Journal of Animal Research: v.13 n.01, p. 71-80. February 2023

DOI: 10.30954/2277-940X.01.2023.9

Does Provision of Open Area Improve Growth Performance and Welfare of Large White Yorkshire Fattener Pigs during Summer Season in Tropical Indian Conditions?

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Received: 12 Nov., 2022 **Revised:** 20 Jan., 2023 **Accepted:** 26 Jan., 2023

ABSTRACT

Indian Standard (3916-1966) for pig housing, recommends a range of 0.9- 1.8 m^2 floor area under covered and open space from weaning to finisher stage. Present study assessed whether, IS recommended open area is advantageous to improve welfare and growth performance of fattener pigs during summer season. A total of 20 piglets (10 castrated male and 10 females) at 3 months of age with average body weight 18.94 ± 1.04 Kg were randomly assigned to two housing treatments groups namely Tc; with lower limits of IS recommended covered floor space of 0.9 m^2 per pig and To; with higher limit of IS recommended floor area of 1.8 m^2 per pig, in which half, 0.9 m^2 was under covered space and remaining half 0.9 m^2 open space. Results revealed that provision of additional floor area of 0.9 m^2 in open space did not improve growth performance and welfare of pigs during summer season. Therefore, IS recommended open space in pig housing is not necessary and can be removed to improve space, labour and overall economic efficiency of pig production.

HIGHLIGHTS

- Floor area and space type critically affects production and economics of pig production.
- This study assesses the effect of removal of IS recommended open area on performance and welfare of pig.

Keywords: Pig housing, open area, heat stress, growth and welfare

Indian meat sector has grown at the high annual rate of 6.26 % during 2011-12 to 19-20 (DAHD, 2020-21). However, the meat availability in India is only about 15g/person/day against the ICMR recommendation of 30g/person/day (Islam *et al*., 2016). This huge gap of 50% in meat demand, offers a great opportunity of rapid growth of Indian meat sector. Being highly prolific and growth rate, intensive pig farming has great potential for income and employment generation (Prasad *et al*., 2011).

As average ambient temperature 25.93 ºC across the India (Jaganmohan M, 2022), is much higher than thermo-neutral zone of 16-20ºC for grower-finisher pigs (Berton *et al*., 2015), so heat stress is serious challenge to intensive pig production in India. Furthermore, lack of sweat glands and thick subcutaneous fat layer increases susceptibility of pigs to heat stress (St-Pierre *et al*., 2003). Type and area of floor is one of the critical factors, affecting not only welfare and performance but also resource use efficiency (land, labour and water) and economics of intensive pig production system (Anil *et al*., 2007). In addition to age, breed, feeding system and other management criteria (Thompson *et al*., 2002), stocking density optimum floor allowance for pigs under intensive system greatly depends

How to cite this article: Kanwarpal, Sharma, A., Kaswan, S., Singh, C., Hundal, J.S. and Malik, D.S. (2023). Does Provision of Open Area Improve Growth Performance and Welfare of Large White Yorkshire Fattener Pigs during Summer Season in Tropical Indian Conditions?. *J. Anim. Res.*, **13**(01): 71-80.

Source of Support: None; **Conflict of Interest:** None

on prevailing environmental conditions (White *et al*., 2008). Indian standards (1966) (3916-1966 recommends 0.9-1.8 m^2 covered from weaning to finisher stage with provision of equal additional open floor area. However, earlier few studies have been successfully reduced IS recommended covered floor area for grower finisher pigs up to 33 % without compromising performance and welfare (Bhatt *et al*., 2010 and Kaswan *et al*., 2015) but no study has been conducted to assess the effect of provision of open area on performance and welfare of pigs' *vis a vis* heat stress conditions during summer season.

MATERIALS AND METHODS

Location and ethical permission

The study was carried out during summer season between from April to June, 2020 at the Pig Farm, Department of Livestock Production Management, Guru Angad Dev Veterinary and Animal Science University, Ludhiana-1411004, Punjab (India) located at l30.90° N latitude, 75.80° E longitudeand altitude of 230 m above mean sea level. The permission for experimental protocol and ethical use of animals were granted by CPCSEA, New Delhi vide memo no. 25/23/2019, CPCSEA, dated 09.12.2019.

Experimental animals and housing facilities

The experimental animals consisted of 20 piglets of both sex (10 castrated male and 10 females) of 3 months of age with average body weight of 18.94 ± 1.04 Kg. The experimental shed was open type having pens with provision of covered and open area. The dimensions of open and covered area of each pen were 3.28 × 2.75-meter (L×W) meter. The shed roof was 3 meter in height, flat type reinforced concrete (RCC). Partition wall of pens was of brick with mortar up to a height of 0.64 meter and above was installed with two horizontal GI railings at vertical distance of 0.30 meter. The floor of pens was of concrete with slope towards open area. Each pen was provided with two linear GI feeders having 183 cm length, 14 cm depth and 20 cm width, thus making a provision of feeding space of 36.6 cm per pig. In order to ensure round the clock availability of water, each pen was installed with two drinking bowls.

Experimental design

A total of 10 male and 10 female piglets were randomly distributed to two experimental pens (T_c and T_o). Each experimental pen had total 10 piglets, 5 male and 5 female. Each piglet in T_c pen had access to only covered area with floor space allowance of 0.9 square meter per piglet. While, piglets in T_o pen, had access to both covered and open area with total floor area of 1.8 square meter (0.9 square meter each covered and open floor space allowance) per piglet.

Shed microclimatic

In order to assess level of heat stress conditions, Daily maximum and minimum temperature (°C) and relative humidity (%) were recorded with two digital thermo cum hygrometers (TH028 Electronic®) installed at a height of 5 feet at two different locations in experimental shed. Minimum and maximum temperature humidity index (THI) for the day and different fortnights was calculated as per THI formula for pig (National Weather Service Central Region, Missouri, USA, 1976).

$$THI = [1.8*T) + 32] - 0.55*(RH/100)] *((1.8*T) + 32)-58]$$

Where T is ambient temperature in °C and RH is % relative humidity.

Feed and feeding

All pigs in both the treatment groups were fed similar experimental diet as per ICAR (2013) standards. The diet had 19, 17 and 17% CP and 3100, 3100 and 2731 Kcal/Kg crude protein and metabolizable energy during 3-4 months and 4-5 months and 5-6 months of age, respectively. The diet was offered daily twice, in morning and evening and to a record daily feed intake, every morning left over feed in feeder was weighed for each treatment.

Growth performance

Fortnightly body weight of individual pig for each treatment and daily feed intake for each treatment was recorded using digital weighing platform with accuracy of 1 g. Whereas, the daily feed intake was calculated by subtracting the feed residue in feeder by total amount of feed offered a day for in the next morning). The data of body weight and daily feed intake was used to find out

weight gain, protein and energy intake and FCR, PER and EER over different fortnights of experiment.

Welfare assessment

The welfare of pigs was assessed on the basis of physiological, behavior and biochemical changes along with body and limb lesions. Body surface temperature was recorded with infrared thermometer (CE Rohs®) held 0.5 feet away from the base of ear while respiration rate was recorded with visual observation of flank movement of each pig at 15 IST on three different days during a fortnight. Behavioral activities of pigs were recorded with Mi Note 5 Pro Xiomi ® mobile camera with 12-megapixel resolution using phase wise scan sampling technique, in which recording of entire pen in single vision was done 3 times per day at 12:00, 15:00 and 18:00 IST for 15 minutes on 5th, 10th and 15th day of each fortnight, thus, in total behavioral activities were recorded for 3 times 135 minutes for each pig in each pen during each fortnight. Additionally, to assess the resting preference of pigs in open and closed area during non-sunny period of the day, recording of pen with provision of open area was done before sunrise and after sunset at 6 IST and 20 IST for 15 minutes 3 times per fortnight. Skin lesion scoring at modified 4 point ordinal scale of 0-3 (de Greef *et al*., 2011) and hoof lesion scoring at modified 3 point ordinal scale 0-2 (Lisgara *et al*., 2015) was done to assess the level of physical injury. In order to assess stress related biochemical changes, 5 ml blood from 6 pigs (3 males and 3 females) per treatment was collected aseptically from the anterior vena cava in sterilized disposable syringes at the end of 4, 5 and 6 months of age. These samples were immediately transferred to heparinized centrifuge tubes and centrifuged at 3000 rpm for 10 minutes for separation of plasma. Further, plasma was stored at -20ºC for estimation of glucose, glycerides, total protein, albumin, BUN, creatinine, SGPT and SGOT using Erba Mannheim (TransAsia Bio-Medicals Ltd.®) kit with fully automatic chemistry analyzer (Global BPC). While, porcine ELISA (Bioassay Technology Laboratory®) kit was used for estimation of plasma NEFA and cortisol.

STATISTICAL ANALYSIS

The data was analyzed with statistical software SPSS 20. The data on growth performance and blood biochemical changes were subjected to independent two tail t-test, while ordinal data of agonistic, resting behavior and skin and hoof lesion score were subjected to non-parametric Kruskal-Wallis test. However, the data for resting behavior preference in the pen with provision of open area were using one-way ANOVA.

RESULTS AND DISCUSSION

Microclimate profile during experiment

Microclimate profile data (Fig. 1,2&3) show that maximum and minimum temperature ranged of pens during experimental period ranged between 24.65-34.94 ºC and 18.49-28.90 ºC. Thermo-neutral temperature for growing pigs vary between 18-25 ºC with 15 ºC as critical cold limit and 20 ºC for critical heat stress (Sampaio *et al*., 2004). However, upper critical temperature of thermo neutral zone has been recorded 28.5 ºC (Verstegen and Close, 1994) for finisher pigs.

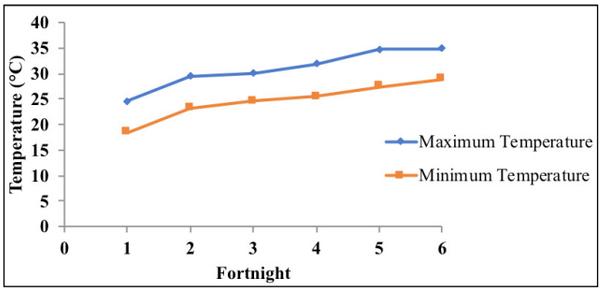

Fig. 1: Temperature profile of pens during experiment period

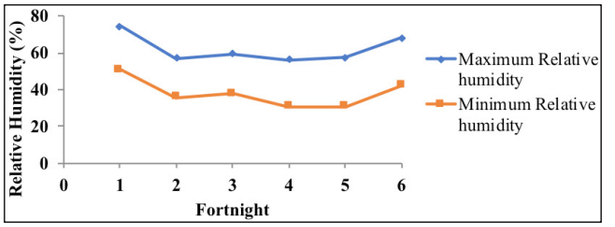

Fig. 2: Relative humidity (%) of pens during experiment period

In present study except during 1st fortnight, maximum ambient temperature in pens was beyond upper critical limit of thermo neutral zone, whereas minimum ambient temperature was higher than critical heat stress limit only

during for 5th and 6th fortnight during the experimental period. The maximum relative humidity in pens varied from 56.06 % during 4th fortnight to 74.69% during 1st fortnight and minimum relative humidity ranged from 30.80% during 5th fortnight to 50.87% during 1st fortnight. During the experimental period, maximum and minimum RH% tends to decrease from 1st to 5th fortnight, however again increase during 6th fortnight due to precipitation. For the pigs weighing over 30 kg in the thermal comfort zone, optimum range of relative humidity varies between 50-70 % (Muller, 1989). In present study, minimum and maximum RH % was observed lesser and higher than the reported range of optimum RH.

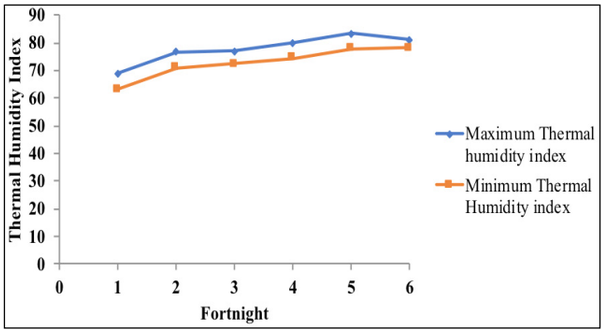

Fig. 3: THI of pens during experiment period

Growth performance

The data on growth performance (Table 1) indicate that average body weight of pigs during different fortnights and final body weight of pigs between T_C and T_O groups did not differ significantly but was numerically higher in T_O than T_C. However, average daily body weight gain of pigs in T_C increased with age up to 4th fortnight (5 months of age) whereas in T_O increased up to 5th fortnight (5.5 months of age) and subsequently during 6th fortnight (between 5.5-6.0 month of age) decreased in both T_C and T_O. Although, daily body weight gain of pigs in T_O group was significantly ($P \leq 0.04$) higher than T_C group during, 1st and 5th fortnights but no significant effect was recorded for mean daily body weight gain for entire experimental period. The data on feeding efficiency indicate, that daily feed, so consequently protein and energy intake also, over different fortnights up to 5 months of age in T_C was significantly ($p<0.01$) higher than T_O but subsequentially later between 5-6 months of age and overall mean feed intake during entire experimental period in T_O was significantly ($p<0.01$) higher than T_C.

However, FCR and PER over different fortnights and cumulative FCR and PER between T_C and T_O group did not differ significantly ($p \leq 0.05$). However, EER of piglets in T_O group was significantly ($p<0.02$) better only during 1st fortnight, 5th and 6th fortnight.

Contrary to present findings, White *et al*. (2008) at high ambient temperature of 32.2 ºC with much lower space allocation 0.66 m^2 than 0.9 m^2 per pigs in present study, reported significant reduction in growth and feeding efficiency of finisher pigs. But Rossi *et al*. (2008) with reduction of floor space from 1.4 to 1.0 m^2 per pig and Kaswan *et al*. (2018) in during hot humid season, even with much higher of BIS recommended floor space from 0.9-1.8 to 0.45-0.9 m^2 for weaner-grower observed no reduction in growth and feed efficiency of pig.

Welfare of pigs

Physiological response

Body skin temperature (ºC) and respiration rate of pigs (Table 2) in both T_C and T_O group increased over the fortnights with age of pigs. This increase in skin temperature and respiration rate of pigs with age could be attributed to increased susceptibility to heat stress with age and corresponding increase in environmental THI of experimental pens. Although, respiration rate between the treatment groups during experimental period did not differ significantly ($p \leq 0.05$) and except during 1st ($p<0.002$) and 5th ($p<0.001$) fortnight body skin temperature (ºC) also did not vary between in T_O and T_C groups. As increased respiration rate is first physiological response to increased temperature and inflection point temperature (IPt) from 21.3 to 23.4°C followed by rectal temperature with IPt from 24.6 to 27.1°C at 80% RH (Huynh *et al*., 2005). So, non-significant difference in respiration and skin temperature of pigs in both the groups can be explained, as in present study from second fortnight onward minimum shed temperature, 23.30 - 28.90°C in both the groups during the entire experimental period was beyond the inflection point temperature and THI for pigs ranged from critical to dangerous (Botto *et al.,* 2014).

Table 1: Growth performance of pigs with and without provision of open area

Parameter	Treatment	Fortnight (Age, Month)						
		0 (3 M)	**1 (3.5 M)**	**2 (4.0 M)**	**3 (4.5 M)**	**4 (5.0M)**	**5 (5.5M)**	**6 (6.0M)**	**Mean**
Body weight (Kg)	T_C	18.30 ± 0.91	22.70 ± 1.11	29.90 ± 1.31	36.70 ± 1.57	44.60 ± 1.79	50.90 ± 1.86	57.50 ± 2.13	—
	T_O	19.70 ± 0.96	25.10 ± 1.16	33.00 ± 1.59	39.30 ± 1.96	47.00 ± 2.29	55.20 ± 2.73	62.20 ± 2.87	—
	P Value	0.30	0.15	0.15	0.31	0.42	0.21	0.21	—
Daily body weight gain (g)	T_C	—	286.67 ± 15.99	480.67 ± 22.08	455.33 ± 30.24	524.67 ± 30.19	438.67 ± 21.12	422.67 ± 30.31	434.78 ± 17.11
	T_O	—	347.33 ± 210.62	524.67 ± 45.78	429.33 ± 32.87	520.67 ± 30.49	540.67 ± 41.50	460.67 ± 31.21	470.56 ± 24.01
	P Value	—	0.04*	0.40	0.57	0.93	0.04*	0.39	0.24
Daily Feed Intake (kg)	T_C		0.93 ± 0.00	1.43 ± 0.00	1.53 ± 0.00	1.74 ± 0.00	1.79 ± 0.00	1.75 ± 0.00	1.53 ± 0.00
	T_O		0.92 ± 0.00	1.43 ± 0.00	1.51 ± 0.00	1.71 ± 0.00	1.84 ± 0.00	1.81 ± 0.00	1.54 ± 0.00
	P Value		<0.01	1.00	<0.01	<0.01	<0.01	<0.01	<0.01
Daily Protein Intake (g)	T_C		179.49 ± 0.00	273.34 ± 0.00	260.94 ± 0.00	303.45 ± 0.00	304.69 ± 0.00	319.37 ± 0.00	273.55 ± 0.00
	T_O		169.38 ± 0.00	273.34 ± 0.00	262.71 ± 0.00	298.21 ± 0.00	314.17 ± 0.00	337.33 ±0.00	275.86 ± 0.00
	P Value		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Daily Energy Intake (ME, Kcal)	T_C		2897.98 ± 0.00	4413.37 ±0.00	4648.86 ±0.00	5406.21 ±0.00	4877.57 ±0.00	5112.60 ±0.00	4559.4 3±0.00
	T_O		2734.72 ± 0.00	4413.37 ± 0.00	4680.48 ±0.00	5312.92 ±0.00	5029.32 ±0.00	5400.08 ±0.00	4595.15 ±0.00
	P Value		<0.01	**1.00**	***<0.01***	***<0.01***	***<0.01***	***<0.01***	***<0.01***
Feed Conversion Ratio	T_C		3.30 ± 0.26	3.00 ± 0.15	3.40 ± 0.27	3.50 ± 0.22	4.10 ± 0.23	4.40 ± 0.37	3.52 ± 0.13
	T_O		2.80 ± 0.20	2.90 ± 0.23	3.90 ± 0.35	3.50 ± 0.17	3.40 ± 0.27	4.10 ± 0.28	3.33 ± 0.18
	P Value		0.15	0.72	0.27	1.00	0.06	0.53	0.41
Protein Efficiency Ratio	T_C		1.70 ± 0.15	1.90 ± 0.10	1.80 ± 0.13	1.80 ± 0.13	1.40 ± 0.16	1.30 ± 0.15	1.62 ± 0.06
	T_O		2.10 ± 0.18	2.00 ± 0.21	1.60 ± 0.16	1.80 ± 0.13	1.80 ± 0.20	1.40 ± 0.16	1.74 ± 0.09
	P Value		0.12	0.67	0.36	1.00	0.14	0.66	0.31
Energy Efficiency Ratio	T_C		10.30 ± 0.63	9.40 ± 0.40	10.80 ± 0.84	10.50 ± 0.76	11.50 ± 0.60	12.70 ± 0.93	10.42 ± 0.40
	T_O		8.20 ± 0.53	9.00 ± 0.88	11.50 ± 0.97	10.50 ± 0.60	9.80 ± 0.68	12.30 ± 0.84	9.84 ± 0.54
	P Value		0.02*	0.68	0.59	1.00	0.08	0.75	0.40

Means within same column for any parameter with p value < 0.05 differ significantly.

Table 2: Physiological response of pigs in different housing pens

Parameter	Treatment	Fortnight (Age, Month)					
		1 (3.5 M)	**2 (4.0 M)**	**3 (4.5 M)**	**4 (5.0 M)**	**5 (5.5 M)**	**6 (6.0 M)**
Skin Temperature (°F)	T_C	100.3± 0.6	100.8± 0.5	102.7± 0.6	102.8± 0.6	103.6± 0.3	103.6± 0.4
	T_O	97.9± 0.4	100.7± 0.4	101.7± 0.7	103.0± 0.5	102.2± 0.4	102.8± 0.2
	P Value	*0.002**	*0.97*	*0.24*	*0.72*	*0.01**	*0.08*
Respiration rate/min.	T_C	27.1± 0.9	55.6± 3.7	52.9± 4.1	68.6± 2.1	78.2± 4.1	86.9± 3.3
	T_O	28.2± 1.1	56.8± 4.5	50.9± 4.2	71.4± 3.1	70.3± 3.9	89.2± 2.7
	P Value	0.46	0.84	0.74	0.44	0.17	0.60

Means within same column for any parameter with p value < 0.05 differ significantly.

Behavioral response

The data of behavioral response of pigs indicate (Table 3 and 4) that total excretory (urination, defecation), drinking and playful activity (running, walking and rubbing) time and frequency of total agonistic (parallel pressing and inverse parallel pressing, head-to-head knock, levering and biting) activities and exploratory (chewing, nosing, sniffing, nose to body interaction and nose to nose interaction) activities did not differ significantly ($p \leq 0.05$) between T_C and T_O. However, only during 6th fortnight, total resting time was significantly ($p \leq 0.01$) higher and feeding time in T_O group than T_C. Similar to Kaswan *et al*. 2018a in present findings also, obliteration of open area along with reduction of covered area in relation to IS specifications, showed no increase in agonistic and decrease in ingesting and resting behavior but Anil *et al.* (2007) with higher reduction of floor space from 0.88 m^2 to 0.64 m^2 per grower finisher with reduction of observed significant ($p \leq 0.05$) increase in aggressive interactions.

The results of resting preference shows that even during non-sunny time pigs preferred ($p<0.009$) to rest under covered area. These results of resting preference (Table 5) in covered area in evening hours could be due to high temperature of concrete floor due to long sun exposure during the day and/or feeling of protection under covered area associated natural habitat. Mean frequency of head, limb, tail and hoof lesions of pigs (Table 6) in TC and TO group did not vary significantly ($p \leq 0.05$) during the entire experimental period.

Table 3: Behavioral welfare activities (relative time spent in seconds) of pigs housed in without and with open area

Parameter	Treatment	Fortnight (Age, Month)					
		1(3.5)	**2(4.0)**	**3 (4.5)**	**4 (5.0)**	**5 (5.5)**	**6 (6.0)**
Total Resting Time	T_C	727.48 ± 31.84	602.87 ± 43.53	673.70 ± 46.13	689.28 ± 41.24	776.02 ± 35.24	789.39 ± 34.53
	T_O	736.82 ± 29.02	620.86 ± 64.51	571.50 ± 68.16	609.32 ± 63.07	757.82 ± 57.64	888.96 ± 9.95
	P Value	*0.83*	*0.81*	*0.21*	*0.28*	*0.77*	*0.01**
Total Ingestive time	T_C	32.24 ± 15.08	166.85 ± 43.70	205.54 ± 45.42	147.48 ± 35.84	86.22 ± 27.95	94.56 ± 31.93
	T_O	0.50 ± 0.35	197.00 ± 66.77	274.61 ± 64.08	192.93 ± 57.31	118.61 ± 56.14	6.89 ± 5.91
	P Value	*0.04**	*0.70*	*0.38*	*0.48*	*0.56*	*0.01**
Total Excretion	T_C	12.07 ± 2.63	9.78 ± 2.21	1.48 ± 0.88	4.52 ± 1.80	1.15 ± 0.69	1.63 ± 1.15
	T_O	8.86 ± 2.88	5.86 ± 2.31	1.54 ± 1.08	7.79 ± 3.03	2.64 ± 1.47	2.14 ± 2.14
	P Value	*0.45*	*0.22*	*0.97*	*0.33*	*0.36*	*0.82*
Total Others	T_C	128.20 ± 25.39	120.50 ± 22.52	19.28 ± 6.44	58.72 ± 14.36	36.61 ± 13.10	14.43 ± 9.90
	T_O	153.82 ± 27.44	76.29 ± 21.18	52.36 ± 14.19	89.96 ± 26.40	20.93 ± 9.91	2.00 ± 1.93
	P Value	*0.53*	*0.16*	*0.04**	*0.26*	*0.43*	*0.37*

Means within same column for any parameter with p value < 0.05 differ significantly.

Table 4: Mean frequency rank of welfare related behavioral activities of pigs housed without and with open area

Parameter	Treatment	Fortnight (Age, Month)					
		1(3.5)	**2(4.0)**	**3(4.5)**	**4(5.0)**	**5(5.5)**	**6 (6.0)**
Total Agonistic	T_C	54.83	57.31	55.68	51.43	54.94	55.05
	T_O	54.17	51.69	53.32	57.57	54.06	53.95
	P Value	*0.29*	*0.23*	*0.53*	*0.17*	*0.73*	*0.71*
Total Exploratory	T_C	53.42	54.88	49.69	54.86	57.21	55.1
Total Social Behavior	T_C	54.74	53.69	49.94	53.74	54.41	55.56
	T_O	54.26	55.31	59.06	55.26	54.59	53.44
	P Value	*0.93*	*0.76*	*0.06*	*0.75*	*0.95*	*0.44*

Means within same column for any parameter with p value < 0.05 differ significantly.

Table 5: Resting preference of pigs before and after sunset (non-sunny period) in pens with open area

Time	Resting preference	SD Mean
Morning (6 IST)	Inside	65±7.99[a]
	Outside	35±7.99[b]
Evening (20 IST)	Inside	57.5±7.99[a]
	Outside	42.5±7.99[b]
Total	Inside	61.25±5.66[a]
	Outside	38.75±5.66[b]

Mean value with different superscripts differs significantly ($p<0.01$).

Table 6: Mean frequency rank of body and limb lesion of pigs housed without and with open area

Parameter	Treatment	Days (Age, Month)		
		30 days (4 M)	**60 days (5 M)**	**90 days (6 M)**
Head	T_C	10.35	10.95	10.95
	T_O	10.65	10.05	10.05
	P Value	***0.89***	***0.58***	***0.70***
Trunk	T_C	10.2	11	11.6
	T_O	10.8	10	9.4
	P Value	***0.79***	***0.54***	***0.30***
Limb	T_C	10.5	10.5	10
	T_O	10.5	10.5	11
	P Value	***1.00***	***1.00***	***0.62***
Tail	T_C	10.5	10.5	10.5
	T_O	10.5	10.5	10.5
	P Value	***1.00***	1.00	1.00
Right Fore Limb	T_C	10.5	11	12.6
	T_O	10.5	10	8.4
	P Value	***1.00***	***0.66***	***0.06***
Left Fore Limb	T_C	9.5	11.2	11.6
	T_O	11.5	9.8	9.4
	P Value	***0.15***	***0.54***	***0.36***
Total Fore Limb	T_C	9.5	11	11.75
	T_O	11.5	10	9.25
	P Value	***0.15***	***0.65***	***0.28***
Right Hind Limb	T_C	9.5	10	12.1
	T_O	11.5	11	8.9
	P Value	***0.28***	0.68	0.17
Left Hind Limb	T_C	9.5	12.75	11.1
	T_O	11.5	8.25	9.9
	P Value	***0.15***	***0.04****	***0.59***
Total Hind Limb	T_C	9.5	11.25	10.95
	T_O	11.5	9.75	10.05
	P Value	***0.28***	***0.51***	***0.69***

Means within same column for any parameter with p value < 0.05 differ significantly.

Biochemical response

Plasma biochemicals (Table 7) glucose, triglycerides, NEFA, total protein and albumin did not differ significantly ($p<0.05$) between T_C and T_O group during the different sampling period of 4th, 5th and 6th month of age. The mean value of plasma glucose concentration between 57.78-69.12 mg/dl, triglycerides 34.62-53.06 mg/dl, NEFA 53.74-184.95 µmol/l, total protein 4.23-6.58 g/dl and albumin 2.49-3.70 g/dl were within the physiological range of pigs (Yu Kuai *et al*., 2019). The plasma concentration of liver function enzymes SGPT was between 31.90-65.17 IU/l and SGOT 51.47-75.26 IU/l whereas the plasma concentration of bilirubin was between 4.92-6.9 mg/dl. Plasma concentration of kidney

Table 7: Effect of provision of open area on blood biochemical changes

Parameter	Treatment	Days (Age, month)			Overall Mean
		30 Days (4 Month)	60 Days (5 Month)	120 Days (6 Month)	
Glucose (mg/dl)	T_C	69.05±10.46	57.78±5.29	76.84±6.05	67.89±4.76
	T_O	62.54±5.61	59.81±7.62	69.13±2.04	63.83±2.06
	P Value	*0.60*	*0.83*	*0.27*	*0.45*
Total Protein (g/dl)	T_C	5.59±0.37	4.23±0.27	6.58±0.21	5.47±0.16
	T_O	4.98±0.28	5.00±0.38	5.18±0.92	5.05±0.40
	P Value	*0.22*	*0.13*	*0.17*	*0.36*
Albumin (g/dl)	T_C	2.59±0.29	2.49±0.21	3.70±0.11	2.92±0.12
	T_O	2.77±0.30	2.86±0.18	2.87±0.39	2.83±0.21
	P Value	*0.66*	*0.21*	*0.07*	*0.71*
Triglyceride (mg/dl)	T_C	34.62±6.66	43.50±5.28	53.06±3.40	43.73±3.40
	T_O	45.81±9.05	45.05±5.02	45.78±2.91	45.55±3.38
	P Value	*0.34*	*0.83*	*0.06*	*0.58*
NEFA (µmol/L)	T_C	73.64±22.41	58.16±5.08	133.26±21.47	88.35±5.46
	T_O	70.40±7.67	53.74±6.15	184.95±39.86	103.03±14.86
	P Value	*0.89*	*0.59*	*0.28*	*0.38*
SGPT (IU/L)	T_C	46.14±11.18	31.90±2.86	54.58±4.89	44.20±3.91
	T_O	41.93±5.17	43.94±4.44	65.17±4.38	50.35±1.45
	P Value	*0.74*	*0.05**	*0.14*	*0.17*
SGOT (IU/L)	T_C	52.13±5.21	74.72±8.90	75.26±8.43	67.37±3.60
	T_O	51.47±4.09	60.05±4.85	76.52±4.06	62.68±2.34
	P Value	*0.92*	*0.18*	*0.90*	*0.30*
Bilirubin (mg/dl)	T_C	5.69±1.57	5.77±0.84	4.92±1.09	5.46±0.63
	T_O	5.31±1.21	6.56±1.15	6.91±1.02	6.26±0.94
	P Value	*0.85*	*0.59*	*0.21*	*0.49*
Blood Urea Nitrogen (mg/dl)	T_C	22.64±2.47	28.98±1.81	35.17±1.24	28.93±1.51
	T_O	28.50±1.59	32.17±4.02	34.90±2.06	31.86±2.48
	P Value	*0.07*	*0.49*	*0.91*	*0.34*
Creatinine (mg/dl)	T_C	1.05±0.16	1.16±0.08	1.90±0.06	1.37±0.07
	T_O	0.94±0.02	1.31±0.11	1.63±0.07	1.29±0.06
	P Value	*0.49*	*0.29*	*0.01**	*0.44*
Cortisol (nM/L)	T_C	12.22±0.45	12.13±0.38	13.45±1.12	12.60±0.47
	T_O	16.25±4.52	12.23±0.43	16.31±4.42	14.93±1.97
	P Value	*0.42*	*0.86*	*0.54*	0.23

Means within same column for any parameter with p value < 0.05 differ significantly.

function indicator BUN was between 22.64-35.17 mg/dl and creatinine was between 0.94-1.63 mg/dl. Similarly, plasma concentration of stress related hormone cortisol varied between 12.13-16.31 ng/dl. Earlier a number of reports indicated significant increase in total protein, BUN, NEFA, SGOT and SGPT and decrease in glucose plasma concentration in pigs in response to heat stress (Ajuogu *et al*., 2010; Kim *et al*., 2014 and Oh *et al*., 2017). Therefore, results of biochemical parameters indicate no difference in stress at cellular level among pigs housed in pen with and without accessibility to open area during summer season.

CONCLUSION

So, it can be concluded that provision of open area as suggested in Indian standards (1966) (3916-1966) for pig housing, had no beneficial effect on growth performance and improving welfare, so provision of open area can be removed in open sided pens in tropical Indian conditions with simultaneous reduction of cost of production through reducing investment on housing in intensive pig production.

ACKNOLEDGEMENTS

The authors are highly thankful to Director Research, GADVASU, Ludhiana for the financial support extended under RKVY project for this research work.

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