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PRODUCTION AND REPRODUCTIVE PERFORMANCE OF HY-LINE BROWN PARENT STOCK IN THE THREE POULTRY BREEDING CENTRES IN BHUTAN

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Abstract: *Poultry farming is an important part of Bhutan's livestock production systems, playing an important role in enhancing food security and supporting rural livelihoods. Optimizing the performance of the parent stock (PS) is vital for improving farm productivity and sustaining egg production. This study assessed and compared the production and reproductive performance of Hy-Line Brown PS among the three government poultry breeding centres in Bhutan: Regional Poultry Breeding Centre (RPBC), Paro, National Poultry Development Centre (NPDC), Sarpang, and Regional Pig and Poultry Breeding Centre (RPPBC), Mongar. Farm records from 2023 to 2024 were analyzed using descriptive and inferential statistics. RPBC recorded the highest hen-day and hen-housed egg production, followed by RPPBC, while NPDC showed the lowest performance. Feed Conversion Ratio (FCR) was lowest at RPBC (1.83±0.15), followed by RPPBC (2.06±0.31), and highest at NPDC (2.79±0.91), and the differences were statistically significant at 95% confidence interval ($p< 0.05$). Mortality differed significantly ($p< 0.05$) between ages 1-17 weeks and 18-75 weeks. In the early stage of rearing, female mortality was highest at RPBC, while male mortality was highest at NPDC. In the later phase, female mortality was highest at NPDC and male mortality at RPBC. NPDC recorded the earliest age at first lay (134 days), whereas RPPBC achieved 50% lay earlier at 149 days, compared to RPBC (151 days) and NPDC (159 days), respectively. Age at peak lay was achieved earlier by RPPBC (173 days), followed by NPDC (186 days) and RPBC (219 days). Fertility and hatchability rates also varied significantly ($p< 0.05$) among the centers. Fertility was highest at RPBC (88.37±4.15%), followed by NPDC (85.91±3.66%) and RPPBC (85.58±5.89%). Hatchability of both set and fertile eggs was highest at RPPBC (56.20±10.64% and 70.47±9.93%, respectively), followed by NPDC (55.81±11.82% and 64.91±12.90%, respectively) while RPBC recorded the lowest hatchability at 44.78±13.67% and 56.80±15.88%, respectively. These findings highlight substantial variation in performance across centers demanding a need for targeted centre-specific management interventions to improve efficiency and reproductive success of Hy-Line Brown PS in Bhutan.*

Keywords: Poultry; Hy-Line Brown; Parent stock; Production performance; Reproductive performance.

1. INTRODUCTION

In Bhutan, livestock sector plays a crucial role in agricultural production by enhancing the diets of Bhutanese farmers, providing draft power and contributing to soil fertility (Namgay 2013). Poultry farming, in particular has emerged as a key enterprise, supported through the establishment of the three poultry breeding centres: Regional Poultry Breeding Centre (RPBC) in Paro, Regional Pig and Poultry Development Centre (RPPBC) in Mongar, and National Poultry Development Centre (NPDC) in Sarpang (Nidup and Dorji 2009). The layer farming sector, comprises of 160 subsistence, 145 semi-commercial, and 230 commercial farms (Gaylal and Dorjee 2024). These farms rely heavily on quality day-old chicks (DoCs) from the three government-owned centres, all of which rear Hy-Line Brown parent stock (PS) imported from Australia. These PS are critical to the supply chain, as their production and reproductive performance directly influence the availability and affordability of commercial layers. However, there is limited evaluation of the performance of these breeding centres for key parameters such as egg production, feed conversion ratio (FCR), mortality, sexual maturity, fertility, and hatchability. To address this gap, the present study aimed to assess and compare the productive and reproductive performance of Hy-Line Brown PS across the three poultry breeding centres in Bhutan.

2. MATERIALS AND METHODS

2.1 Study area

This study was conducted at the three government-owned poultry breeding centres in Bhutan responsible for rearing Hy-Line Brown PS and supplying commercial DoCs to layer farms. The RPBC is located in Wangchang Gewog (sub-distict), Paro Dzongkhag (27.409112° N, 89.416849° E), at an elevation of 2200-2340 meters above sea level (masl). The area experiences and receives average annual temperature ranging from 5.92°C to 20.46°C receives an annual rainfall of 376.6 mm annually, with over 66 rainy days (NCHM 2023).

The RPPBC is located in Saleng Gewog, Mongar Dzongkhag (27.260514° N, 91.19985° E), at an elevation of 1600 masl. The area experiences an average temperature ranging from 13.76°C to 22.3°C and receives an annual rainfall of 695.3 mm over 90 rainy days (NCHM 2023). The NPDC is situated in Gakiling Gewog under Sarpang Dzongkhag (26.5248° N, 90.1530° E), at an elevation of 369 masl, with an average temperature ranging from 20.92°C (low) to 29.65°C (high) and has an annual rainfall of 5376.2 mm over 136 rainy days (NCHM 2023).

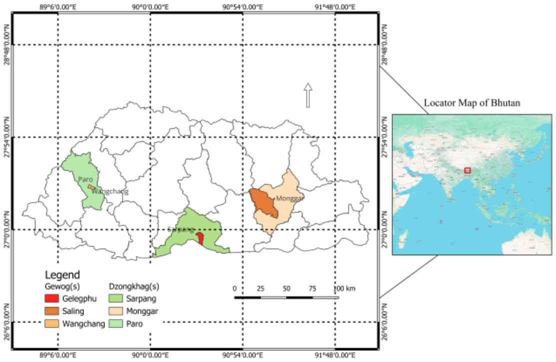

Figure 1: Study area (shaded in colors).

2.2 Data collection

Data were obtained from farm records maintained at the three poultry breeding centres covering one production cycle from February 2023 to July 2024. The variables included egg production, feed consumption, mortality rates, and hatchery performance. Farm visits and follow-up communications were carried out to verify the accuracy of the records and ensure consistency across the centres.

2.3 Calculation of performance parameters

Hen-day egg production (HDEP) was expressed as a percentage and calculated as the number of eggs produced on a given day divided by the number of hens available in the flock on the same day, as illustrated in equation 1.

$$\text{HDEP}(\%) = \frac{(\text{No. of eggs produced on a day})}{(\text{No. of hens present on the same day}} \times 100 \quad (1)$$

Hen-housed egg production (HHEP) was expressed as a percentage and calculated by dividing the total number of eggs produced by the total number of hens initially housed (2).

$$\text{HHEP}(\%) = \frac{\text{Total no. of eggs produced in a flock}}{(\text{Total number of hens housed}} \times 100 \quad (2)$$

Feed conversion ratio (FCR) was calculated as the total feed consumed in kilograms (kg) divided by the total number of eggs produced, expressed in dozens (3).

$$\text{FCR} = \frac{\text{Amount of feed consumed (kg)}}{\text{Number of eggs produced}} \quad (3)$$

Mortality rate (MR) was expressed as a percentage and calculated as the number of bird deaths divided by the initial number of birds housed (4).

$$\text{MR (\%)} = \frac{\text{Number of bird deaths}}{\text{Initial number of birds}} \times 100 \quad (4)$$

Fertility rate (FR) was expressed as a percentage and calculated as the number of fertile eggs divided by the total number of eggs set for incubation (5).

$$\text{FR} = \frac{\text{Number of fertile eggs}}{\text{Total number of eggs set}} \times 100 \quad (5)$$

Hatchability rate of fertile eggs (HFE) was expressed as a percentage and calculated as the number of chicks hatched divided by the total number of fertile eggs set for incubation (6).

$$\text{HPE (\%)} = \frac{\text{Number of eggs hatched}}{\text{Total number of fertile eggs}} \times 100 \quad (6)$$

Likewise, the hatchability rate of set eggs (HR) was expressed as a percentage and calculated as the number of chicks hatched divided by the total number of eggs set for incubation (7).

$$\text{HR (\%)} = \frac{\text{Number of eggs hatched}}{\text{Total number of set eggs}} \times 100 \quad (7)$$

2.4. Data analysis

Data were recorded in Microsoft Excel 2013 and exported to International Business Machines-Statistical Package for Social Sciences (IBM-SPSS) version 26 for further analysis. Descriptive statistics for FCR, fertility and hatchability rates were presented in means and standard deviations. Prior to analysis, normality tests were conducted to assess the distribution of the data. As the data were normally distributed, parametric tests were applied One-way analysis of variance (ANOVA) was conducted to compare performance parameters among the three poultry breeding centres at $p < 0.05$. Further, a pair-wise comparison was carried out using Tukey's honesty significant difference (HSD) test to determine specific group differences.

3. Results and Discussion

3.1. Hen-day egg production (HDEP %)

Figure 2 illustrates the weekly production trends across the centres. Weekly HDEP varied significantly ($p < 0.05$) among the centres. At RPBC, HDEP increased rapidly from week 21, reaching a peak at week 31. This was followed by a sharp decline (week 31-34), which may be due to roundworm and mite infestation within the flock. There was a gradual downward trend after recovering from a drop at week 34. RPPBC maintained a moderate and stable production, with a noticeable decline after week 49. NPDC recorded the lowest overall HDEP, with a delayed peak at week 27, followed by two distinct declines during weeks 41-46 and 49-52. The increased HDEP at RPBC may be attributed to its cooler climatic conditions with an annual maximum temperature of 20°C, which falls within the thermoneutral zone for laying hens (15-20°C). In contrast, RPPBC experiences slightly higher ambient temperature (22°C), which may induce mild heat stress, while the substantially warmer conditions at NPDC with average temperature of 30°C are likely to induce chronic heat stress, contributing to reduced laying performance. Previous studies have consistently showed the negative effects of high temperatures on egg production. Barrett et al. (2019) reported a decline in egg production from 90.15% to 84.4% under cyclic heat exposure, with persistent low productivity post-stress. Similarly, Mignon-Grasteau et al. (2015) observed significant drops in egg production at temperatures ranging from 30°C to 35°C. However, some studies suggest that temperature alone may not fully explain production variability. For instance, Rahayu and Widjastuti (2019) reported minimal differences in egg production between low altitude (22-31°C) and high altitude (15-22°C) environment. In this study, the reduced performance observed at NPDC was also associated with flock health issues, particularly coccidiosis. This parasitic infection impairs gastrointestinal function and induces oxidative stress, inflammation, and immune suppression, leading to decreased production (Sharma and Kim 2024).

Although Hy-Line Brown hen have been reported to maintain acceptable production levels at temperatures around 30°C (Kim et al. 2022*)*, the lower egg productivity at NPDC was likely due to the combined effects of heat stress and disease pressure.

3.2 Hen-housed egg production (HHEP %)

Weekly hen-housed egg production (HHEP) also differed significantly ($p < 0.05$) among the three centres. As shown in Figure 3, RPBC recorded the highest HHEP, characterized by a rapid increase at the onset of lay and sustained high production throughout the laying period. RPPBC had a moderate production pattern, with a gradual increase followed by a mid-level plateau and a slow decline thereafter. In contrast, NPDC showed the lowest HHEP, with production declining after peak lay. The higher performance at RPBC may be attributed to favorable climatic conditions, effective disease control, and strategic culling of underperforming laying hens. According to W. Namgyel (personal communication, 2025), mitigation strategies such as use of shade nets, basket fans, and mineral supplementation were implemented to counteract heat stress. The moderate performance at RPPBC may be due to implementation of similar management interventions. Braga et al. (2024) reported that the use of shade nets can drastically reduce thermal stress and improve laying conditions. Likewise Ranjan et al. (2019) highlighted that heat stress adversely affects egg production by causing mineral depletion, reducing serum and liver concentrations of essential nutrients,

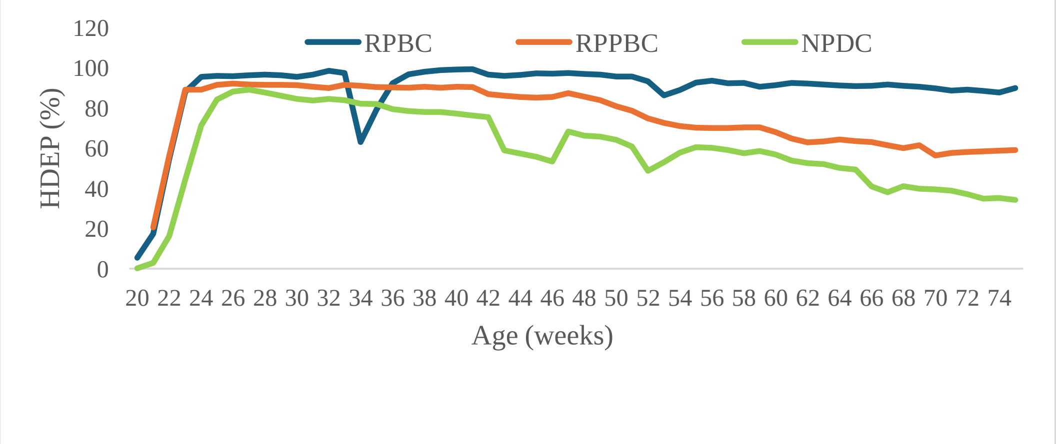

Figure 2: Weekly hen-day egg production (HDEP) of Hy-Line Brown PS at the three poultry breeding centres: RPBC (Paro), RPPBC (Mongar), and NPDC (Sarpang).

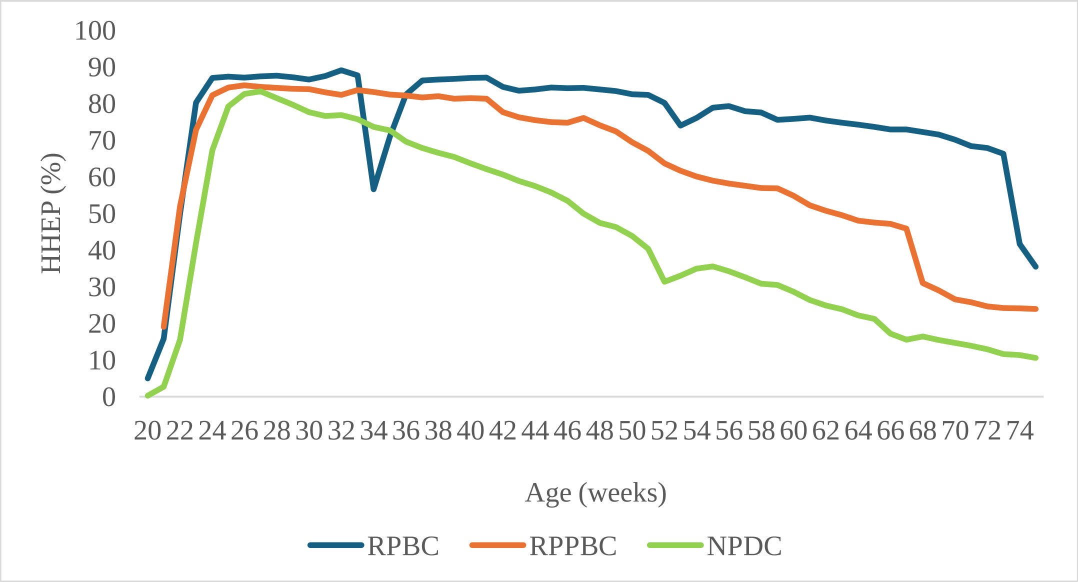

Figure 3: Weekly hen-housed egg production (HHEP) of Hy-Line Brown PS at the three poultry breeding centres: RPBC (Paro), RPPBC (Mongar) and NPDC (Sarpang).

while supplementation under such conditions can improve productivity. The low HHEP at NPDC reflects reduced efficiency, likely driven by higher ambient temperatures and insufficient heat mitigation measures.

3.3.Feed conversion ratio (FCR)

The feed conversion ratio (FCR, kg feed per dozen eggs) differed significantly ($p < 0.05$) among the centers. NPDC recorded the highest FCR (2.79±0.91), followed by RPPBC (2.06±0.31), while RPBC has the lowest (1.83 ±0.15) (Table 1) indicating better feed efficiency at RPBC compared to the other two centres. Environmental factors, particularly heat stress Sudjarwo et al. (2022), reported that FCR increases progressively increase in FCR under heat stress, due to reduced feed intake, impaired nutrient absorption, and lower productivity. Under such conditions, birds tend to prioritize thermoregulation over growth and egg production. Increased water intake may also dilute digestive enzymes, further reducing nutrient utilization. In addition, high temperature and humidity may compromise the feed quality during storage, by accelerating nutrient degradation, thereby exacerbating inefficiencies in feed conversion.

Table 1: Feed conversion ratio (FCR, kg feed per dozen eggs) of Hy-Line Brown parent stock across three poultry breeding centres (Mean±SD).

Centres	**FCR (Kg/dozen)**
RPBC	1.83±0.15^{a}
RPPBC	2.06±0.31^{b}
NPDC	2.79±0.91^{c}

**Values with different superscript letters in a column indicate significant difference at* $p < 0.05$.

Enteric diseases such as coccidiosis can further reduce feed efficiency by damaging the intestinal lining and reducing nutrient absorption. Another factor contributing to poor FCR may be the use of commercial layer feed (Karma Feed) across all centres, which may not adequately meet the nutritional requirements of PS birds. The layer diet feed contains 16.55% crude protein (CP), 2750 kcal/kg metabolizable energy (ME), and 4.1% calcium (Ca), which are slightly below the recommended levels of the Hy-Line International (2023). The Hy-Line International 2023 recommends 17.28% CP, 2650-3300 kcal/kg ME, 4.3% Ca and 0.35% phosphorus (P). Addressing these nutritional gaps may help mitigate these deficiencies. For instance, Wasti et al. (2020) reported that supplementation with vitamin C and E under heat stress improved gut integrity and nutrient absorption, resulting in enhanced feed efficiency.

3.4. Mortality rate

3.4.1. Mortality rate during 1-17 weeks of age

Figure 4 shows female mortality across the three farms with the mortality highest at RPBC, followed by RPPBC and lowest at NPDC. Significant differences ($p < 0.05$) in female mortality were recorded across centres during 1-17 weeks of age across the farms. The higher mortality at RPBC may be attributed to its lower mean ambient temperature (5.2°C) during the initial brooding period when DoCs are introduced. Despite standard brooding practices, such cold conditions can likely induce cold stress, impair thermoregulation, and increased mortality risk. Abdul-Rahman (2017) reported higher mortality rates during the wetter, colder season for both chicks and growers. In contrast, the relatively milder climatic conditions at RPPBC (13.76°C) and NPDC (20.92°C) likely reduced cold stress, contributing to lower female mortality at these centres.

Similarly, significant differences ($p < 0.05$) in male mortality were observed across the centres. As shown in Figure 5, NPDC recorded the highest male mortality, followed by RPBC, while RPPBC had the lowest. Nevertheless, mortality levels at all poultry centres remained below the 6%, which falls within the recommended standard of Hy-Line International 2023.

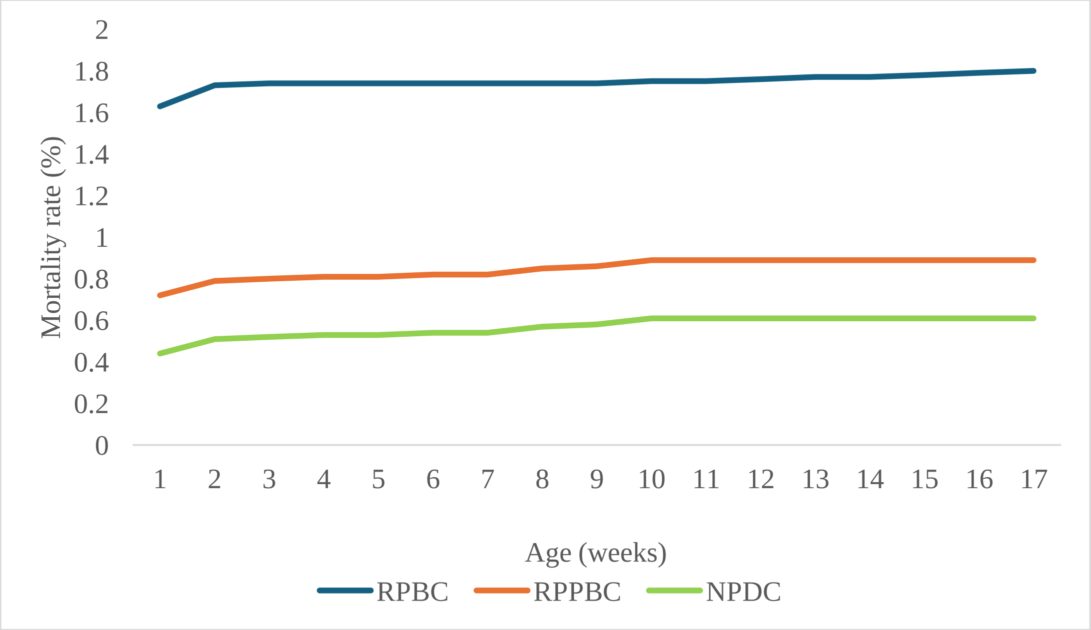

Figure 4: Female mortality rate (1-17 weeks of age).

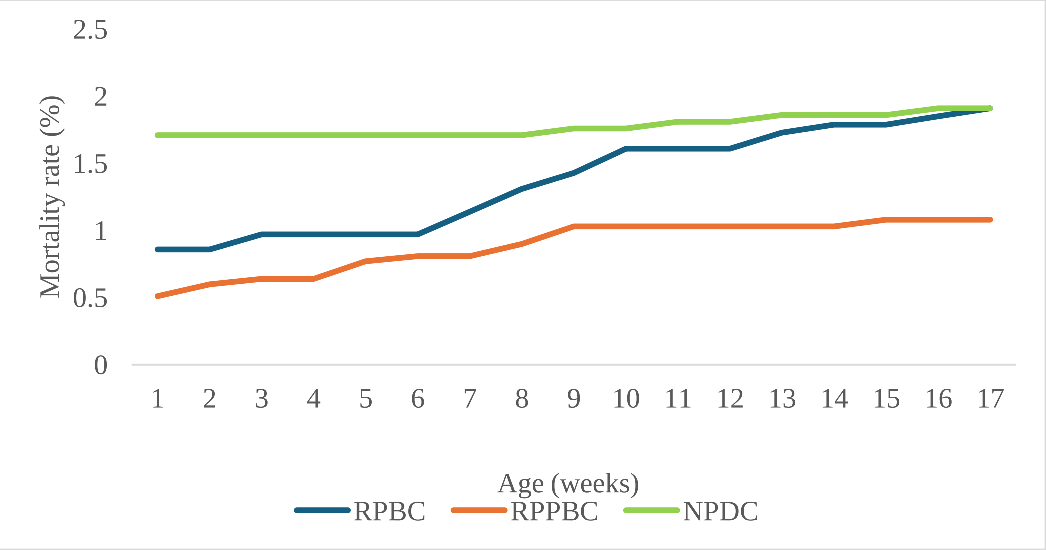

Figure 5: Male mortality rate (1-17 weeks of age).

The higher male mortality at NPDC may be associated with heat stress during brooding. Male chicks are generally more susceptible to heat stress due to their relatively higher metabolic rate, making them more vulnerable to environmental stressors. This is supported by Mitchell et al. (2018), who reported that male chicks are particularly sensitive to transport temperature fluctuations and handling procedures.

3.4.2. Mortality rate from 18-75 weeks of age

Significant differences ($p < 0.05$) in female mortality from 18-75 weeks of age were observed across the three poultry centres. As illustrated in Figure 6, NPDC recorded the highest female mortality, with a sharp increase starting at 32 weeks of age that persisted throughout the laying period. In contrast, RPBC and RPPBC maintained lower mortality levels, both remaining below the 11% standard recommended by the Hy-Line International 2023 wheras NPDC exceeded this threshold.

Comparatively, the lower mortality at RPBC and RPPBC may be due to more effective management practices during the early laying phase. Shittu et al. (2014), emphasized that layers between 19-38 weeks of age are particularly susceptible to physiological and environmental stressors. The increased mortality at NPDC is likely multifactorial. Higher ambient temperatures may have suppressed feed intake, limiting nutrient availability for body maintenance and egg production, while increasing risk of disease and mortality as reported by Bhawa et al. 2023. In addition, behavioral issues such as feather pecking and cannibalism, if inadequately managed, can further elevate mortality. Although beak trimming is commonly practiced to mitigate these behaviors, improper or poorly timed trimming may further induce additional pain and stress, leading to increased mortality.

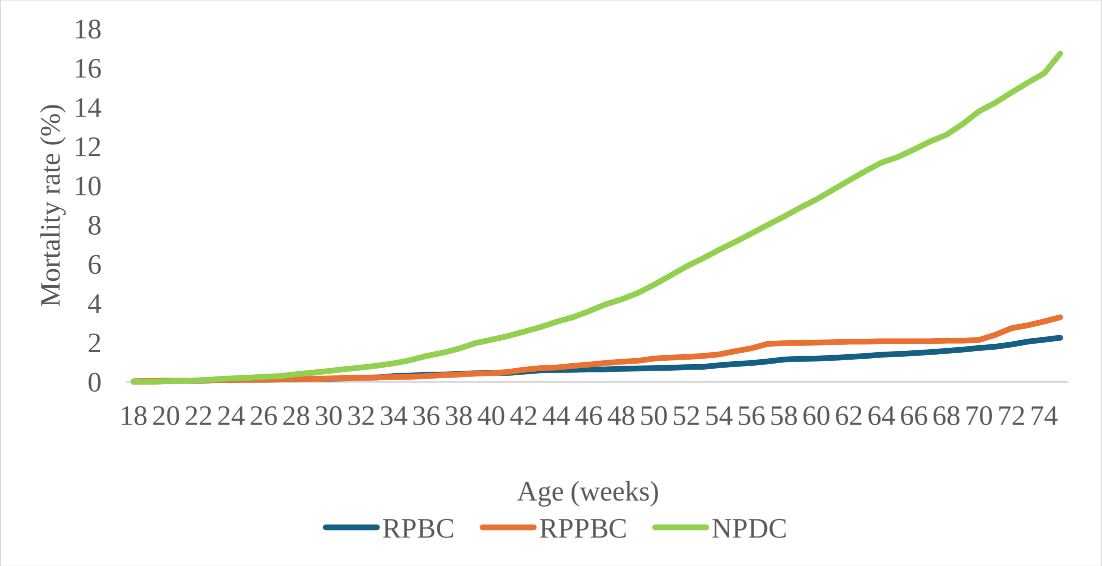

Figure 6: Female mortality (18-75 weeks of age).

Male mortality across the three poultry centres also differed significantly ($p < 0.05$). As shown in Figure 7, RPBC recorded the highest male mortality between 18-75 weeks of age, increasing rapidly after 50 weeks of age, RPPBC showed a steady increase, while NPDC recorded the lowest and most gradual trend. Male mortality for both RPPBC and NPDC remained below the 12% standard recommended by the Hy-Line International 2023. The sharp increase in male mortality observed at NPDC around week 63 was due to roundworm infestation which resulted in weakness and loss of appetite. Roundworm infection can increase mortality by impairing nutrient absorption and immune functionality, making the host more susceptible to secondary infections (Sharma et al. 2019).

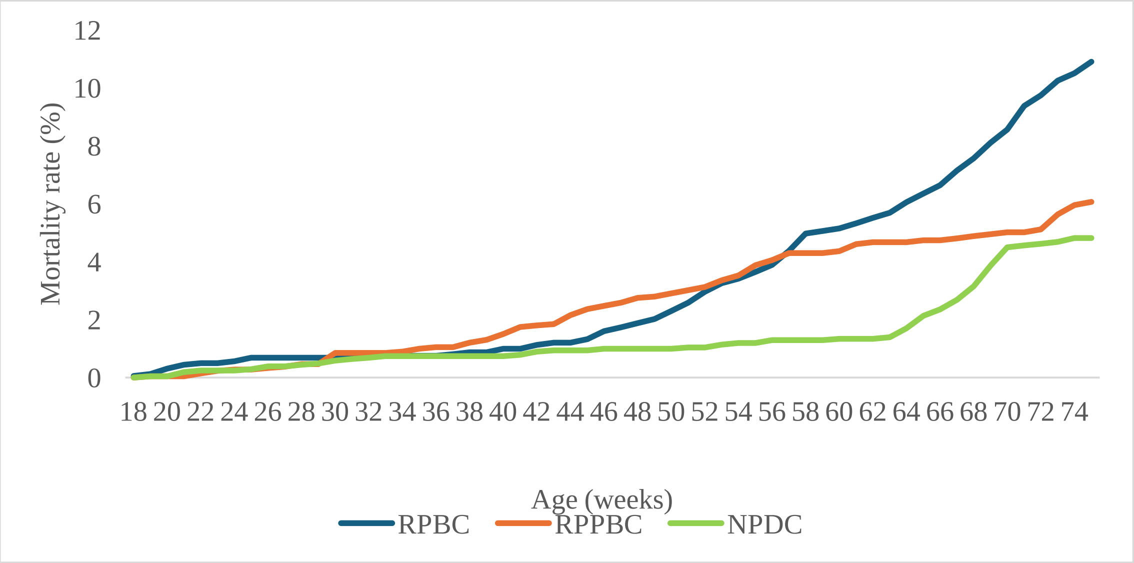

Figure 7: Male mortality rate (18-75 weeks of age).

3.5. Reproductive performance

In this study, the age at first lay was 134 days for NPDC, 136 days for RPBC and 146 days for RPPBC (Table 2). The recommended age at first lay is 140 days (Hy-Line International 2023). Accordingly, both NPDC and RPBC showed an early onset of lay, while RPPBC showed delayed start. The age at 50% lay was 149 for RPPBC, 151 days for RPBC, and 159 days for NPDC. RPBC reached 50% lay at 151 days, which is in alignment with the standard recommended by Hy-Line International 2023, while RPPBC reached 50% lay earlier than the recommended age standard. In contrast, NPDC exhibited a delay in achieving 50% production. Peak egg production was achieved at 173 days for RPPBC, 186 days for NPDC, and 219 days for RPBC.

Compared to the standard peak age of lay at 182 days, RPPBC reached peak production earlier than this benchmark whereas RPBC and NPDC exhibited a delayed peak production. The age at sexual maturity is influenced on multiple factors, with nutrition playing a fundamental role. Adequate energy intake is essential for supporting growth and initiating of reproductive function (Bahry 2024). Photoperiod also plays a key regulatory role, as extended daylight hours stimulate the release of gonadotropin-releasing hormone (GnRH), which subsequently promotes follicle-stimulating hormone (FSH) and luteinizing hormone (LH) secretion, leading to gonadal development (Bédécarrats et al. 2009). Besides, body weight is a key determinant of reproductive readiness. As reported by Hanlon et al. (2022), underweight hens may lack the required energy to commence lay, while overweight hens may accumulate excess fat around the oviduct, negatively impacting egg production efficiency.

For fertility rates, significant differences ($p < 0.05$) were observed among the centres. RPBC showed the highest fertility rate (88.37±4.15%), followed by NPDC (85.91±3.66%) and RPPBC (85.58±5.89%) (Table 3). Hatchability rates, both in terms of set eggs and fertile eggs, also varied significantly ($p < 0.05$). RPPBC achieved the highest hatchability performance, with set 56.20±10.64% for set eggs and 70.47±9.93% for fertile eggs. NPDC followed closely (55.81±11.82% for set eggs and 64.91±12.90% for fertile eggs), while RPBC recorded the lowest hatchability (44.78±13.67% for set eggs and 56.80±15.8% for fertile eggs).

Notably, the hatchability of fertile eggs are lower than the recommended standard of 78.41% set by Hy-Line International 2023. In contrast, Ajayi et al. (2021) reported higher fertility rates for Hy-Line Brown parent stock ranging from 91.66% to 96.32%, while El-Safty (2012) documented fertility rates ranging from 87.1% to 94.5% and hatchability between 76.4% and 83%. The variability in fertility and hatchability including environmental conditions, egg handling and incubation practices. Extreme temperatures negatively impact the reproductive health of male layer PS. Low ambient temperatures may impair semen production and sperm viability, while high temperatures can reduce fertility and embryo

Table 2: Age at sexual maturity (days).

Particulars	RPBC	RPPBC	NPDC
Age at first lay (days)	136	146	134
Age at 50% lay (days)	151	149	159
Age at peak lay (days)	219	173	186

Table 3: Fertility and hatchability rates of Hy-Line Brown parent stock across three poultry breeding centres (Mean±SD).

Particulars	**RPBC**	**RPPBC**	**NPDC**
Fertility (%)	88.37 ± 4.15^{a}	85.58 ± 5.89^{b}	85.91 ± 3.66^{b}
Hatchability set (%)	44.78 ± 13.67^{a}	56.20 ± 10.64^{b}	55.81 ± 11.82^{b}
Hatchability fertile (%)	56.80 ± 15.88^{a}	70.47 ± 9.93^{b}	64.91 ± 12.90^{b}

Values with different superscript letters in a row indicate significant difference at $p < 0.05$.

survival. Irivboje et al. (2019) also highlighted the influence of seasonal variation, noting decreased reproductive performance during dry seasons compared to wet seasons. In addition, poor sanitary conditions during egg collection and incubation can increase microbial contamination, leading to early embryonic mortality.

4. CONCLUSION

The study revealed significant variation in the production and reproductive performance of Hy-Line Brown PS across the three poultry breeding centres in Bhutan. RPBC, Paro consistently demonstrated better performance in egg production and fertility, RPPBC exhibited moderate production but achieved higher hatchability rates. These differences reflect the combined influence of environmental conditions, management, and hatchery practices. Although the findings are based on a single flock cycle, they provide baseline insights to guide targeted interventions for improving productivity and reproductive efficiency in Bhutan's poultry breeding program.

To enhance overall performance, it is recommended to adopt integrated management strategies, including optimized environmental control, improved biosecurity, centre-specific nutritional formulations, and enhanced hatchery management practices supported by targeted technical training. These interventions, coupled with continuous performance monitoring and data collection over multiple flock cycles, can help standardize performance across centres and ensure sustainable improvements in Bhutan's poultry breeding program.

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