production only. This can be attributed to the sensitivity of laying hens to heat stress, which leads to reduced feed intake, reduced egg production, increased mortality rates, and mortality.

Attia *et al.* (2017) observed that heat stress leads to higher mortality rates among broiler and layer chickens because the combination of elevated temperature and humidity causes heat stroke, dehydration, and respiratory distress, leading to a higher incidence of mortality. In contrast, *Tswana* chickens showed minimal effects of heat stress, with no recorded cases of profit loss due to mortality or reduced egg production. This could be attributable to the breed's adaptation to hot climates and their generally small body size, making them relatively resilient to heat stress compared to their counterparts. The present results emphasize the economic consequences of heat stress on poultry enterprises, particularly in terms of profit loss due to mortality.

Mortality rates serve as a critical indicator of the severity of heat stress and its impact on poultry welfare and profitability (Aengwanich and Wandee, 2022). Talebi *et al.* (2022) argued that understanding the specific effects on different poultry types can guide the development of targeted management strategies to mitigate heat stress impacts and minimize economic losses.

As mentioned earlier, the signs of heat stress provide valuable insights into the manifestation and extent of heat stress symptoms in poultry. The signs of heat stress reported in this study are consistent with Mignon-Grasteau *et al.* (2015) who stated that heat-stressed layers exhibit behavioral changes such as open-mouthed breathing, reduced activity, and spending more time near water sources. In contrast, *Tswana* chickens appeared t.o exhibit lower counts of most heat stress signs compared to layers and broilers, implying that *Tswana* chickens may be more tolerant to heat stress than commercial chickens.

The common indicator of heat stress in poultry is panting, as birds attempt to regulate their body temperature by increasing their respiratory rate. Additionally, heat-stressed poultry show increased water intake as they try to stay hydrated and cool down. Restricted movement is also noticeable as birds tend to stay near water sources or in shaded areas to seek relief from the heat. Another sign is the spreading of wings to dissipate body heat. Heat-stressed birds also display a decreased appetite and reduced feeding activity due to high temperatures. Lastly, low egg production is often observed in heat-stressed layer chickens as stress impacts their reproductive system (Kumar *et al.*, 2021). For Quinteiro-Filho *et al.* (2010), the prevalence of panting, increased water intake, restricted movement, spreading of wings, decreased feed intake, and low egg production indicates the potential impact of heat stress on poultry welfare and productivity. By recognizing and monitoring these signs, poultry farmers can promptly address heat stress and implement appropriate measures to mitigate its detrimental effects and optimize bird health and productivity.

The results of the management strategies employed by farmers to alleviate heat stress in the present study may not have a significant effect in mitigating heat stress in layers, broilers, and *Tswana* chickens. On the contrary, Mashaly *et al.* (2004) reported the positive effects of certain treatments such as cooling fans, putting ice in drinking water, and ventilation methods with improved feed conversion efficiency and reduced mortality rates during heat waves.

The Standardized Pearson Residuals (SPR) values revealed that individual treatment and group combinations did not exhibit significant deviations (the difference between the observed and expected values) under the assumption that there is no association between poultry type and treatment. The lack of significant deviations in the observed frequencies supports the notion that treatments and groups are independent factors influencing poultry performance. Therefore, the chosen treatments, including cool water, electrolytes, ventilation, *Aloe vera*, water containing sugar, an electric fan, and controlled feeding, did not impact the performance of layers, broilers, and *Tswana* chickens.

Several factors could have contributed to the non-significant results observed in this study such as genetics, feed composition, and hydration practices, which may play a major role in determining poultry performance under heat stress conditions. He *et al.* (2018) reported that genetic variations among poultry breeds can influence their heat tolerance and response to different management strategies. Specific environmental conditions, such as the local climate variations and housing conditions, could have impacted the effectiveness of heat stress mitigation strategies in this study. Furthermore, individual variations among the animals, such as age, health status, and prior exposure to heat stress, might have contributed to the observed results. According to Khan *et* *al.* (2023), poultry individuals within each group may respond differently to the treatments, leading to variations in performance outcomes; hence, it is necessary to consider individual variations when evaluating the impact of heat stress and management strategies on poultry performance.

About 77% of the poultry farmers in Greater Gaborone invested money in heat stress management strategies. The majority of those who invested money in heat stress management strategies were broiler farmers, followed by layer and *Tswana* chicken farmers, respectively. This could be attributable to the economic importance and commercial value of commercial chickens compared to *Tswana* chickens. Also, farmers perceive layers and broilers to be more prone to heat stress than *Tswana* chickens; hence the need to prioritize allocating funds to ensure the birds' well-being (Moreki *et al.*, 2016).

Approximately 23% of commercial farmers in the present study did not allocate funds for heat stress management. This according to Onagbesan *et al.* (2023) suggests that the poultry farmers may be facing challenges such as limited budgets or lack of funds, that prevent them from implementing effective heat stress mitigation strategies. Even among those who invested money, the amounts invested appeared to be insufficient to fully address heat stress concerns. This could result in the adoption of suboptimal strategies that may have a limited impact on reducing heat stress in poultry, leading to reduced productivity, increased mortality rates, and compromised welfare for the birds (Saeed *et al.*, 2017). The current findings highlighted the economic considerations and prioritization of heat stress mitigation in poultry farming, aiding in the development of targeted strategies and recommendations for effective heat stress management across different poultry enterprises.

It is concluded that the management strategies employed by farmers were not effective in mitigating heat stress, thus revealing the complex interplay of factors influencing their success. Therefore, it is advisable to explore cost-effective tailored interventions, and intensively educate farmers to manage the adverse effects of heat stress to ensure sustained productivity, and bird welfare, and achieve economic prosperity for small-scale farmers in Greater Gaborone.

Acknowledgments

The authors express their gratitude to the Department of Animal Production for providing the list of poultry farmers in Greater Gaborone. We also wish to thank the respondents for sharing their experiences on heat stress management in poultry, and Kaelo Pelotshweu for her assistance with data collection.

References

Abidin, Z. and Khatoon, A. (2013). Heat stress in poultry and the beneficial effects of ascorbic acid (vitamin C) supplementation during periods of heat stress. World's Poultry Science Journal, 69:135-152.

Abougabal, M. and Taboosha, M. (2023). Effects of different types of available litter materials on the performance and welfare of broiler chickens. Al-Azhar Journal of Agricultural Research, https://doi.org/10.21608/ajar.2023.146979.1070

Aengwanich, W. and Wandee, J. (2022). The effect of increased ambient temperature on Hsp70, superoxide dismutase, nitric oxide, malondialdehyde, and caspase activity in relation to the intrinsic and extrinsic apoptosis pathways of broiler blood cells. Journal of Thermal Biology, 105:103211 https://doi.org/10.1016/j.jtherbio.2022.103211

Arjona, A. A., Denbow, D. M. and Weaver, W. D. (1988). Effect of heat stress early in life on mortality of broilers exposed to high environmental temperatures just prior to marketing. Poultry Science, 67:226-231.

Attia, Y. A. Al-Harthi, M. A. and Sh Elnaggar, A. (2017). Productive, physiological, and immunological responses of two broiler strains fed different dietary regimens and exposed to heat stress. Italian Journal of Animal Science, 17:686-697.

Badubi, S. S., Rakereng, M. and Marumom, M. (2006). Morphological characteristics and feed resources available for indigenous chickens in Botswana. Livestock Research for Rural Development, 18: Retrieved from http://www.lrrd.org/lrrd18/1/badu18003.htm

Baliyan, S. P. and Masuku, B. M. (2017). Socio-economic factors as determinants of farm management skills among broiler poultry producers in Botswana. International Journal of Agricultural Economics, 2:27-34.

Bari, M. S., Howlider, M. A. R., Hossain, M. M., Afrose, S. and Islam, S. K. M. A. (2019). Comparison of performance, egg quality traits, and economic returns of laying hens under cage and floor systems. Journal of Animal and Poultry Science, 8:89-95.

Bhawa, S., Morêki, J. C. and Machete, J. B. (2023). Poultry management strategies to alleviate heat stress in hot climates: A review. Journal of World's Poultry Research, 13:1-19.

Dabbou, S., Hajji, H., Létourneau-Montminy, M. P. and Atti, N. (2016). Comparison of rearing effects on growth performance, carcass composition, and meat quality of indigenous chicken genotypes from Tunisia. Poultry Science, 95:916-925.

Durmuş, M., Kurşun, K., Polat Açık, İ., Tufan, M., Kutay, H., Benli, H., Baylan, M. and Kutlu, H. R. (2023). Effect of different litter materials on growth performance, the gait score and footpad dermatitis, carcass parameters, meat quality, and microbial load of litter in broiler chickens. Poultry Science, 102:102763. https://doi.org/10.1016/j.psj.2023.102763

Garcês, A. P. J. T., Afonso, S. M. S., Chilundo, A. and Jairoce, C. T. S. (2017). Evaluation of different litter materials for broiler production in a hot and humid environment: 2. Productive performance and carcass characteristics. Tropical Animal Health and Production, 49:369-374.

He, X., Lu, Z., Ma, B., Zhang, L., Li, J., Jiang, Y., Zhou, G. and Gao, F. (2018). Effects of chronic heat exposure on growth performance, intestinal epithelial histology, appetite-related and genes expression in broilers: Effects of chronic heat exposure on growth appetite. Journal of Science of Food and Agriculture, 98:4471-4478.

Khan, R. U., Naz, S., Ullah, H., Ullah, Q., Laudadio, V., Qudratullah, Bozzo, G. and Tufarelli, V. (2023). Physiological dynamics in broiler chickens under heat stress and possible mitigation strategies. Animal Biotechnology, 34:438-447.

Kpomasse, C. C., Oke, O. E., Houndonougbo, F. M. and Tona, K. (2021). Broiler production challenges in the tropics: A review. Veterinary Medicine Science, 7:831-842.

Kumar, M., Ratwan, P., Dahiya, S. P. and Nehra, A. K. (2021). Climate change and heat stress: Impact on production, reproduction and growth performance of poultry and its mitigation using genetic strategies. Journal of Thermal Biology, 97:102867 https://doi.org/10.1016/j.jtherbio.2021.102867.

Liu, Z. L., Xue, J. J., Huang, X. F., Luo, Y., Liang, M. R., Li, C. J., Wang, Q. G. and Wang, C. (2020). Effect of feeding frequency on the growth performance, carcass traits, and apparent nutrient digestibility in geese. Poultry Science, 99:4818-4823.

Mashaly, M. M., Hendricks, G. L., Kalama, M. A., Gehad, A. E. and Abbas, A. O. (2004). Effect of heat stress on production parameters and immune responses of commercial laying hens. Poultry Science, 83:889-894.

Mignon-Grasteau, S., Moreri, U., Narcy, A., Rousseau, X., Rodenburg, T. B., Tixier-Boichard, M. and Zerjal, T. (2015). Robustness to chronic heat stress in laying hens: a meta-analysis. Poultry Science, 94:586-600.

Moreki, J. C., Nelson, K. and Boitumelo, W. (2016). Assessment of management practices of Tswana chickens at North East District of Botswana. Journal of Animal Science and Veterinary Medicine, 1:29-38.

Moreki, J. C., Mpho, K. and Manyeula, F. (2019). A survey on rabbit production in the city of Gaborone, Botswana. Journal of Animal Science and Veterinary Medicine, 4:90-99.

Onagbesan, O. M., Uyanga, V. A., Oso, O., Tona, K. and Oke, O. E. (2023). Alleviating heat stress effects in poultry: updates on methods and mechanisms of actions. Frontiers in Veterinary Science, 10:1255520 https://doi.org/10.3389/fvets.2023.1255520

Quinteiro-Filho, W. M., Ribeiro, A., Ferraz-de-Paula, V., Pinheiro, M. L., Sakai, M., Sá, L. R. M., Ferreira, A. J. P. and Palermo-Neto, J. (2010). Heat stress impairs performance parameters, induces intestinal injury, and decreases macrophage activity in broiler chickens. Poultry Science, 89:1905-1914.

Riber, A. B., Casey-Trott, T. M., Herskin, M. S. and Schrøder-Petersen, D. L. (2018). The influence of litter on leg health in broilers. Poultry Science, 97:3753-3762.

Saeed, M., Abbas, G., Alagawany, M., Kamboh, A. A., Abd El-Hack, M. E., Khafaga, A. F. and Chao, S. (2017). Heat stress management in poultry farms: A comprehensive overview. Journal of Thermal Biology, 84:414-425.

Sebego, R. J. and Gwebu, T. D. (2013). Patterns, determinants, impacts and policy implications of the spatial expansion of an African capital city: The Greater Gaborone example. Int. J. Sustain. Built Environ. 2:193-208. https://doi.org/10.1016/j.ijsbe.2013.12.002

Swain, B. K., Johri, T. S., Majumdar, S. and Mandal, A. B. (2002). Influence of cage and deep litter rearing systems on growth, laying performance, and egg quality of White Leghorn layers. International Journal of Poultry Science, 37:49-54.

Talebi, E., Dolatkhah, A. and Joyani, M. (2022). The effect of high temperature on poultry and effective factors on reducing the adverse effects of heat stress: A Review Journal of Emerging Trends in Engineering and Applied Sciences, 13:2141-7016.

Toghyani, M., Gheisari, A., Modaresi, M., Tabeidian, S. A. and Toghyani, M. (2010). Effect of different litter material on performance and behavior of broiler chickens. Applied Animal Behaviour, 122:48-52.

Wasti, S., Sah, N. and Mishra, B. (2020). Impact of heat stress on poultry health and performance and potential mitigation strategies. Animals, 10:1266.

World Bank (2020). Climate change knowledge portal. Retrieved from https://climatechangeknoweledgeportal.worldbank.org

R Core Team (2022). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. https://www.R-project.org/

Statistics Botswana (2022). Population and Housing Census 2022. Retrieved from https://www.statsbots.org.bw/sites/default/files/publications/Population&HousingCensus2022PopulationofCities,Towns,VillagesAssociatedLocalities.pdf

(Received: 10 November 2023, Revised: 8 March 2024, Accepted: 9 March 2024)