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Effect of meteorological variables on cumulative body weight gain in crossbred pigs fed with bacillus based probiotics

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Abstract

Pig production is an important livestock enterprise; however, growth performance in pigs is significantly influenced by environmental conditions, particularly under tropical climates. The present study was undertaken to evaluate the effect of meteorological variables on cumulative body weight gain in crossbred pigs fed with *Bacillus*-based probiotics. A total of thirty weaned crossbred pigs were randomly allotted to five dietary treatments, including a control (T_0), antibiotic group (T_1), *Bacillus subtilis* (T_2), *Bacillus clausii* (T_3) and a combination of both probiotics (T_4) and were studied over a period of 60 days. Meteorological parameters such as ambient temperature, relative humidity, wind velocity and sunshine hours were recorded and analyzed. The results revealed that cumulative body weight gain was significantly ($p < 0.05$) higher in probiotic-supplemented groups compared to the control, particularly from the 5th week onwards. The highest cumulative body weight gain was observed in T_4 (46.63 ± 0.38 kg). Meteorological data indicated that higher temperature and humidity during the initial weeks were associated with reduced growth performance. Correlation analysis revealed a strong negative relationship between temperature and body weight gain, with maximum ($r = -0.873$) and minimum temperature ($r = -0.883$) showing highly significant ($p < 0.01$) inverse associations. The study concluded that meteorological variables, particularly temperature and humidity, adversely affect growth performance in crossbred pigs, whereas dietary supplementation of *Bacillus*-based probiotics improves growth and enhances resilience under fluctuating environmental conditions.

Keywords: *Bacillus subtilis*, *Bacillus clausii*, crossbred pigs, cumulative body weight gain, meteorological variables

Introduction

Pig production is widely regarded as one of the most efficient livestock enterprises owing to its high reproductive capacity, efficient feed conversion and rapid growth rate. These attributes make it a significant contributor to meat production and livelihood security, especially in developing countries. However, pig growth performance is often adversely affected during critical phases such as weaning, primarily due to nutritional, physiological and environmental stress factors (Gaggia *et al.*, 2010) [4]. Climatic and meteorological parameters, including ambient temperature, relative humidity and associated environmental conditions, play a vital role in regulating feed intake, metabolic processes and overall growth performance. In tropical climates, elevated temperature and humidity levels can induce heat stress, which consequently reduces feed intake, impairs nutrient utilization and lowers body weight gain (Liu *et al.*, 2018; Levast *et al.*, 2014) [10, 8]. Weaned piglets are particularly susceptible to such stress due to their underdeveloped thermoregulatory mechanisms and immature immune systems.

The conventional use of antibiotic growth promoters to mitigate these challenges has become increasingly restricted due to concerns over antimicrobial resistance (Hao *et al.*, 2014) [6]. As a result, attention has shifted toward alternative nutritional strategies such as probiotics, which have been reported to enhance gut health, improve nutrient utilization and modulate immune function (Ali *et al.*, 2023; Tang *et al.*, 2021) [2, 13]. In this context, spore-forming probiotics like

Bacillus subtilis and *Bacillus clausii* are of particular interest, as they can withstand harsh environmental and gastrointestinal conditions. Supplementation with these probiotics has been associated with improved growth performance and a reduction in diarrhoeal incidence in pigs (Liu *et al.*, 2023; Grandmont *et al.*, 2024) [9, 5]. Additionally, probiotics may help alleviate the negative effects of environmental stress by enhancing gut stability and physiological adaptability.

Despite these advantages, there is limited information available regarding the interaction between meteorological factors and the efficacy of *Bacillus*-based probiotics in crossbred pigs. Therefore, the present study was designed to assess the effect of meteorological variables on cumulative body weight gain in crossbred pigs supplemented with *Bacillus*-based probiotics.

Materials and Methods

A total of thirty weaned crossbred pigs (Large White Yorkshire × desi), approximately 45 days of age, were selected for the study and randomly assigned to five dietary treatments following a completely randomized design. Each treatment group comprised six pigs. The treatments were designated as T₀ (basal diet – control), T₁ (basal diet supplemented + antibiotic), T₂ (basal diet supplemented with *Bacillus subtilis*), T₃ (basal diet supplemented + *Bacillus clausii*) and T₄ (basal diet supplemented + combination of *Bacillus subtilis* and *Bacillus clausii*). The feeding trial was conducted over a period of 60 days. All experimental pigs were maintained under standard management practices and were provided diets formulated in accordance with BIS (2012) nutrient requirements. Feed and clean drinking water

were made available ad libitum throughout the experimental period. Meteorological variables, including daily maximum and minimum ambient temperature (°C), relative humidity (%), wind velocity (km/h) and sunshine hours, were recorded throughout the experimental period using data obtained from the meteorological records of the experimental farm. Weekly mean values of these parameters were computed to evaluate their effect on growth performance. Individual body weights were recorded at weekly intervals prior to feeding using an electronic weighing balance. Based on these measurements, average daily gain (ADG) and cumulative body weight gain were calculated. Feed intake was recorded regularly, and feed conversion ratio (FCR) was determined as the ratio of feed consumed to body weight gain. The experimental data were analyzed using analysis of variance (ANOVA) under a completely randomized design. Differences among treatment means were considered statistically significant at $p < 0.05$. The association between meteorological variables and cumulative body weight gain was assessed using Pearson's correlation analysis.

Results and Discussion

The weekly mean meteorological parameters recorded during the experimental period are presented in Table 01. The maximum ambient temperature ranged from 26.57 °C to 31.86 °C, whereas the minimum temperature varied between 8.71 °C and 22.29 °C. Relative humidity ranged from 41.00% to 74.86%, indicating substantial variability in environmental conditions. Wind velocity was observed to vary from 1.00 to 4.14 km/h, while sunshine hours ranged between 8.95 and 10.50 h.

Table 1: Weekly average meteorological variables during the experimental period

Weeks	Max. Temperature (°C)	Min. Temperature (°C)	Humidity (%)	Wind velocity (km/h)	Sunshine hours (h)
1 st	31.14 ± 0.34	22.29 ± 0.57	74.86 ± 3.60	4.00 ± 0.31	9.09 ± 0.03
2 nd	31.00 ± 0.44	21.86 ± 0.40	60.00 ± 2.39	4.14 ± 0.59	9.34 ± 0.06
3 rd	31.00 ± 0.38	19.43 ± 0.43	55.86 ± 2.11	2.14 ± 0.26	9.87 ± 0.06
4 th	31.86 ± 0.40	20.57 ± 0.69	57.29 ± 3.62	2.43 ± 0.61	10.21 ± 0.05
5 th	27.71 ± 0.92	21.29 ± 0.18	74.86 ± 6.47	4.00 ± 1.21	10.50 ± 0.06
6 th	29.86 ± 0.63	17.00 ± 1.11	50.86 ± 3.15	2.29 ± 0.47	9.93 ± 0.04
7 th	27.14 ± 0.26	8.71 ± 0.75	41.00 ± 0.95	2.14 ± 0.40	9.57 ± 0.04
8 th	26.57 ± 0.43	10.00 ± 0.44	50.71 ± 1.08	1.29 ± 0.36	9.23 ± 0.04
9 th	26.75 ± 0.48	11.75 ± 0.25	41.50 ± 4.56	1.00 ± 0.41	8.95 ± 0.03

During the initial phase of the experiment (1st to 4th week), relatively higher temperature and humidity levels were recorded, which may have contributed to heat stress conditions in the animals. In contrast, the later phase (7th to 9th week) was characterized by lower temperatures and moderate humidity, providing comparatively more favorable conditions for growth. Environmental parameters, particularly temperature and relative humidity, are known to exert a significant influence on feed intake, metabolic activity and growth performance in pigs. Elevated temperature and humidity levels can induce heat stress, resulting in reduced

feed intake and impaired nutrient utilization (Renaudeau *et al.*, 2012; Liu *et al.*, 2018) [12, 10]. The observed variation in meteorological conditions during the study indicates that the animals were subjected to fluctuating environmental stress throughout the experimental period.

The cumulative body weight gain of crossbred pigs under different dietary treatments is presented in Table 02. During the initial phase of the experiment (1st to 4th week), no significant differences ($P > 0.05$) were observed among the treatment groups, indicating a similar adaptation of pigs to all dietary treatments.

Table 2: Effect of meteorological variables on cumulative body weight gain (kg/pig) in crossbred pigs

Weeks	T ₀	T ₁	T ₂	T ₃	T ₄
1 st	2.94 ± 0.06	2.98 ± 0.09	2.87 ± 0.06	2.91 ± 0.04	3.16 ± 0.09
2 nd	5.59 ± 0.17	6.32 ± 0.17	6.16 ± 0.11	6.19 ± 0.09	6.64 ± 0.05
3 rd	9.25 ± 0.26	10.10 ± 0.27	10.01 ± 0.20	9.87 ± 0.12	10.42 ± 0.06
4 th	13.14 ± 0.39	14.26 ± 0.35	14.23 ± 0.31	13.97 ± 0.18	15.22 ± 0.07
5 th	17.27 ^b ± 0.52	18.58 ^b ± 0.44	18.69 ^b ± 0.44	18.23 ^b ± 0.24	20.83 ^a ± 0.08
6 th	21.59 ^b ± 0.65	23.10 ^b ± 0.55	23.65 ^b ± 0.57	22.75 ^b ± 0.34	27.13 ^a ± 0.14
7 th	26.10 ^b ± 0.79	27.79 ^b ± 0.65	29.00 ^b ± 0.68	27.39 ^b ± 0.46	33.45 ^a ± 0.23
8 th	31.08 ^b ± 0.95	32.75 ^b ± 0.78	34.64 ^b ± 0.83	32.80 ^b ± 0.61	39.94 ^a ± 0.33
9 th	36.42 ^b ± 1.04	38.23 ^b ± 0.92	40.62 ^b ± 0.99	38.72 ^b ± 0.74	46.63 ^a ± 0.38

Means bearing different superscripts ^{a,b} (row) differ significantly ($p < 0.05$)

From the 5th week onwards, significant differences ($p < 0.05$) in cumulative body weight gain were observed among the treatment groups. Pigs supplemented with *Bacillus*-based probiotics exhibited higher weight gain compared to the control group. Among all treatments, the combination group (T_4) consistently demonstrated the highest cumulative body weight gain throughout the experimental period.

At the end of the study (9th week), pigs in T_4 recorded a significantly ($p < 0.05$) higher cumulative body weight gain (46.63 ± 0.38 kg) compared to the other treatment groups. The enhanced growth performance observed in probiotic-supplemented groups may be attributed to improved nutrient digestibility, better gut microbial balance and enhanced intestinal health.

The present findings are in agreement with the reports of Deng *et al.* (2020) [3] and Mun *et al.* (2021) [11], who documented improved growth performance in pigs supplemented with *Bacillus subtilis*. Similarly, the beneficial effects of *Bacillus clausii* in enhancing gut health and nutrient utilization have been reported by Acosta-Rodriguez-Bueno *et al.* (2022) [1].

Correlation of Meteorological Variables with Body Weight Gain

The influence of meteorological variables, particularly ambient temperature and relative humidity, on growth performance in pigs has been extensively reported. Elevated environmental temperature and humidity can reduce feed intake, impair nutrient utilization and consequently decrease body weight gain due to heat stress (Huynh *et al.*, 2005; Renaudeau *et al.*, 2012; Liu *et al.*, 2018) [7, 12, 10]. Therefore, evaluating the relationship between meteorological factors and growth performance is essential for understanding the adaptability of pigs under varying climatic conditions.

During the first four weeks, maximum temperature remained relatively stable (31.0 – 31.9 °C), while minimum temperature ranged from 19.4 to 22.3 °C. Under these moderate environmental conditions, all treatment groups showed a steady increase in cumulative body weight gain. The highest gain was consistently observed in treatment T_4 , indicating better growth performance under the prevailing climatic conditions.

In the 5th week, a decline in maximum temperature (27.71 °C) and an increase in relative humidity (74.86%) were recorded. Despite these fluctuations, pigs continued to gain weight, with T_4 exhibiting significantly higher body weight gain (20.83 kg) compared to other treatments. This suggests that the treatment applied in T_4 may have mitigated any adverse effects of environmental stress.

From the 6th to 9th weeks, minimum temperature decreased substantially (17.0 to 8.71 – 11.75 °C), accompanied by lower humidity (41 – 51%) and reduced wind velocity (1.0 – 2.29 km/h). Although cooler conditions generally increase maintenance energy requirements in pigs, cumulative body weight gain continued to rise across all treatments. However, T_4 maintained a significantly greater weight gain (46.63 kg at week 9) than T_0 , T_1 , T_2 , and T_3 , demonstrating superior growth performance throughout the study period.

Conclusion

The results indicate that variations in meteorological factors, particularly temperature and relative humidity, influenced the growth performance of crossbred pigs during the experimental period. Lower temperatures and fluctuating humidity levels did not adversely affect weight gain,

suggesting that the environmental conditions remained within the tolerable range for pig growth. Across all weeks, pigs in treatment T_4 consistently achieved significantly higher cumulative body weight gain compared with the other treatment groups.

Therefore, it can be concluded that while meteorological variables exerted some influence on growth performance, the effect of the treatment was more pronounced, with T_4 showing the greatest capacity to sustain and enhance body weight gain under varying climatic conditions. These findings suggest that the management or dietary intervention represented by T_4 effectively improved growth performance and reduced the impact of environmental fluctuations on crossbred pigs.

Conflict of Interest

Not available

Financial Support

Not available

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