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EGG PRODUCTION PERFORMANCE OF DIFFERENT STRAINS OF LAYER CHICKENS IN ENVIRONMENTALLY CONTROLLED HOUSE IN BANGLADESH

[1]Sanjida Akter Swarna, [2]Md. Taimur Islam, [3]M. Nazmul Hoque,
[4]Sheikh Arafatur Rahman and [5]*Md. Golam Haider

[1]MS student, Department of Pathobiology, Gazipur Agricultural University, Gazipur-1706, Bangladesh.

[2,5]Professor, Department of Pathobiology, Gazipur Agricultural University, Gazipur-1706, Bangladesh.

[3]Associate Professor, Department of Gynecology, Obstetrics and Reproductive Health, Gazipur Agricultural University, Gazipur-1706, Bangladesh.

[4]Associate Professor, Department of Pathobiology, Gazipur Agricultural University, Gazipur-1706, Bangladesh.

*Corresponding Author

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ABSTRACT

The poultry industry in Bangladesh has shown remarkable growth, significantly contributing to the economy and meeting the increasing demand for animal protein. This study evaluates the egg production performance of four commercial layer strains Hy-Line Brown, ISA Brown, Novogen Brown, and Bovans Brown under controlled housing conditions. Data were collected from Diamond Eggs Limited (DEL) and Protein House Limited (PHL), Kapasia, Gazipur, and analyzed. The findings revealed that the controlled housing systems effectively mitigated environmental stress, such as high temperatures and fluctuating humidity levels, which are known to adversely affect production and increase mortality rates. ISA Brown groups in Protein House Limited showed an average production rate that was 72% to 91%, while in Diamond Egg Limited, production rate of ISA Brown was 72% to 88%. Similarly, Hy-Line Brown groups demonstrated an average production range that was 74% to 83%. Results indicate that Hy-Line Brown and ISA Brown strains were performed better than others in terms of egg production under controlled conditions, highlighting their potential as sustainable choices for poultry farming in Bangladesh. Furthermore, the study confirms that controlled housing systems provide superior results compared to traditional housing.

Keywords: Poultry, Layer, Strains, Egg, Environment, Housing

1. INTRODUCTION

Since the year of 1990, a significant annual average growth rate in the commercial poultry has been achieved. The commercial poultry gained 15-20% annual average growth rate during this period. Poultry is an important sub-sector of livestock and contributes 1.6% in national GDP, and approximately 6 million people work in this sector to earn livelihood in Bangladesh (Haider MG 2025). In Bangladesh, more than 150,000 commercial poultry farms provide employment for 6 to 8 million people, primarily women and young people without jobs (Rahman et al., 2021). The poultry subsector plays a vital role in Bangladesh's agricultural growth, contributing to food security and reducing malnutrition by providing high-quality meat and eggs. It is an essential part of the country's agricultural system, supporting various stakeholders such as farmers, feed producers, veterinarians, nutritionists, poultry equipment providers, and pharmaceutical companies (Hasan et al., 2021). With urbanization and population growth, the demand for high-quality eggs has significantly increased, driving the need for improved production techniques and the selection of high performing layer strains (Chebo et al., 2022).

The production of high-quality eggs is influenced by several factors, including strain selection, ambient conditions, nutrition, feeding practices, climate, and biosecurity (Rahaman et al., 2022). Breeding companies select layer strains based on several desirable characteristics such as livability, peak egg production age, egg output per hen, age of sexual maturity, laying performance before and after molt, and the incidence of blood and flesh spot eggs (Underwood et al., 2021).

Recently, environment play major role in the egg production in Bangladesh. Importantly, comparative studies show that all of these strains adapt to the local climate of Bangladesh by performing similarly in controlled housing circumstances (Chebo et al., 2021). To enhance egg production and improve the health and productivity of layer chickens, the poultry industry has increasingly adopted controlled housing systems. These systems regulate critical factors such as temperature, humidity, and lighting, providing a stable and disease-reduced environment that promotes optimal egg production (Nawab et al, Chowdhury, 2021).

Studies on various commercial layer strains in controlled housing environments have shown promising results, particularly with strains such as ISA Brown, Shaver-579 Brown, and Novogen Brown, which have demonstrated high productivity and efficiency under controlled conditions in different countries [Hasan et al, 2021]. Despite the promising results from controlled housing systems, there is insufficient data on the egg production performance of different layer strains in controlled houses in Bangladesh. This knowledge gap limits the ability to optimize egg production and meet the growing demand for eggs in the country. This research aims to fill this gap by evaluating the egg production performance of several commercial layer strains in controlled housing systems. By understanding which strains perform best under these conditions, the study

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will help farmers make informed decisions to optimize productivity and sustainability in the poultry sector. The proposed research work is designed to evaluate the egg production performance of different layer strains under controlled housing systems and to identify sustainable layer strains for commercial poultry farming.

2. MATERIALS AND METHODS

2.1 Ethical Consideration

The experimental procedures applied in this research were approved by the Research Ethics Committee of the Veterinary Medicine and Animal Science Faculty, Gazipur Agricultural University, Gazipur-1706, Bangladesh Issue number FVMAS/AREC/2023/60.

2.2 Study Area

Layers in the control house were used as a main biological material. The layers were feed ad libitum as per demand of the nutrition. Necessary vaccines and medicines were used during study period. This study aims to evaluate the impact of temperature, humidity, feed intake, and water intake on the egg production performance of various layer strains. Additionally, the research seeks to assess the egg production performance of different layer strains and identify sustainable strains. The study is quantitative, as all variables are measurable, and the data collection approach is secondary in nature, relying on existing records. Data were obtained from the shed logbooks of different shed (L) two poultry farms: Diamond Eggs Limited (DEL) and Protein House Limited (DEL), Kapasia under the Gazipur district, Bangladesh.

2.3 Layer Population and Strain

The study was started with different number of birds at different sheds. The numbers were changed over times due to changes of flocks. In DEL, shed L1 and L6, L2, L4 and L5, L3 and L7 were reared Novogen, ISA Brown and Bovans Brown, respectively. ISA Brown strains of layer were reared in all shed of PHL.

2.4 General Management Practices of Farms

Houses were well-ventilated with controlled lighting and waste management systems. Standard biosecurity and management were practiced. Balanced feeds were formulated and fed as per requirement accordingly to the age and stains of layer. Clean continuous water was supplied for hydration and egg production.

2.5 Data Collection

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Temperature and humidity of inside and outside the shed were collected. Feed and water intake per day, and percentage of egg production of different sheds of DEL and PHL were collected from the logbook of the respective shed.

2.6 Variable Measurement

The dependent variable of the study is egg production, while the independent variables are temperature, humidity, feed intake, and water intake.

2.7 Data Analysis

The raw data was collected from the shed logbooks which were systematically entered into a spreadsheet using Microsoft Office Excel. Data analysis was done with single test ANOVA.

3. RESULTS

This study was evaluated the impact of temperature, humidity, feed intake, and water intake on the egg production performance of various layer strains of Diamond Eggs Limited (DEL) and Protein House Limited (DEL). The research was assessed the egg production performance of different layer strains and identified sustainable strains in Bangladesh.

3.1 The Effects of Different Parameters (Temperature, Humidity, Feed Intake, and Water Intake) on Egg Production at DEL

Over the three-year period (2018-2020), environmental conditions, particularly temperature and humidity have played a significant role in bird health and performance (Table 1). The slight decrease in inner shed temperature, coupled with an increase in humidity, could have influenced the overall production of the birds. In 2019, egg production was dropped to 61.52%, which could be attributed to the stress induced by environmental conditions (Table 1). However, in 2020, egg production was increased to 76.11%, likely due to improvements in farm management practices, such as better climate control, enhanced nutrition, and improved flock management.

The low p-values observed in the analysis indicate that the changes across the years are statistically significant, suggesting that environmental and management factors had a clear impact on egg production as well as bird performance. The interaction between environmental stressors and farm management highlights the importance of adjusting management strategies to mitigate these challenges.

In 2019, the L2 layer bird group saw a noticeable improvement in egg production (80.73% vs. 66.39% in 2018), which can be primarily attributed to improved management practices (Table 1). From 2018 to 2020, the L3 farm made significant improvements in temperature and humidity management, which contributed to a reduction in mortality in 2020 (Table 1). Egg production on

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the farm saw a decline in 2019 (76.16%), which may be attributed to fluctuating environmental factors, including temperature and humidity, which are known to affect laying hen performance. In 2019, the L4 group experienced improved egg production (76.48%) compared to 2018 (72.87%), despite an increase in inner shed temperatures (30.94°C vs. 29.91°C) (Tabel 1). This improvement in egg production, despite the rise in temperature, suggests that better management practices likely offset some of the negative effects of heat stress. Although the increase in inner shed temperature suggests a potential for heat stress, the significant increase in water intake, from 223.68 ml to 274.83 ml per bird, reflects the birds' physiological response to elevated temperatures.

The significant p-values (6.3E-102 and 1.25E-40) indicate that the changes observed in the farm's performance are statistically meaningful, suggesting that environmental conditions, along with improved management practices, had a significant impact on farm productivity. These findings emphasize the critical role of managing environmental factors and implementing effective management strategies to ensure optimal poultry performance under variable conditions.

In 2019, egg production on the L5 group is decreased slightly (77.29%) compared to 2018 (79.99%), likely due to the higher temperatures (30.89°C vs. 30.08°C) (Table 1). From 2018 to 2020, L6 group experienced a significant drop in egg production in 2019 (63.28%) but a recovery in 2020 (77.75%) (Table 1). However, the recovery in 2020 suggests that improved farm management and environmental control helped mitigate the negative effects of heat stress. Water intake increased significantly from 212.21 ml in 2018 to 249.15 ml in 2020, reflecting the birds' need for more hydration to cope with higher temperatures.

Table 1: Effects of temperature, humidity, feed intake, and water intake on egg production in the different layer sheds of DEL in the year 2018-2020.

Shed No	Year	Temp °C (inn)	Temp °C (out)	Humidity (%)	Water Intake (ml/b)	Feed Intake (gm/b)	Total Bird	Egg (%)	p-Value
L1	2018	30.64	30.61	78.50	215.07	100.33	130365	72.92	4.2
	2019	30.21	30.33	74.74	233.40	99.22	125742	61.52	2.5
	2020	29.45	30.06	80.23	249.46	107.79	199048	76.11	6.36
L2	2018	29.52	30.34	76.67	208.68	102.76	128993	66.39	1.17
	2019	29.73	30.03	66.97	270.29	109.20	123202	80.73	7.38
L3	2018	30.21	31.25	76.79	217.32	108.23	121935	82.73	4.95
	2019	29.55	30.78	83.38	229.81	105.99	117404	76.16	4.63

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	2020	28.98	29.57	78.44	242.27	112.77	104716	79.54	1.79
L4	2018	29.91	30.74	77.35	223.68	98.97	130965	72.87	6.3
	2019	30.94	31.33	74.59	274.83	111.28	132981	76.48	1.25
L5	2018	30.08	30.71	77.83	217.86	99.94	134244	79.99	8.68
	2019	30.89	31.04	74.98	267.31	109.77	118436	77.29	1.3
L6	2018	30.28	31.84	77.66	212.209	100.74	269028	70.85	1.4
	2019	30.06	31.11	75.47	220.70	101.69	263009	63.28	2.24
	2020	28.78	29.99	78.51	249.15	108.68	238567	77.75	1.27
L7	2018	28.01	27.97	73.74	195.77	101.51	196804	39.27	2.89
	2019	30.19	30.34	76.99	284.02	112.09	221360	80.02	6.58

The significant p-values (1.4E-137, 2.24E-65, and 1.27E-30) confirm that the observed changes in egg production, water intake, feed intake, and mortality are statistically significant, emphasizing the influence of environmental factors and management practices on farm performance. These results highlight the importance of managing environmental conditions and implementing effective management strategies to maintain productivity and ensure bird welfare.

From 2018 to 2019, L7 group experienced a significant improvement in egg production, increasing from 39.27% to 80.02%, despite higher temperatures and humidity (Table 1). This remarkable improvement in egg production, even under potentially stressful environmental conditions, suggests that effective management practices played a key role in mitigating the negative effects of heat stress. Water intake increased significantly from 195.77 ml to 284.02 ml per bird, reflecting the birds' response to higher temperatures and humidity.

The significant p-values (2.89E-14 and 6.5756E-106) confirm that the changes observed in egg production, water intake, and feed intake are statistically significant, suggesting that the management interventions and environmental factors had a meaningful impact on farm performance. These findings underscore the importance of effective farm management and environmental control in maximizing productivity, even under challenging environmental conditions.

3.2 The Effects of Different Parameters (Temperature, Humidity, Feed Intake and Water Intake) on Egg Production at PHL

From 2017 to 2018, L2 group experienced a significant improvement in egg production, increasing from 55.36% to 88.51% (Table 2). This improvement is likely due to the decrease in both inner and outer shed temperatures (30.14°C to 29.02°C and 32.10°C to 29.65°C, respectively) and a

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reduction in humidity (83.87% to 72.77%). Environmental conditions, particularly temperature and humidity, have a strong impact on egg production in poultry. The increase in water intake from 163.48 ml to 193.52 ml and the rise in feed intake from 94.66 g/bird to 109 g/bird reflect the birds' response to better management and improved environmental conditions. The significant p-values confirm that the changes in egg production, water intake, feed intake, mortality, and culling are statistically meaningful, further emphasizing the role of environmental management in enhancing poultry farm performance.

From 2017 to 2018, L3 group observed a slight improvement in egg production, increasing from 81.87% to 83.52%, along with a decrease in bird mortality (from 9.73 to 7.37) and culling (from 4.22 to 2.25) (Table 2). This positive change in farm performance can be attributed to the stable temperatures and humidity levels that prevailed during this period. The significant p-values (3.28E-61 and 1.28E-60) confirm that the observed changes in egg production, mortality, and culling rates are statistically significant. These findings highlight the critical role of stable environmental conditions and improved management practices in enhancing poultry productivity and health. The data comparing key metrics for L4 layer birds on PHL farm between 2017 and 2018 reveals a period of environmental and management stability, with no significant changes in inner and outer shed temperatures or humidity levels (Table 2). This stable climate control is important as it minimizes the risk of environmental stress, which can negatively impact poultry health and productivity.

Performance metrics, such as egg production (82.74%), water intake (188.63 ml), and feed intake (106.34 g), remained consistent over the two years, demonstrating that the farm management practices were stable and effective. Consistent egg production reflects optimal care and feeding strategies, as well as an absence of environmental disruptions. The statistically significant p-value (1.67E-73) further supports the conclusion that the observed stability in performance metrics is due to the consistent and effective environmental and management practices implemented on the farm. This reinforces the idea that stable environmental control, combined with effective management strategies, leads to improved farm productivity and health.

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Table 2: Effects of temperature, humidity, feed intake, and water intake on egg production in the different layer sheds of PHL in the year 2017-2018.

Shed No	Year	Temp °C (inn)	Temp °C (out)	Humidity (%)	Water Intake (ml/b)	Feed Intake (gm/b)	Total Bird	Egg (%)	p-Value
L2	2017	30.14	32.10	83.87	163.48	94.66	79469	55.36	2.02
	2018	29.02	29.65	72.77	193.52	109.0	77928	88.51	2.15
L3	2017	28.70	29.92	72.56	191.90	109.26	72411	81.87	3.28
	2018	28.30	29.86	71.77	191.88	109.53	72976	83.52	1.28
L4	2017	28.47	29.15	72.29	188.63	106.34	72548	82.74	1.67
	2018	28.47	29.14	72.29	188.63	106.34	725483	82.74	1.67

3.3 Correlation of Various Parameters with Egg Production at PHL and DEL Farm

This dataset presents the correlation between various environmental and operational parameters on poultry farm and egg production. The key parameters include indoor temperature (Temp ^{0}C inside), outdoor temperature (Temp ^{0}C outside), humidity, bird health metrics (Dead, Culled, Total Bird), water intake, feed intake, and egg percentage are shown (Table 3).

Indoor temperature shows a moderate negative correlation with egg production (-0.86), suggesting that higher indoor temperatures might negatively affect egg production. Outdoor temperature has a moderate positive correlation (0.87) with indoor temperature, implying that fluctuations in the outdoor temperature significantly influence the indoor environment. Humidity has a moderate negative correlation with egg production (-0.84), indicating that high humidity may hinder egg production. Dead and culled birds have strong negative correlations with egg production (- 0.91 and -0.84, respectively), signifying that higher mortality and culling rates are detrimental to overall egg yield. Water intake correlates positively with egg production (0.93), suggesting that higher water intake is beneficial for maintaining egg production. Feed intake shows a negative correlation with egg production (-0.84), indicating that insufficient or poor-quality feed might lead to a decrease in egg yield. This analysis highlights the significant influence of environmental and farm management factors, such as temperature, humidity, and bird health, on egg production. Optimizing these factors is critical for improving poultry farm productivity.

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Table 3: PHL farm correlation with egg production

Parameters	Temp ^{0}C (in)	Temp ^{0}C (out)	Humidity (%)	Dead	Culled	Water intake (ml/b)	Feed intake (gm/b)	Total Bird	Egg (%)
Temp ^{0}C (inside)	1								
Temp ^{0}C (outside)	0.868	1							
Humidity %	0.952	0. 074	1						
Dead	0.666	0.221	0.748	1					
Culled	0.565	0.119	0.688	0.979	1				
Water intake (ml/b)	0.857	0.9383	0. 612	0.252	0.097	1			
Feed intake (gm/b)	-0.061	0.291	-0.333	-0.466	-0.507	0.315	1		
Total Bird	-0.678	-0.252	-0.757	-0.995	-0.984	-0.260	0.418	1	
Egg (%)	-0.864	-0.852	-0.837	-0.909	-0.844	-0.589	0.122	0.92	1

This dataset presents the correlation between various environmental and operational parameters and egg production on DEL poultry farm. The key parameters analyzed include indoor temperature (Temp ^{0}C inside), outdoor temperature (Temp ^{0}C outside), humidity, bird health metrics (Dead, Culled), water intake, feed intake, total bird count, and egg percentage are shown (Table 4).

Indoor temperature shows a strong positive correlation with outdoor temperature (0.92), suggesting that changes in the outdoor climate significantly influence indoor conditions. Additionally, indoor temperature is positively associated with water intake (0.92), indicating that warmer conditions lead to increased water consumption. However, indoor temperature has a moderate negative correlation with feed intake (-0.65), implying that higher temperatures may reduce birds' appetite. Outdoor temperature has a moderate positive correlation with egg production (0.43), highlighting that external temperature plays a role in egg yield, likely through its influence on indoor environmental conditions. Humidity demonstrates a moderate positive correlation with water intake (0.80) but a negative correlation with feed intake (-0.57).

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Dead birds and culled birds are both negatively correlated with egg production (-0.62 for Dead, and -0.70 for Culled). These correlations underscore the negative impact of mortality and culling rates on egg production, highlighting the importance of effective health and management practices. Water intake has a moderate positive correlation with egg production (0.35), suggesting that ensuring adequate hydration is critical for maintaining optimal egg yield. Feed intake shows a very weak negative correlation with egg production (-0.05), indicating that while feed intake is crucial, its direct impact on egg production in this farm is less pronounced. This analysis demonstrates that environmental factors, particularly temperature and humidity, along with bird health indicators have a notable influence on egg production.

Table 4: DEL farm correlation with egg production

Parameters	Temp^{0}C (in)	Temp ^{0}C (out)	Humidity (%)	Dead	Culled	Water intake (ml/b)	Feed intake (gm/b)	Total Bird	Egg (%)
Temp^{0}C (inside)	1								
Temp^{0}C (outside)	0.922	1							
Humidity %	0.730	0.648	1						
Dead	-0.286	-0.366	0.315	1					
Culled	-0.428	-0.318	-0.700	-0.459	1				
Water intake (ml/b)	0.924	0.817	0.801	-0.170	-0.556	1			
Feed intake (gm/b)	-0.650	-0.377	-0.571	-0.200	0.539	-0.592	1		
Total Bird	-0.289	-0.145	-0.293	-0.116	0.347	-0.471	0.326	1	
Egg (%)	0.263	0.425	0.137	-0.615	0.062	0.347	0.411	-0.058	1

4. DISCUSSION

This investigation was the egg production performance of different strains of layer chickens housed in a controlled environment. By analyzing strain-specific productivity under stable conditions, the research identifies variations in egg production and highlights the potential for

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optimizing strain selection. These findings provide valuable insights for enhancing efficiency and sustainability in poultry farming, contributing to economic viability and improved management practices in controlled housing systems.

4.1 The Effects of Different Parameters (Temperature, Humidity, Feed Intake, and Water Intake) on Egg Production at DEL

The slight decrease in inner shed temperature, coupled with an increase in humidity, could have influenced the overall production of the birds. Elevated humidity levels are known to contribute to heat stress, reduce feed intake, and negatively affect egg production in laying hens (Wasti et al, 2020). Additionally, temperature and humidity fluctuations may increase the birds' physiological stress, which can impair their immune system and make them more susceptible to diseases (Goel, 20210). Previous studies have demonstrated that environmental stressors, including high humidity and suboptimal temperatures, can lead to reduced egg production (Karcher et al, 2015). The drop in production during 2019 may also reflect other factors such as management challenges and potential disease outbreaks, which are more prevalent under suboptimal conditions (Laca and Diaz, 2021).

Effective management practices are essential to mitigate the negative effects of environmental stress, as indicated by research suggesting that good management can offset the adverse effects of heat stress and optimize egg production (Sakhatsky et al, 2020). The increased in feed and water intake, especially in 2020, could be indicative of higher environmental stress or a larger farm scale, which may require more resources to maintain optimal performance (Karcher et al, 2015).

The low p-values observed in the analysis indicate that the changes across the years are statistically significant, suggesting that environmental and management factors had a clear impact on egg production as well as bird performance. The interaction between environmental stressors and farm management highlights the importance of adjusting management strategies to mitigate these challenges. Continued monitoring of environmental conditions and the implementation of effective management strategies were crucial to optimizing bird health and performance in future years (George and George, 2023).

In 2019, the L2 layer bird, effective management strategies, such as optimized feeding schedules, health monitoring, and environmental control, have been shown to significantly increase egg production in laying hens (Chowdhury, 2021). Although egg production increased, the slight rise in mortality and culling rates in 2019 suggests that the farm may have still faced challenges with environmental stress, such as high temperatures or disease, which can lead to increased culling (George and George, 2023).

The marked increase in water intake, from 208.68 ml to 270.29 ml per bird, reflects higher temperatures, which are known to increase water consumption as birds attempt to maintain thermal balance (Freitas et al, 2017). This increase in water intake is consistent with studies on poultry under heat stress, where water intake typically rises as the birds compensate for the energy expended in regulating their body temperature (He et al, 2018). This behavior is crucial for maintaining hydration and supporting metabolic processes under high environmental temperatures.

Feed intake also increased, from 102.76 g/bird to 109.20 g/bird, likely due to the farm's management adjustments and the increased need for energy to cope with environmental stress. Similar findings have been reported where increased feed intake occurs in poultry during periods of higher temperature, as birds try to meet their energy demands (Mujahid, 2011).

In L3 shed from 2018 to 2020, proper environmental management is crucial for maintaining poultry health, particularly in terms of reducing heat stress, which is a key factor in poultry mortality (Ahaotu et al, 2020). Studies have shown that effective environmental control can significantly improve survival rates in poultry by preventing conditions that lead to heat stress and related diseases (Goel, 2021). The improvement in environmental conditions likely played a role in the reduction of mortality was observed in 2020 on the L3 shed.

Egg production on the farm saw a decline in 2019 (76.16%), which may be attributed to fluctuating environmental factors, including temperature and humidity, which are known to affect laying hen performance. A decrease in egg production due to environmental stress is well-documented, with studies indicating that high temperatures can negatively impact reproductive performance in poultry (Kim, 2020). However, in 2020, egg production rebounded to 79.54%, which can be linked to better environmental management and farm practices, as optimal environmental conditions are critical for maximizing egg production (Xin et al, 2011, Kim et al, 2024).

The increase in water intake each year, from 2018 to 2020, reflects the higher temperatures and humidity levels, which are known to cause poultry to drink more in order to cope with heat stress (Gutierrez et al, 2009). Similar studies have found that higher water intake in response to increased environmental stress is common in poultry, and adequate water supply is essential for maintaining their health and productivity (He et al, 2018). The increase in feed intake in 2020 also suggests that, despite the higher temperatures, birds were adjusting their intake to meet their increased energy needs due to the environmental stress (Kocaman et al, 2006).

Effective flock management, which includes reducing culling rates while maintaining or improving performance, is an indicator of better health management and environmental control (Kim *et al*., 2024). The statistically significant p-values reported in the analysis confirm that the improvements in performance between the years are meaningful, underlining the positive impact of better environmental management on the farm's overall productivity.

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In 2019 L4 shed, the findings have shown that poultry can continue to perform well under suboptimal temperature conditions if effective management practices, such as adjusting feeding schedules, improving ventilation, and controlling humidity, are in place (Goel, 2021). The increase in egg production in this case could be attributed to such management strategies, which may have mitigated the adverse effects of heat stress (Xin et al, 2011).

Although the increase in inner shed temperature suggests a potential for heat stress, the significant increase in water intake, from 223.68 ml to 274.83 ml per bird, reflects the birds' physiological response to elevated temperatures. As temperatures rise, poultry generally increase water consumption to help regulate body temperature and maintain hydration (Kim et al, 20200. This increased water intake is consistent with findings that poultry under heat stress conditions typically show higher water consumption as a response to environmental challenges (He et al., 2018). The increase in feed intake (from 98.97 g/bird to 111.28 g/bird) in 2019 further supports this, suggesting that the birds are compensating for the additional energy required to cope with the heat and maintain normal metabolic function (Kim et al, 2020, Yameen et al, 2025). The overall performance of the farm in terms of egg production and feed intake indicates that, on balance, the farm was able to manage the challenges posed by heat stress.

In 2019, egg production on the L5 group is decreased slightly (77.29%) compared to 2018 (79.99%), likely due to the higher temperatures (30.89°C vs. 30.08°C). Increased temperatures can cause heat stress, which negatively affects egg production (Kim et al, 2020). Despite this, water intake rose significantly from 217.86 ml to 267.31 ml, reflecting the birds' response to higher temperatures for thermoregulation (Kim et al, 2020). Similarly, feed intake increased from 99.94 g/bird to 109.77 g/bird to meet higher energy demands (Kocaman et al, 2006; Wang et al, 2017).

This decline in 2019 may be attributed to environmental stressors, as elevated temperatures and humidity are known to negatively affect egg production in laying hens (Karcher et al, 2015). High temperatures impaired reproductive performance by disrupting hormonal regulation and affecting egg quality (Mashaly et al, 2004).

As heat stress increases, poultry tend to drink more water to regulate body temperature and prevent dehydration (Ranjan et al, 2019). Similarly, feed intake increased from 100.74 g/bird in 2018 to 108.68 g/bird in 2020, likely due to higher energy demands associated with coping with environmental stress (Osti et al, 2017).

Bird mortality increased in 2019, which can be attributed to heat stress and its impact on poultry health. Mortality rates are known to rise during periods of heat stress, as higher temperatures can compromise immune function and increase susceptibility to diseases (Lara and Rostagno, 2013). However, mortality decreased in 2020, which indicates that improved management practices, such

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as better environmental control and feeding strategies, helped reduce the negative impacts of heat stress on the flock.

In L7 from 2018 to 2019, poultry performance is often adversely affected by high temperatures, but studies have shown that good management, including proper ventilation, feeding schedules, and the use of cooling systems, can help to offset the impact of heat stress and improve productivity (Nidamanuri et al, 2017). The improvement in farm performance indicates that these management strategies likely helped maintain egg production levels despite unfavorable conditions.

Water intake increased significantly from 195.77 ml to 284.02 ml per bird, reflecting the birds' response to higher temperatures and humidity. Increased water consumption is a typical response to heat stress, as poultry require more water to regulate body temperature and maintain hydration (Kim et al., 20200. This increase in water intake is consistent with the physiological adaptations poultry make to cope with environmental stressors. Additionally, the rise in feed intake from 101.51 g/bird to 112.09 g/bird suggests that the birds are compensating for the increased energy expenditure associated with thermal stress (Daghir, 2008). Although the birds are under heat stress, the increase in feed intake could indicate that the farm management practices effectively supported the birds' nutritional needs.

4.2 The Effects of Different Parameters (Temperature, Humidity, Feed Intake and Water Intake) on Egg Production at PHL

Environmental conditions, particularly temperature and humidity, have a strong impact on egg production in poultry. Lower temperatures and reduced humidity can alleviate heat stress, which typically impairs egg production by affecting the hens' reproductive system and overall health (Kilic and Simsek, 2013). Improved environmental conditions help maintain thermal balance, which supports optimal egg production (Gržinić, et al., 2023).

The increase in water intake from 163.48 ml to 193.52 ml and the rise in feed intake from 94.66 g/bird to 109 g/bird reflect the birds' response to better management and improved environmental conditions. Higher water consumption is a common response to decreased heat stress, as poultry need to maintain hydration, especially during hotter conditions (Kim et al., 2020). Similarly, the increase in feed intake is likely due to a reduction in stress and better access to nutrients, which would contribute to improved overall health and egg production (He et al., 2016).

Effective environmental control and better management practices, such as providing optimal temperature, humidity, and feeding strategies, can significantly reduce mortality and culling rates (Nawab et al., 2018). These improvements are consistent with studies that show a direct correlation between improved environmental conditions and reduced mortality and culling rates (Kuczynski et al., 2011).

Environmental stability plays a crucial role in improving poultry health, as laying hens are sensitive to fluctuations in temperature and humidity. When environmental conditions are kept within optimal ranges, poultry are better able to regulate their body temperature, which directly impacts egg production and overall health (Weeks et al., 2016). A stable environment minimizes heat stress, which is known to impair reproduction and increase mortality and culling rates (Osti et al., 2017). Water intake remains constant, indicating that the birds are able to maintain their hydration levels without the added stress of fluctuating environmental conditions. This is consistent with findings that show water consumption tends to stabilize in comfortable environmental conditions, with less need for compensatory hydration during periods of heat stress (Sterling et al., 2003). Feed intake showed a slight increase, which could reflect improved farm management practices such as better feeding strategies or access to higher-quality feed. The increase in feed intake indicates that birds may have slightly increased their nutritional intake, contributing to the observed improvements in egg production and reduced mortality and culling (Powers and Angel, 2008).

The data comparing key metrics for L4 layer birds on PHL farm between 2017 and 2018 reveals a period of environmental and management stability, with no significant changes in inner and outer shed temperatures or humidity levels. This stable climate control is important as it minimizes the risk of environmental stress, which can negatively impact poultry health and productivity. Consistent environmental conditions help maintain thermal comfort, which is crucial for optimizing egg production (Sakhatsky et al., 2020). Heat stress is a known factor that affects egg production, feed intake, and overall bird health, so the lack of significant change in environmental factors suggests effective management of the poultry house climate (Vandana et al., 2021).

Performance metrics, such as egg production (82.74%), water intake (188.63 ml), and feed intake (106.34 g), remained consistent over the two years, demonstrating that the farm management practices were stable and effective. Consistent egg production reflects optimal care and feeding strategies, as well as an absence of environmental disruptions. A study by (Bryden et al., 2021) emphasized that stable management practices, including controlled feeding and water provision, are vital for maintaining consistent production in poultry. The consistency observed in feed and water intake further supports this notion, as laying hens typically adjust their intake in response to environmental conditions, ensuring that their nutritional needs are met (Xin et al., 2011).

In a study by (Van De et al., 2009), it was found that consistent health management practices, such as vaccination programs and disease monitoring, help reduce mortality rates, particularly when environmental stressors are controlled. The minimal changes in these health indicators suggest that the farm's management practices successfully minimized the risk of diseases and maintained bird health.

4.3 Correlation of Various Parameters with Egg Production at PHL and DEL Farm

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Indoor temperature shows a moderate negative correlation with egg production (-0.86), suggesting that higher indoor temperatures might negatively affect egg production. Feed intake shows a negative correlation with egg production (-0.84), indicating that insufficient or poor-quality feed might lead to a decrease in egg yield. This analysis highlights the significant influence of environmental and farm management factors, such as temperature, humidity, and bird health, on egg production. Optimizing these factors is critical for improving poultry farm productivity. These findings were also corresponded with the others authors (Freitas et al., 2017; He et al., 2018).

Indoor temperature shows a strong positive correlation with outdoor temperature (0.92), suggesting that changes in the outdoor climate significantly influence indoor conditions. Humidity demonstrates a moderate positive correlation with water intake (0.80) but a negative correlation with feed intake (-0.57). High humidity levels appear to drive increased water consumption, but may also reduce feed intake due to heat stress or discomfort for the birds. (Ahaotu et al., 2019) were also reported the similar results.

Feed intake shows a very weak negative correlation with egg production (-0.05), indicating that while feed intake is crucial, its direct impact on egg production in this farm is less pronounced. This analysis demonstrates that environmental factors, particularly temperature and humidity, along with bird health indicators have a notable influence on egg production. These findings were also supported by the other authors (Elbayoumi, et al., 2019).

5. CONCLUSION

This study evaluated the egg production performance of various layer strains in controlled housing systems in Bangladesh, aiming to identify sustainable and profitable strains for commercial poultry farming. The findings revealed that ISA Brown and Hy-Line Brown strains exhibited significantly higher egg production rates compared to other strains. Specifically, ISA Brown groups in Protein House Limited showed an average production rate was 72% to 91%, while in Diamond Egg Limited, ISA Brown produced between 72% and 88%. Similarly, Hy-Line Brown groups demonstrated an average production range was 74% to 83%. These high egg production rates contribute directly to increased profitability and meet the growing demand for eggs in Bangladesh's poultry industry. Environmentally controlled housing with optimal conditions (temperature 18°C- 25°C, humidity 50-70%, proper ventilation, and light management) minimizes heat stress, enhances feed conversion, promotes consistent egg production, and improves egg quality, reducing mortality rates and improving profitability. Overall, ISA Brown and Hy-Line Brown strains are more adaptable and profitable in Bangladesh compared to other strains, making them the preferred choice for commercial layer farming. These strains, combined with controlled housing systems, offer a sustainable path to higher productivity and profitability in the layer farming sector. However, further research is recommended to assess the performance of different

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commercial layer strains under identical environmental conditions in farm trials, to provide more comprehensive insights for the poultry industry.

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