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Influence of different bedding materials on microclimatic variables in farrowing pens[#]

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Abstract

This study was conducted at the Centre for Pig Production and Research, Mannuthy to investigate the influence of flooring enrichments on the microclimatic environment of Large White Yorkshire (LWY) sows and their piglets. Three flooring systems were evaluated: T1 (concrete floor), T2 (hay bedding) and T3 (wood shavings bedding). The bedding was maintained at a uniform thickness of 7.5 cm and replaced as required based on moisture content. All sows were housed in pens measuring 3 m × 2 m. Microclimatic parameters like air temperature (°C), relative humidity (%) and floor surface temperature (°C) were recorded weekly at 9:00 a.m., 1:00 p.m. and 5:00 p.m. using a mini data logger (Testo 174h) and infrared thermometer (Testo 835). Results showed that relative humidity was consistently highest in T1, followed by T2 and T3 (P<0.05). Air temperature was largely consistent across groups (P>0.05) with slightly higher values in enriched groups and diurnal variation was evident, with peak values at 5:00 p.m. Floor temperatures were lowest at 9:00 a.m., with significantly high values in T2 at 5:00 p.m. Techno-economics indicate that the use of bedding materials as floor enrichments, particularly hay, not only enhanced animal comfort but also improved overall profitability under experimental conditions. Overall, enriched flooring moderated pen microclimate and improved thermal comfort compared to concrete floors despite the temperature variations.

Keywords: *Micro-climate, relative humidity, enrichments, floor temperature, techno economics*

Microclimatic conditions within pig housing are a major concern of animal welfare and productivity. Pigs, with their limited sweat gland, are highly sensitive to environmental variations, relying on behavioural and respiratory mechanisms to maintain thermal balance. Elevated ambient temperatures, particularly when combined with high relative humidity (RH), exacerbate heat stress, leading to increased respiration rate, rectal temperature and reduced feed intake, ultimately impairing growth and welfare (Huynh et al., 2005, Pourouchottamane et al., 2013). Housing design, especially flooring and bedding systems, plays a significant role in regulating pen microclimate. Solid concrete floors are commonly used in intensive pig production but often retain higher humidity levels, whereas enriched systems using organic substrates

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such as hay or wood shavings provide insulation, moisture absorption and environmental enrichment, thereby moderating floor temperature and humidity. Studies have demonstrated that bedding materials enhance animal comfort and promote natural behaviours, depending on material type and management (Hötzel et al., 2009; Amaral et al., 2021; George, 2023). Similar findings in dairy cattle highlight that bedding depth and replacement frequency influence microclimatic conditions and welfare outcomes (Geetha, 2022).

Furthermore, microclimatic variations between different flooring systems significantly affect pig performance and thermal comfort (Subhalekha et al., 2021). The present study was conducted to assess the impact of flooring enrichments with hay and wood shavings over concrete floor on micro-climatic parameters like air temperature, relative humidity and floor surface temperature, with emphasis on their implications for the welfare of Large White Yorkshire sows and piglets.

Materials and methods

This study was conducted at the Centre for Pig Production and Research, Mannuthy to investigate the influence of flooring enrichments on the microclimatic environment of Large White Yorkshire (LWY) sows and their piglets. Three flooring systems were evaluated: T1 (concrete floor), T2 (hay bedding) and T3 (wood shavings bedding). The bedding was maintained at a uniform thickness of 7.5 cm and replaced as required based on moisture content (>25%). All sows were transferred to their respective farrowing pens with dimensions 3m×2m, 10 days prior to the expected date of farrowing and remained there until weaning of piglets. Micro-climatic parameters like air temperature, floor surface temperature and relative humidity in each pen were recorded to determine their effects on the welfare of LWY sows and their piglets.

Microclimatic parameters like the air temperature, relative humidity and floor temperature were recorded once weekly at 9:00 am, 1:00 pm and 5:00 pm throughout the study period. The relative humidity (%) and air temperature (°C) of each pen were recorded using mini data logger (Testo 174h). Surface temperatures (°C) of the floor of each pen were measured using infrared thermometer (Testo 835). Techno economics of different models were also assessed.

Statistical analysis

The collected data were statistically analyzed by repeated measures ANOVA followed by Least Significance Difference test (LSD) using Statistical Product and Service Solutions (SPSS) Version 24.0.

Results and discussion

Air temperature (°C)

The mean air temperature of the interior of the shed at 9:00 a.m., 1:00 p.m. and 5:00 p.m. are presented in

Table 1. Mean air temperature (°C) within pens

Week	Treatment	Time (Mean ± SE)		
		9a.m.	1p.m.	5p.m.
1	1	30.74 ^{B} ± 0.59	31.59 ^{B} ± 0.44	32.06 ^{A} ± 0.65
	2	29.99 ^{C} ± 0.82	31.4 ^{B} ± 0.42	32.87 ^{A} ± 0.3
	3	30.17 ^{B} ± 0.4	31.71 ^{AB} ± 0.48	32.51 ^{A} ± 0.74
2	1	29.6 ^{B} ± 0.67	30.73 ^{A} ± 0.47	31.44 ^{A} ± 0.28
	2	30.44 ^{C} ± 0.63	32 ^{A} ± 0.6	32.2 ^{A} ± 0.51
	3	30.23 ^{A} ± 0.61	31.53 ^{A} ± 0.5	31.66 ^{A} ± 0.18
3	1	30.71 ^{A} ± 0.57	30.77 ^{A} ± 0.52	31.74 ^{A} ± 0.53
	2	30.87 ^{C} ± 0.61	32.24 ^{B} ± 0.62	32.27 ^{A} ± 0.53
	3	30.41 ^{A} ± 0.3	31.27 ^{A} ± 0.25	32.07 ^{A} ± 0.83
4	1	30.77 ^{A} ± 0.63	30.77 ^{A} ± 0.52	31.23 ^{A} ± 0.55
	2	29.8 ^{B} ± 0.52	31.87 ^{A} ± 0.24	32.16 ^{A} ± 0.67
	3	30.47 ^{A} ± 0.84	31.44 ^{A} ± 0.54	32.11 ^{A} ± 0.58
5	1	29.89 ^{C} ± 0.63	30.83 ^{B} ± 0.33	32.27 ^{A} ± 0.47
	2	30.2 ^{B} ± 0.39	31.39 ^{AB} ± 0.38	32.88 ^{A} ± 0.26
	3	30.71 ^{A} ± 0.88	31.66 ^{A} ± 0.5	32.46 ^{A} ± 0.68
6	1	29.57 ^{C} ± 0.69	31.11 ^{B} ± 0.34	32.47 ^{A} ± 0.47
	2	30.27 ^{B} ± 0.51	32.23 ^{A} ± 0.43	32.97 ^{A} ± 0.48
	3	30.69 ^{B} ± 0.7	31.63 ^{B} ± 0.52	32.44 ^{A} ± 0.35

Means with different superscripts (A-C within row) differ significantly at 0.05 level

Table 1. Throughout the six weeks, air temperature at 9:00 a.m. was generally consistent across treatments, with no significant differences (*P*>0.05) observed in most weeks. However, wood shavings pens (T3) tended to maintain relatively warmer mornings compared to hay bedding (T2) and concrete flooring (T1), which showed the lowest morning values.

By 1:00 p.m., temperatures rose significantly in all treatments compared to morning readings, though differences between groups were non-significant and midday values consistently reflected the diurnal rise, with wood shavings pens maintaining slightly higher values than the other treatments. At 5:00 p.m., temperatures peaked across treatments, significantly higher (*P*<0.05) than both morning and midday readings in certain weeks. During this period, hay bedding (T2) and wood shavings (T3) groups generally recorded the highest evening temperatures, while concrete floors (T1) maintained the lowest, with no significant differences observed for six weeks.

Relative humidity (%)

The mean relative humidity of the interior of the shed at 9:00 a.m., 1:00 p.m. and 5:00 p.m. are presented in Table 2.

Across all six weeks, relative humidity (RH) at 9:00 a.m. was consistently highest in T1 (concrete floor), followed by T2 (hay bedding) and T3 (wood shavings). Within each week, concrete floor pens maintained significantly higher (*P*<0.05) RH than both enriched-floor treatments, while hay-bedded pens recorded significantly higher values than those with wood shavings. RH at 9:00 a.m. remained statistically consistent across weeks in T1, whereas T3 showed significant week-wise variation, with lower values in weeks 2 and 5. At 1:00 p.m., RH followed a similar trend, with T1 recording the highest values, significantly exceeding those of T2 and T3, and wood shavings maintaining higher RH than hay in all weeks. Midday RH was generally lower than morning values across all treatments. By 5:00 p.m., RH was lowest compared to both earlier readings, though T1 still maintained significantly higher values than T2 and T3 (*P*<0.05), and hay bedding exceeded wood shavings in most weeks. Additionally, in concrete floor pens, evening RH was significantly lower than both morning and midday measurements.

The microclimatic variables, particularly relative humidity (RH) and air temperature (°C), inside the farrowing pens showed consistent trends across treatments and time points. At 9:00 a.m., RH was significantly higher in concrete-floored pens (80.6–85.6%) compared to hay-bedded (72.3–81.3%) and wood shavings (63.2–75.6%) treatments. This variation may be attributed to differences in absorbency and evaporative properties among the flooring materials. Morning air temperatures were generally lower than those observed later in the day. Although no significant treatment differences were detected in the morning, T1 and T2 remained cooler than their midday

Table. 2. Mean relative humidity (%) within pens

Week	Treatment	Time (Mean ± SE)		
		9a.m.	**1p.m.**	**5p.m.**
1	**1**	$85.53^{aA} \pm 0.74$	$82.56^{aB} \pm 0.49$	$80.47^{aC} \pm 0.71$
	2	$75.57^{bA} \pm 0.82$	$74.3^{bA} \pm 1.05$	$74.91^{bA} \pm 1.14$
	3	$66.29^{cC} \pm 0.74$	$66.97^{cB} \pm 0.6$	$69.27^{cA} \pm 0.72$
2	**1**	$85.54^{aA} \pm 0.7$	$83.17^{aB} \pm 0.59$	$80.81^{aC} \pm 0.61$
	2	$75.03^{bA} \pm 0.92$	$74.3^{bA} \pm 1.05$	$74.91^{bA} \pm 1.14$
	3	$64.36^{cC} \pm 0.85$	$66.97^{cB} \pm 0.6$	$69.27^{cA} \pm 0.72$
3	**1**	$84.96^{aA} \pm 0.43$	$83.47^{aA} \pm 0.67$	$80.71^{aB} \pm 0.53$
	2	$75.79^{bA} \pm 0.95$	$74.1^{bB} \pm 0.57$	$72.49^{bC} \pm 1.00$
	3	$63.64^{cC} \pm 1.04$	$67.63^{cB} \pm 0.67$	$71.13^{bA} \pm 0.64$
4	**1**	$86.91^{aA} \pm 0.88$	$84.34^{aB} \pm 0.71$	$80.59^{aC} \pm 1.18$
	2	$75.73^{bA} \pm 0.67$	$73.13^{bB} \pm 0.95$	$70.86^{bC} \pm 1.07$
	3	$63.99^{cC} \pm 0.64$	$67.23^{cB} \pm 0.87$	$70.39^{bA} \pm 1.34$
5	**1**	$83.77^{aA} \pm 1.23$	$81.74^{aB} \pm 1.12$	$80.27^{aC} \pm 0.66$
	2	$75.5^{bA} \pm 1.21$	$74.36^{bA} \pm 0.9$	$72.36^{bB} \pm 0.98$
	3	$65.06^{cB} \pm 0.94$	$66.74^{cB} \pm 0.79$	$69.43^{cA} \pm 1.01$
6	**1**	$86.67^{aA} \pm 1.36$	$82.4^{aB} \pm 0.43$	$79.26^{aC} \pm 0.46$
	2	$74.7^{bA} \pm 0.82$	$72.61^{bB} \pm 0.43$	$71.3^{bB} \pm 0.94$
	3	$63.84^{cC} \pm 0.96$	$67.47^{cB} \pm 0.65$	$70.63^{bA} \pm 0.58$

Means with different superscripts (a-c within column for each week, A-C within row) differ significantly at 0.05 level and evening values, while T3 maintained relatively warmer conditions. At 1:00 p.m., RH declined in all groups but continued to be highest in concrete floors. Hotzel et al. (2009) similarly reported no significant air temperature differences between deep-bedded systems with wood shavings, rice husks, and concrete flooring, concluding that such substrates are suitable despite minimal thermal variation.

The present findings are consistent with Subhalekha et al. (2021), who noted higher air temperatures in pens with raised slatted polypropylene flooring, and with Amaral et al. (2021), who described deep bedding as a thermal insulator that may increase environmental heat due to composting activity. By 5:00 p.m., RH reached its lowest daily values across treatments, while air temperatures peaked, significantly exceeding both morning and midday levels. These results corroborate Ram (2015), who reported daily maximum temperatures ranging from 27.20°C to 34.39°C and RH values between 55.02(%) and 84.49(%).

Floor surface temperature

The mean floor temperature of the pens at 9:00 a.m., 1:00 p.m. and 5:00 p.m. are presented in Table 3. At 9:00 a.m., floor temperatures were generally lower than at later time points across all treatments, and within each week, no consistent significant differences (P>0.05) were observed, except in week 6 when T3 (wood shavings) recorded a significantly lower temperature than T1 (concrete) and T2 (hay). Morning readings for T1 and T2 were often slightly higher than T3, though not always significantly different. By 1:00 p.m., floor temperatures increased compared to morning values, with minimal differences between treatments within the same week, and midday readings were generally significantly higher than morning values for each treatment. At 5:00 p.m., floor temperatures were high (P<0.05) in T2 when compared to T1 and T3, reached their peak for most treatments and were significantly higher (P<0.05) than both morning and midday measurements. The floor surface temperature across all treatments exhibited a clear diurnal pattern, with the lowest values observed at 9:00 a.m., moderate levels at 1:00 p.m., and peak readings at 5:00 p.m. This progressive increase from morning to evening reflects the influence of ambient temperature fluctuations and solar heat load on the pen microclimate.

Differences among treatments at the same time points were generally non-significant, suggesting that flooring type had only a limited impact on floor temperature under the present conditions. These results agree with Hotzel et al. (2009), who found no significant effect of deep bedding materials such as rice husk and wood shavings on floor surface temperature in finishing pens. The findings are also consistent with George et al., (2024), who reported comparable floor surface temperatures across pens with wood shavings, paddy husk, paddy straw, and concrete flooring. The only exception in the current study occurred

Table. 3. Mean floor surface temperature within the sheds

Week	Treatment	Time (Mean ± SE)		
		9a.m.	**1p.m.**	**5p.m.**
1	**1**	$28.46^{aC} \pm 0.23$	$29.8^{aB} \pm 0.4$	$31.27^{aA} \pm 0.75$
	2	$29.36^{aB} \pm 0.28$	$30.26^{aB} \pm 0.57$	$31.66^{aA} \pm 0.93$
	3	$28.54^{aC} \pm 0.45$	$29.96^{aB} \pm 0.33$	$30.86^{aA} \pm 0.51$
2	**1**	$28.04^{aA} \pm 0.66$	$29.83^{bB} \pm 0.31$	$30.96^{aC} \pm 0.34$
	2	$29.21^{aA} \pm 0.89$	$30.50^{abB} \pm 0.43$	$31.84^{aC} \pm 0.56$
	3	$29.63^{aB} \pm 0.48$	$30.83^{aAB} \pm 0.09$	$31.46^{aA} \pm 0.2$
3	**1**	$28.64^{aB} \pm 0.69$	$29.51^{bB} \pm 0.49$	$30.86^{bA} \pm 0.57$
	2	$29.11^{aC} \pm 0.47$	$31.43^{aB} \pm 0.21$	$32.61^{aA} \pm 0.49$
	3	$28.89^{aC} \pm 0.27$	$29.91^{bB} \pm 0.35$	$30.76^{bA} \pm 0.64$
4	**1**	$28.71^{aC} \pm 0.19$	$30.09^{aB} \pm 0.3$	$31.7^{aA} \pm 0.62$
	2	$29.04^{aC} \pm 0.51$	$30.16^{aB} \pm 0.57$	$31.69^{aA} \pm 0.65$
	3	$28.06^{aB} \pm 0.53$	$28.94^{aAB} \pm 0.51$	$29.29^{bA} \pm 0.6$
5	**1**	$29.13^{aB} \pm 0.87$	$30.39^{abA} \pm 0.57$	$31.16^{abA} \pm 0.34$
	2	$30.33^{aAB} \pm 0.55$	$31.06^{aB} \pm 0.23$	$32.10^{aA} \pm 0.34$
	3	$28.41^{aB} \pm 0.84$	$29.26^{bB} \pm 0.35$	$30.34^{bA} \pm 0.51$
6	**1**	$29.44^{abA} \pm 0.58$	$29.80^{bA} \pm 0.3$	$30.34^{bA} \pm 0.93$
	2	$29.73^{aB} \pm 0.25$	$30.83^{aB} \pm 0.31$	$32.23^{aA} \pm 0.52$
	3	$28.19^{bA} \pm 0.48$	$29.33^{bA} \pm 0.2$	$30.33^{bA} \pm 0.68$

Means with different superscripts (a-c within column for each week, A-C within row) differ significantly at 0.05 level

Particulars	Bedding Systems		
Expenditure (Rs.)	**Concrete (T1)**	**Hay (T2)**	**Wood-shavings (T3)**
Number of sows (per treatment)	7	7	7
Total bedding used (kg)	-	1092	1456
Cost of bedding materials (Rs)	-	1092×Rs.10=10920	1456×Rs.4=5824
Maintenance cost (Rs)	-	0.0	0.0
Total cost (A) (Rs)	-	10920	5824
Average sale per sow/litter (Rs)	26508	30242	28270
Group gross return (B) (Rs)	185556	211694	197890
Sale of used bedding (Rs)	-	-	-
Net return (B – A) (Rs)	**185556**	**200774**	**192066**

Assumption: All other production costs (feed, medicines, labour) are equal across treatments. Revenues are summed across 7 sows per treatment; bedding costs cover 7 pens over 55 days. Sale price assumed at Rs 475/kg. Sale of used bedding not done.

in week 6 at 9:00 a.m., when the wood shavings treatment showed a significantly lower floor temperature compared to both concrete and hay-bedded pens.

Techno economics of bedding materials

The cost and return components were calculated based on total expenditure and income obtained from each treatment group (Geetha, 2021). The total cost incurred for bedding materials was Rs. 10,920/- for hay bedding (T2) and Rs. 5,824/- for wood-shavings (T3), while no bedding cost was recorded for the concrete-floored group (T1). The net returns obtained were Rs. 1,85,556/- for concrete flooring, Rs. 2,00,774/- for hay bedding and Rs. 1,92,066/- for wood-shavings. The results revealed that sows maintained on T2 yielded the highest net return, followed by T3, compared to those kept on T1.

Conclusion

The present study demonstrated that flooring type had a notable influence on the microclimatic conditions of farrowing pens. The microclimatic parameters recorded in the present study revealed that air temperature inside farrowing pens followed a distinct diurnal pattern, with minimum values in the morning and peaks in the evening (29.57–32.97°C), while relative humidity (RH) exhibited an inverse trend, being highest during cooler hours (up to 86.9% in T1) and lowest in the evening (as low as 63.6% in T3). This negative correlation reflects the thermodynamic principle that warmer air can hold more moisture, thereby reducing RH if absolute water content remains constant. Floor surface temperatures closely paralleled air temperature fluctuations, with morning minima (28.06°C in T3) and evening maxima (32.61°C in T2), indicating that bedding materials influenced heat retention, with hay occasionally recording higher evening values due to its insulating and fermentative properties. Relative humidity levels were further shaped by bedding moisture dynamics, as hay bedding maintained significantly lower moisture content than wood shavings which could be attributed to the rough, porous structure of hay allowing better aeration and drying. Despite higher water retention, wood shavings contributed to reduce ambient RH, suggesting that absorbed moisture remained localized within the substrate rather than being released into the pen environment. Techno-economics indicate that the use of bedding materials as floor enrichments, particularly hay, not only enhanced animal comfort but also improved overall profitability under experimental conditions. Overall, enriched flooring systems moderated humidity and stabilized pen microclimate more effectively than concrete floors, with hay bedding offering the most balanced combination of lower bedding moisture, moderate RH and thermally comfortable floor conditions, thereby supporting improved welfare of sows and piglets in Kerala.

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Conflicts of interest

The authors declare that they have no conflict of interest.

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