DETERMINANTS OF REPEAT BREEDING IN SOWS AND GILTS AT THE NATIONAL PIGGERY DEVELOPMENT CENTRE IN BHUTAN: A RETROSPECTIVE STUDY

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Abstract: Repeat breeding represents a substantial economic repercussion in pig breeding. A retrospective analysis of EliteHerd database (April 2005- March 2023) and monthly technical reports (October 2015- March 2023) were analyzed to investigate repeat breeding cases at the National Piggery Development Center (NPiDC) in Bhutan. Data associated with repeat breeding were exported to Microsoft Excel from the EliteHerd database for descriptive statistics. Data from monthly technical reports were compiled in Microsoft Excel, and correlation and Kruskal-Wallis rank sum tests were performed using R v4.2.0. Overall, 19.2% of sows and gilts showed repeat breeding, with 44.2% (n=540) repeating regularly within specific interval (18-24 or 39-45 days), and 55.8% (n=682) repeating irregularly at varying times (0-17 or 25-38 or 46-108 days). Gilts representing 28.2% (n=461) of cases, experienced comparatively more repeat breeding, which declined with increasing parity. While a low positive correlation was observed between repeat breeding and thermal indices (temperature, humidity, and temperature-humidity index), other possible determinants were noticed. Increasing sow numbers (2%) coupled with declining boar numbers (5.8%) seemingly led to high usage of certain superior boars, potentially affecting fertility and return to service. About 38% (n=28) of the breeding boars were at times highly used. About 36% (n=440) of repeat breeders had returned ≥3 times and were not culled as technically required. Therefore, the determinants of repeat breeding were deemed to be the combined effect of hot summer temperature, high humidity, over-use of certain superior boars due to increasing sow levels, and non-culling of severe repeat-breeders on the farm among many other contributing factors.

Keywords: Ambient temperature; correlation; relative humidity; repeat breeding; sow and gilts; temperature-humidity index.

1. INTRODUCTION

Sow performance is an important component of productivity in pig breeding farms (Lopez 2008). The number of pigs weaned per sow per year (PSPY) is commonly used as benchmark to measure and compare the productivity of pig breeding herds (Dial et al. 1992). The pigs weaned PSPY are affected by reproduction problems leading to increased non-productive days (NPD) (Iida and Koketsu 2015). Non-culling of third-returned females can lead to existence of substantial number of severe repeat breeders in a breeding herd, thereby increasing NPD and affecting herd productivity (Koketsu 2005). Reproductive failure occurs in all pig breeding farms (Evans et al. 1990), and is common in pig production (Lopez 2008). The pig reproductive problems mostly result from deficiencies in management, nutrition, genetics, and environmental conditions (Levies 1989), besides disease conditions (Evans et al. 1990). Efficient diagnosis is possible only when reproductive records are accurately maintained, sorted and analysed (Levies 1989). Practically, reproductive problems can be categorized into one or more areas to apply specific investigation.

Repeat breeding (RB), a failure of a sow or gilt to conceive after natural mating or artificial inseminations can have substantial economic loss and welfare concern in pig breeding (Love 2010). Environmental factors, particularly high ambient temperatures and humidity, can influence sow fertility and contribute to RB. Several studies have found negative correlation between THI and sow fertility. The detrimental effects of high temperature-humidity index (THI) on sow fertility are multifactorial. Heat stress triggers physiological responses that disrupt reproductive processes. A meta-analysis by Nardone et al. (2013) found that for each unit increase in THI, conception rate decreased by 0.85%. This decline is mainly attributed to reduced progesterone production during the luteal phase (Munshi et al. 2015), impacting oocyte maturation and embryo development (Wettemann et al. 2012). High THI can also suppress oestrus cycling and ovulation rate in sows (Love 2010).

The EliteHerd© database and monthly technical reporting procedures at NPiDC enabled storage of (re)production data. However, routine analysis of these data was not conducted. Analysis of farm data could increase the dissemination of valuable information and improve reproductive performance of a farm (Koketsu et al. 2017). Given the numerous potential factors that influence RB, a desk study was deemed integral to identify key determinants for future improvement. Therefore, this study aims (1) to determine correlation between RB in sows and gilts and environmental factors such as ambient temperature (AT), relative humidity (RH) and THI, (2) to identify other potential factors contributing to RB in sows and gilts on the NPiDC farm.

2. MATERIALS AND METHODS

2.1.Study area

The NPiDC farm lies at 26˚52’ altitude north and 90˚29’longitude east at an altitude of 300 meters (Google Earth 2018). The area is located in South-Central Bhutan and falls under wet subtropical agro-ecological zone (MoAF 2015). The median annual temperature on the farm area is 26.6°C with a maximum of 38.6°C (July) and minimum of 9.2°C (January). The median humidity is 67.8% with a minimum of 47.7% (January) and maximum of 94.4% (in July). The THI ranged from 62.2 to 85.5 (NPiDC 2023). Likewise, the annual total rainfall was 5930.3 mm (NCHM 2017).

2.2. Data Source, Preparation and Statistical Analysis

A retrospective analysis was conducted using data from two sources - the EliteHerd© database (April 2005 - March 2023) and farm record data (October 2015 - March 2023). Data relevant to RB were extracted from the EliteHerd© database and monthly technical reports, and subsequently reviewed in June 2023. Additionally, individual boar usage data during the study period was retrieved to assess breeding frequency. The extracted data were exported to Microsoft Excel and then imported into R v4.2.0 (Vigorous Calisthenics) for descriptive and statistical analysis.

Kruskal-Wallis rank sum test was performed to evaluate significant differences in repeat breeding cases between hot and non-hot seasons. For this, spring and summer were categorized as the hot season, while autumn and winter were categorized as non-hot season.

Spearman's rank correlation was applied to evaluate the relationship between RB and THI, AT and RH. Average and median AT and RH were calculated from morning, noon, and evening climatic data recordings on the farm. Graphs, figures and tables were generated in Microsoft Excel and R. Data used for descriptive and correlations were from period October 2015 to March 2023. Number of RB female pigs were added for each month based on monthly technical reports. THI is the integration of temperature and humidity into one value (Wojtas et al. 2014), and it is widely used index to measure degree of heat stress in animals. THI was calculated using the formula developed by Thom (1959) and used by Mellado et al. (2018) as in the equation below.

Equation 1: $THI = (0.8*AT) + RH*(AT-14.4) + 46.4$

Where:
AT= ambient temperature in °C
RH=relative humidity in percentage

3. RESULTS AND DISCUSSION

3.1. Repeat breeding

Repeat breeding is the most frequent reproductive failure (Vargas et al. 2009). Parity-wise breeding and RB is presented in table 3.1. Out of 6360 female pigs served between April 2005 and March 2023, 28.2% (n=1637) were gilts (parity 0), resulting to low farrowing rate (54.5%; n=893). As parity increased, the number of RB has decreased resulting in increased farrowing rate (FR). The overall rate of RB was 19.2% (n=1223). However, much lower return rates were reported in literatures. For instance, about 10% (Koketsu 2003) and 11.7% of the served female pigs return to oestrus after mating (Savic et al. 2017). Suboptimal reproductive performance either due to low or high parity was also reported by Koketsu et al. (2017).

The mating index (MI) calculated by dividing 100 by the FR (i.e. 100/FR) indicated a need of 1.8 matings per successful farrowing in gilts and 1.4 matings in multiparous sows, suggesting a higher breeding requirement for primiparous females. In general, 36% (n=440) of sows and gilts served had repeated ≥ 3 times either in the same or later parity (Figure 3.1). Technically, third-returned pigs are to be culled. About 51% of the first return gilts had returned to estrus in the same or later parity which was higher compared to 41% observed by Koketsu et al. (2017). Furthermore, among the 461 gilts that repeated, a total of 74 (16%) had repeated three or more times. The low parity female pigs repeating three or more times can become severe repeat breeders, and thereby Koketsu et al. (2017) has advised close monitoring of low parity sows.

Table 3.1. Parity-wise mating and repeats of gilts and sows from April 2005 to March 2023

Category of female pigs served	No. of mating (served)	No. of repeat breeding	Farrowing rate (FR) (%)	Mating index (100/FR)	Repeat breeding rate (%)
Parity 0 (Gilts)	1637	461	54.5	1.8	28.2
Parity 1	1079	193	71.9	1.4	17.9
Parity 2	933	150	72.8	1.4	16.1
Parity 3	757	116	73.8	1.4	15.3
Parity 4	634	101	72.7	1.4	15.9
Parity 5	503	84	70.4	1.4	16.7
Parity 6	377	51	-	-	13.5
Parity 7	294	53	-	-	18.0
Parity 8	116	14	-	-	12.1
Parity 9	26	0	-	-	0.0
Parity 10	4	0	-	-	0.0
Overall	6360	1223			19.2

Categorization of RB based on the timing of oestrus return within the reproductive cycle allows to streamline diagnostic efforts on the problems most likely to occur during specific phases (Levies and Hoggs 1989). The EliteHerd program was capable of categorizing RB of female pigs as early, regular, irregular and late return to oestrus as presented in table 3.2. Besides, Levis and Hogg (1989) has categorized RB as regular (18-24 days) and delayed (>25 days) aimed at identifying the causes of RB problems more accurately. Repeat breeders tend to have short oestrus duration and weak oestrus signs which are hard to detect and time it appropriately for mating or inseminations (Koketsu et al. 2017).

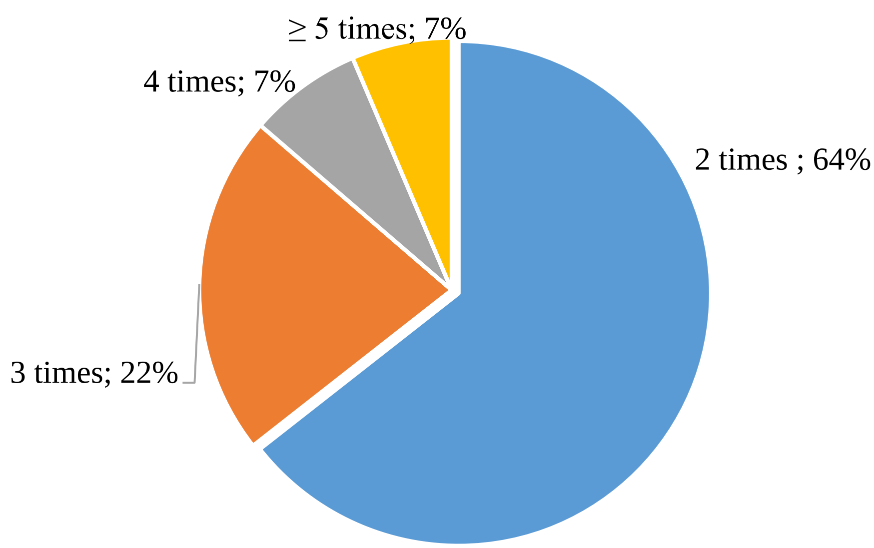

Figure 3.1. Proportion of sows or gilts returned to oestrus prior to their death or culling from the herd (2005-2023).

Table 3.2: Percentage of RB for gilts and sows after mating from April 2005 to March 2023

Early (0 - 17 days)	Regular (18 - 24 days)	Irregular (25 - 38 days)	Regular (39 - 45 days)	Late (46 - 108 days)
3.9	30.7	18.4	13.5	33.5

3.1.1. Regular return to oestrus (conception failure)

About 44.2% (n=540) of bred gilts and sows had repeated regularly either within 18-24 days or 39-45 days after service (Table 3.2). Specifically, the regular RB rate within 18-24 days was 30.7% (n=375) for this study. Evan et al. (1990) suggests to investigate both boar and sow infertility when regular repeat breeding within 18-24 days is more than 15%. A regular RB indicates either no conception or failure of maternal recognition (Almond et al. 2006). The regular RB in gilts is related to age and is due to an immature endocrine system (Koketsu et al. 2017). In this study however, the age of gilts may not be the reason for repeat breeding as the mean age of gilts were 412±94 days. Regular RB could be due to boar infertility and poor timing of mating. As per Levis and Hogg (1989), regular RB could be due to contributing factors such as ratio of boar to sow, sows/gilts are mated only once per oestrus period, short copulation time (less than 1.5 minutes), inadequate rotation of boars/excessive sexual activity of boars, extreme heat stress, and poor body condition scores (BCS) of sows at weaning.

3.1.2. Irregular return to oestrus pregnancy failure)

The remaining 55.8% (n=682) had repeated irregularly within 0-17 days, 25-38 days and 46-108 days after mating (Table 3.2). An irregular RB indicates conception but a subsequent early or late pregnancy loss (Almond et al. 2006). Sows and gilts returning to estrus irregularly after mating are also contributed by factors such as embryonic death, hormonal imbalance and oestrus detection problems (Levis and Hogg 1989).

Embryonic death occurs when sows are (1) heat stressed (> 29°C) during the first 30 days of gestation, (2) physically stressed (3-18 days after breeding) during intrauterine process of ova transport, blastocyst migration, spacing and implantation, and (3) ingestion of large doses (≥ 60 ppm) of the mycotoxin zearalenone in mycotoxin-contaminated feed after mating causing hormonal imbalances in females (Levis and Hogg 1989). Likewise, the delayed RB suggests a loss of early pregnancy (Evans et al. 1990). The late RB increase in higher-aged gilts (Tani et al. 2016) which may have degraded ovary functions and low progesterone concentration (Bertoldo et al. 2012). The annual RB cases had increased in sows/gilts with increasing number of matings over the years (Figure 3.2). The RB cases and sows/gilts served was strongly correlated (r=0.87).

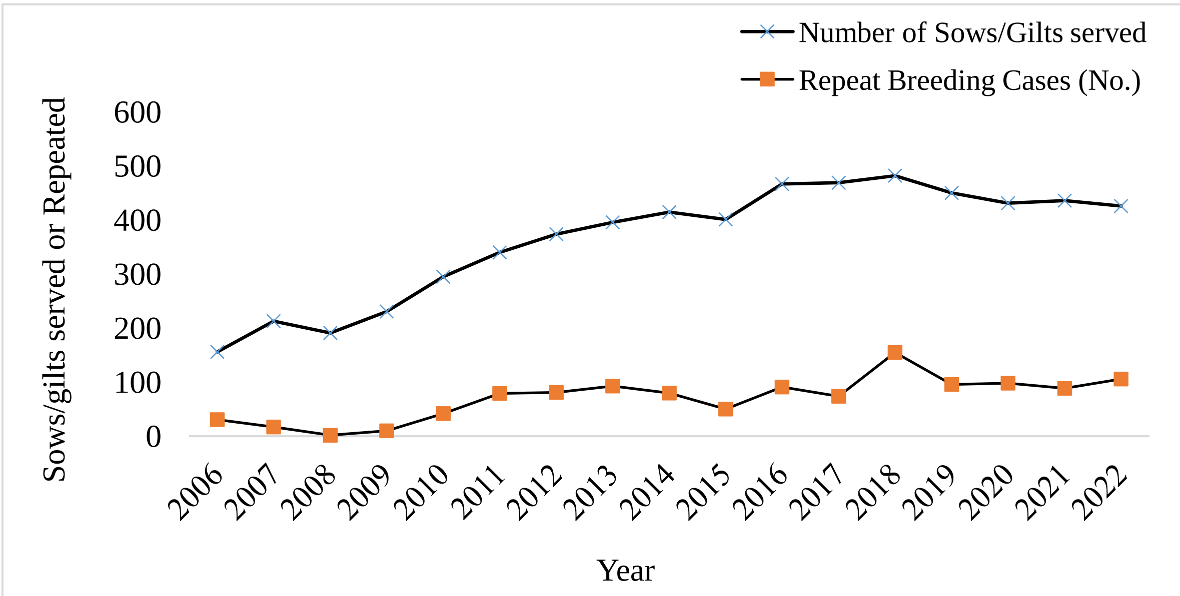

Figure 3.2. Annual trends of repeat breeding (RB) cases and female pigs served, analysed from 2006 to 2022. Data for 2005 and 2023 were excluded due to incomplete records for the entire year

3.1.3. Correlations between repeat breeding and thermal indices

According to Cohen (1988), the correlations between 0.5 and 1.0 were regarded as high, 0.30 and 0.49 as moderate, and correlations up to 0.29 as low. Low positive correlations were observed between RB and THI, AT and RH in this study (Figure 3.3). Although positively correlated, the weak correlation suggests that THI, AT and RH are not the main factor influencing RB rates on the farm. Other factors such as nutrition, health care, pig breed and management practices might be the primary factors influencing RB cases. Nevertheless, higher THI values were associated with a higher number of RB cases, suggesting heat stress could play a role in reducing sow fertility (Figure 3.4). Similar findings were reported by Mellado et al. (2018). Hot and humid conditions might impact various hormonal and physiological processes important for conception (Munshi et al. 2015).

Stress is a biological response to a perceived threat to its homeostasis, mediated by the hypothalamo-pituitary-adrenal (HPA) axis and activation of sympathetic adreno-medullary (SA) system (Einarsson et al. 2008). Summer heat stress disrupts physiological functions and reduces productivity (Haheeb et al. 1992). In pigs, heat stress affects implantation and impairs embryo development (Einarsson et al. 2008; Mellado et al. 2018). For example, Wettermann et al. (1988) observed fragmented embryos in heat-stressed gilts compared to normal (controlled) gilts. However, the negative effects of heat stress on reproduction depends on the duration and intensity of heat stress (Enarsson et al.

2008; Mellado et al. 2018). Temperatures up to 34°C from day 3 to 30 post-mating do not affect embryo survival (Liao and Veum 1994). Conversely, exposing sows to 35°C for 24 hours on the first day of gestation reduces embryo number by about 13% (of embryos per 100 corpora lutea) compared to non-stressed sows (Tompkins et al. 1967). This suggests that sows and gilts in early pregnancy is particularly sensitive to thermal stress.

Although the THI (or index) offers a valuable tool for assessing thermal stress in pigs, it should not be considered a definitive measure of thermal discomfort (Wojtas et al. 2014). Figure 3.5 supports this point as it did not reveal a clear association between hotter seasons and RB cases. Kruskal-Wallis test also did not find a statistically significant difference in repeat breeding cases between hot and non-hot season (*p*-value =0.7). Therefore, further exploration of other potential factors influencing repeat breeding is suggested. Nevertheless, the potential influence of seasonality on RB cannot be ignored, as suggested by the literature. Studies by Mellado et al. (2018) and Koketsu et al. (1997) observed seasonal influences on RB, with higher rates in summer and lower in winter. These findings are consistent with known detrimental effects of heat stress on reproductive processes, including reduced conception rates (Wolfenson and Roth 2019), farrowing rates (Janse van Rensburg and Spencer 2014), and overall reproductive efficiency in tropical environments (Tummaruk et al. 2004; Suriyasomboon et al. 2006). Moreover, Love (1978) reported that heat stress after mating can lead to infertility and litter loss in sows and gilts, suggesting its significant impact on reproductive success.

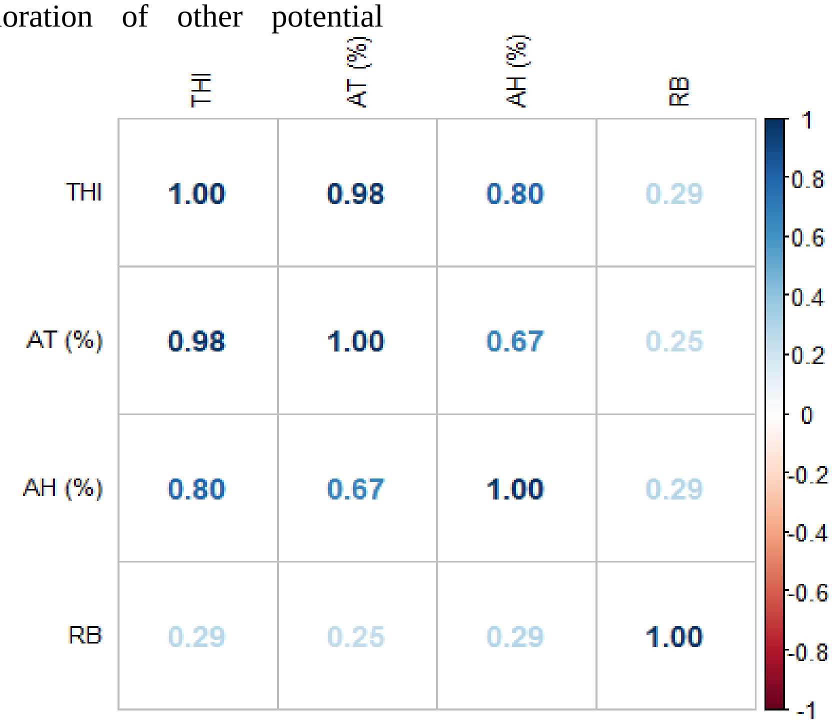

Figure 3.3. Correlation matrix between temperature humidity index (THI), ambient temperature (AT), relative humidity (RH), and Repeat Breeding (RB) in sows/gilts.

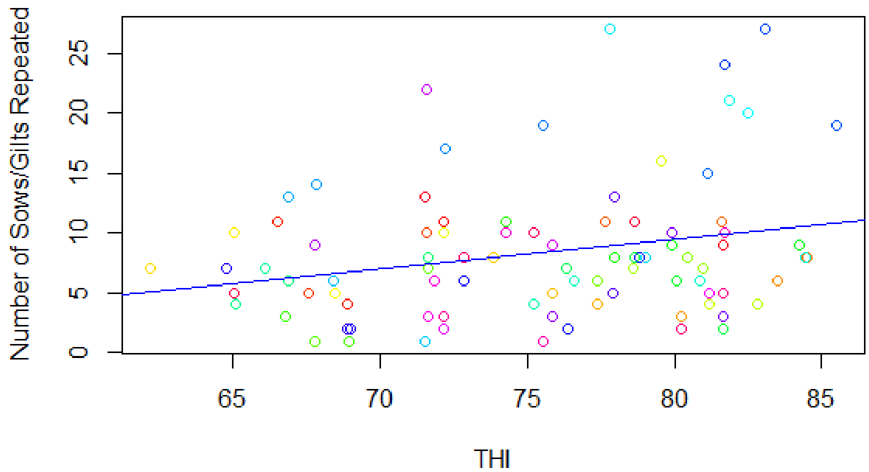

Figure 3.4. Scatter plot (visualization of relationship) between temperature humidity index (THI) and Repeat Breeding (RB) in sows/gilts.

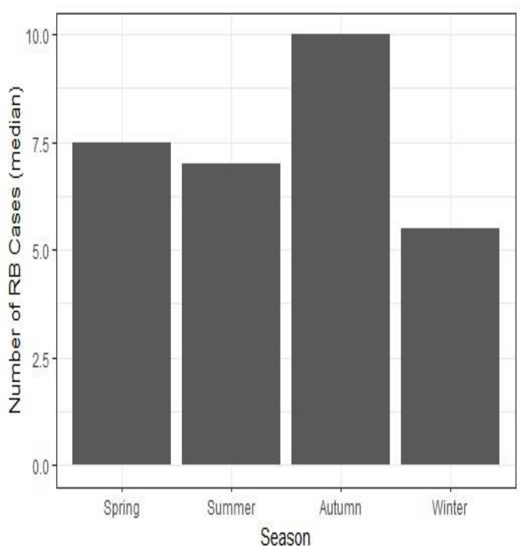

Figure 3.5. Seasonal variation of repeat breeding (RB) cases (median) from October 2015 – March 2023.

Besides sows and gilts, boars are also affected by high AT. Studies like Knecht et al. (2014) had found that boars experience lower sperm concentration during warmer seasons like spring and summer. This can be attributed to disruptions in spermatogenesis, the process of sperm production, due to heat stress. Colenbrander et al. (1993) and Thibault et al. (1966) observed decreased ejaculate volume and total sperm count in boars during and after summer affecting their fertility. Bertoldo et al. (2012) further confirmed this by reporting reduced fertility and prolificacy in boars during summer months. Therefore, investigation on this topic at NPiDC AI lab using enough sample size would be interesting.

3.1.4. Optimal ambient temperature pig breeding farms

Pregnant sows or gilts, including boars begin experiencing heat stress at ambient temperatures exceeding 29°C (Harmon and Levis 2010). Optimal air temperature range for sows and gilts are considered to be between 16°C and 20°C (Harmon and Levis 2010) or 13°C and 29°C (Canaday et al. 2009; Midwest Plan Service 2001). The median temperature on NPiDC farm ranged from 21.0°C (January) and 30.2°C (August). The economic impact of heat stress is substantial. In the United States alone, annual losses due to heat stress was estimated at $1 billion for the swine industry (St-Pierre et al. 2003). Similar losses were reported in regions like China, Brazil and Southeast Asia, highlighting global burden. Nevertheless, the impact of heat stress varies depending on regional climates, and tropical and subtropical regions experience greater losses due to higher ambient temperatures and humidity levels (Canh et al. 2023; Nardone et al. 2023). Heat stress disrupts pig physiology, leading to reduced feed intake, growth rate, and carcass quality. Estimates suggests losses of 5-15% in growth rate and 10-30% in feed efficiency (Mellado et al. 2018; Quinton et al. 2022). Heat stress can directly result in heat stroke and death, particularly in sows and piglets. In addition, heat stress weakens immune systems and make animals more susceptible to diseases, and increase mortality rates (Das eta l. 2016; Stojkovic et al. 2022).

While reproductive issues in swine farms often involve a complex interplay of factors, addressing specific problems can reap improvements in production even without definitive diagnosis (Evans et al. 1990). This observation is particularly relevant in the context of RB cases in sows and gilts at the NPiDC farm in Bhutan. The hot climatic conditions of the wet subtropical zone of Gelephu is suspected to be one of the determinants contributing to RB cases in sows and gilts. Given the complex interplay of factors, Koketsu et al. (2017) recommends seeking veterinary consultation to identify the specific causes of lowered farm productivity. A comprehensive evaluation by a veterinarian, including environmental assessments, physiological examinations, and diagnosis tests, can provide valuable insights into the specific factors contributing to RB. After consultation, targeted interventions addressing heat stress, reproductive management, and potential co-morbidities can be implemented to improve overall herd performance.

3.1.5. Frequency of boar use for optimal fertility

The EliteHerd© database was used to analyse boar usage patterns from October 2015 to September 2023. Boar use frequency was categorized as: low (1 time use per week), moderate (2-4 times use per week) and high (over 4 times use per week). Between October 2015 and March 2023, a total of 74 boars were used for mating (304 sows/gilts). From that, 37.9% (n=28) boars were occasionally subjected to high usage in order to meet the breeding needs of sows and gilts on the farm. The study also revealed a 2% annual increase in sow numbers, while the average number of breeding boars on the farm decreased by 5.8% annually (from 32 in 2015 to 17 boars in 2023), during the same period. The divergences raise concerns about potential overwork for individual boars when the number of females required to serve increases. Ideally, the technical benchmark used by the farm is one breeding boar for every 10 productive female pigs. Previous studies found that frequency of mating impacts sperm quality and conception rates. Singleton and Flowers (2002) observed a rapid decline in sperm count when a boar is mated every 12 hours intervals, potentially reaching levels insufficient for optimal fertilization (2.5-3 billion spermatozoa). As stated by Levis et al. (2011), excessive boar usage can lead to fertility issues. Boars require adequate sexual rest to maintain optimal sperm production and quality. Boars that were mated one time a day has higher pregnancy rates compared to those more than once a day (Levis et al. 2011). Conversely, Umesiobi et al. (2002) observed sperm with high motility and improved conception rate in females with moderate mating frequency. Longer resting periods between matings leads to larger semen volumes, associated with higher farrowing rates and litter sizes (Umesiobi 2010). Based on the understanding from literature, implementing an appropriate rest period and balanced boar usage may be a viable strategy to improve fertility rates in sows and gilts, as well as to ensure both sow and boar welfare on the farm. Therefore, regular monitoring of boar usage pattern and adjusting individual boar mating schedule is recommended.

Pigs are highly susceptible to heat stress due to limited sweat glands and compromised cardiovascular system (Fraser 1970). This vulnerability poses a potential threat to sperm production and boar fertility. Einarsson et al. (2008) emphasized the importance of implementing appropriate technologies to regulate AT and RH and mitigate the negative impacts of heat stress on boar reproductive function. Such measures are crucial for maintaining optimal sperm quality, as well as to improve fertility rates of sows and gilts on the farm.

4. CONCLUSION AND RECOMMENDATIONS

This study investigated repeat breeding in sows and gilts. Thermal indices (AT, RH and THI) showed low positive correlations with RB. Limited sample size available for correlation analysis may be a reason for weak correlations. Additionally, high boar usage, potentially driven by a reducing boar number relative to increased sow numbers, was observed. Considering both study findings and existing literature, addressing environmental, boar usage and gilt selection factors on the farm are deemed important. Therefore, a multi-pronged approached recommended as follow:

- Implement temperature-humidity control systems like sprinkles and fans.
- Implement strict boar usage protocols, boar rotation and limiting services to two per heat period to optimize sperm quality.
- Cull third-returned sows or gilts on the farm to avoid existence of severe repeat-breeders.
- Select gilts from female-biased litters as based on literature, those from male-biased litters (> 67% males) are more likely to experience repeat breeding.
- Comprehensive review extending investigations to other reproductive parameters, including sperm quality traits and refine management strategies on the farm.

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