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Carcass traits of crossbred (Landrace × *Desi*) barrows reared with different floor space allowances under intensive system

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ABSTRACT

Present study assessed the effect of floor space allowances on carcass traits of crossbred (Landrace × *Desi*) barrows in Indian conditions. Crossbred barrows (36) were reared with 3 different floor space allowances (12 each) having group size of 4 pigs/pen. One group (T_{IS}) was provided floor space as per Indian Standards (0.9, 1.35 and 1.8 m^2/pig for weaner, grower and finisher stages, respectively) specifications, while other two groups with 33% ($T_{2/3}$) and 50% ($T_{1/2}$) reduced floor space allowances. Pigs were reared up to 29 weeks of age. Final weight of pigs did not differ significantly among the groups. Six animals from each group were slaughtered. None of the major economic carcass traits, viz. carcass weight, dressing %, back fat thickness (BFT), loin eye area (LEA), estimated lean meat percentage etc. was adversely affected. Major cut-up parts, share of edible as well as inedible offal and composition of pork (moisture, CP and EE) also did not differ among groups. It indicates scope of 50 % reduction in floor space allowance for pig production in India without affecting final body weight and major carcass characteristics.

Key words: Carcass, Crossbred, Dressing, Space allowance

Keeping burgeoning human population in view, sustainable meat production to meet global food security is one of the topmost priorities. It is projected that there will be great demand and growth for red meat and this growth will be highest in developing countries by 2018 (FAO 2009). Pork, being most popular meat, needs special emphasis in this regard. Enhancing pork production is essential, at the same time quality of pigs and pork need not be compromised. Efficient utilization of floor space without adversely affecting the productivity is an important aspect for profitable pork production. For successful rearing of pigs from three weeks onwards, critical factor is to have correct balance between the numbers in the group and the space allowance (Bhat *et al*. 2010). Efficient use of indoor floor space results in low capital investment in buildings and infrastructure, reduces cost of labour and bedding systems, and so represents the principal economic and management benefits (Turner *et al*. 2003, Anil *et al*. 2007). Scientific evidence indicates that space is not as important for pigs as other resources, e.g. food availability if their minimum space requirement is fulfilled (Marchant-Forde 2009). A recent study (De Greef *et al*. 2011) on space use, synchronization and clustering of behavioural activities of pigs indicated that the theoretically derived requirements on space allowance might be reduced without compromising the Comfort Class level (a specific minimal level of husbandry conditions of animals, at which welfare of animals is not compromised).

Cameron (2000) in his report on global pig production found that weaners, growers and finishers are mostly provided about 0.36, 0.5 and 0.75 m^2/pig of floor space, respectively whereas, Indian Standards (IS) suggests floor area (covered) of 0.9 and 1.8 m^2/pig for weaner and finisher pigs, respectively, which is too high in comparison to World average. As IS (IS: 3916–1966) for pigs were formulated in 1966 and not reviewed afterwards, present investigation was carried out to explore possibility of reduction in floor space requirement for Indian crossbred pigs without any adverse effect on major carcass traits. The impact of space allocation on carcass back fat and percentage lean has only been reported in a few trials (Brumm 2004). From the limited data available, it is not possible to predict the impact of space allocation on carcass traits (Brumm 2010). Most of the studies conducted to determine the effect of floor space allowance on carcass traits of pigs are based on developed countries, whereas, developing especially Asian countries have significant contribution in global pork production. In India too, piggery sector is growing with predominant practices of rearing pigs on concrete floor in smaller groups without any provision of slatted floor. Due to difference in environmental conditions and management practices being followed, floor space allowance sufficient

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for healthy pork production in developing countries need to be determined. Furthermore, most of the earlier studies related to floor space allowance had space allowance confounded with group size (Mitchell *et al*. 1983, Edmonds *et al*. 1998, Wolter *et al*. 2000) and, consequently, it is difficult to determine whether differences in performance are due to space or group size (Anil *et al*. 2007). Recently, the pork industry has seen the implementation of single-stage wean-to-finish production systems (De Decker *et al.* 2005). But space is not utilized most efficiently during early stages of life in this single stage system. To overcome it, pigs can be reared with different floor space allowances as per their age category. Therefore, in present study, pigs were reared with different floor space allowances (but same group size) as per their age categories under Indian conditions. Carcass traits of these pigs were studied to assess suitable floor space requirement for pigs under Indian conditions.

MATERIALS AND METHODS

Experimental design and animals: The experiment was conducted at the Swine Production Farm of the Institute during May to November in 2012. It is located at an altitude of 172 m above the mean sea level at latitude of 28.20° North and longitude of 79.24° East. Climatic conditions of this region are similar to most of the places of Northern India. Crossbred {Landrace × *Desi* (local Indian)} male piglets (36), from 14 litters of unrelated sows farrowed contemporarily, were selected randomly taking body weight and age into consideration. Experiment was conducted with approval of Institutional animal ethics committee. These piglets were castrated at one month of age, weaned at 6 weeks of age and subsequently distributed randomly to 3 equal groups (12 each) on the basis of 3 different floor space allowances. Before weaning, these piglets as littermates were kept with respective dam in farrowing pen having 8 m^2 of covered area including provision of creep area. T_{IS} (control) group provided floor space as per Indian Standards (IS: 3916–1966) specification, while $T_{2/3}$ and $T_{1/2}$ treatment groups with 33% and 50% reduced floor space allocation per pig in comparison to IS. Indian Standards suggest covered floor area of 0.9 and 1.8 m^2/pig for weaner and finisher pigs, respectively. During weaner (6–14 weeks), grower (15–22 weeks) and finisher (23–29 weeks) stages, 3 different floor spaces {T_{IS} group (0.9, 1.35 and 1.8 m^2/pig), $T_{2/3}$ group (0.6, 0.9 and 1.2 m^2/pig) and $T_{1/2}$ group (0.45, 0.68 and 0.9 m^2/pig)} were provided (Table 1). Under each treatment group, 3 units of 4 piglets each were made.

Table 1. Floor space allowance (m^2/pig) for different treatment groups

Stages	Group		
	T_{IS}	$T_{2/3}$	$T_{1/2}$
Weaner (6–14 weeks)	0.9	0.6	0.45
Grower (15–22 weeks)	1.35	0.9	0.68
Finisher (23–29 weeks)	1.8	1.2	0.9

Width of each pen measured 2.5 m and specified floor space allocation was ensured by altering length of the pen using metallic grill gates. Floor was made of concrete with serrations to avoid slippage. Animals were fed twice daily in linear feeder with provision of potable water in linear waterer round the clock. Animals with respect to their stage were fed with weaner and grower-finisher feed as per farm's standard. Pigs were provided with corn-barley-soyabean meal-wheat bran based diet. Standard management practices related to health and hygiene were followed as per farm's guidelines.

Microclimatic conditions: Temperature and relative humidity (RH) inside the sty at the level of pigs were also recorded daily to assess microclimatic conditions. Microclimatic indicators were recorded thrice daily i.e. morning (10:00 h), afternoon (14:00 h) and evening (17:00 h). Maximum and minimum temperatures were recorded once every 24 h to indicate extremes of weather. Onset of climatic data recording i.e. sixth week of age of animals coincided with mid of May (summer). During weaner stage, temperature inside the sty ranged from 29 to 41 ºC except last week (onset of monsoon rain) when temperature fell even below 29 ºC and RH during this period ranged from 48.6 to 75.3 %. Temperature during growth stage of animals ranged from 24.5 to 37 ºC and most often it was hovering around 30 ºC. RH was relatively higher during this stage and it ranged from 79 to 94.9 %. Finisher stage of experimental animals was contemporary with end of monsoon and onset of winter season. Temperature during finisher stage ranged from 22 to 34.5 ºC and most of the time it was below 30 ºC mark. RH during this stage ranged from 75.3 to 90.3 %.

Equation for estimating k coefficient for floor space allowance: It is important to estimate *k* value (coefficient used for estimating floor space allocation on the basis of body weight of pigs), as it is widely used as an indicator for discussion on floor space allowances in pigs. Using allometric equation given below considering body weight (BW) and space allowance (A), *k* values were estimated for each group to compare the results with previous studies.
$A\ (m^2) = k \times BW^{0.67} (kg)$

Measurement of carcass characteristics: Six animals (2 large, medium and small each based on body weight) from each group were slaughtered following standard procedure (Saikia *et al.* 2009) at 29 weeks of age to study the carcass characteristics. All the animals were kept in lairage after arrival at the slaughter house, Livestock Products Technology Division, IVRI, Izatnagar. Before slaughter, the barrows were starved for 18 h and the fasting weight or pre-slaughter live weight was measured using electronic balance. The pigs were slaughtered after proper stunning at 70 V, 250 mA by electricity. Then, bleeding by heart puncturing with knife and wet scalding by hot water at 65°C for 5 to 6 min were performed followed by scrapping and removal of hairs. Thereafter, carcass was hanged upright on gambrel and subjected to singeing with the help of blower. The head was severed by a vertical cut immediately behind the base of ears through the atlas joint and then slightly forwarded following the natural line of the first fold of the cheek. For the purpose of evisceration, an incision was made along the medial line on the ventral side and the visceral organs were pulled out and removed carefully. The weight of carcass was recorded before as well as after removal of head. Dressing percentage was calculated by dividing the hot carcass weight with live weight and then multiplied by 100. Length of carcass was taken from the junction of sternum to the aitchbone. BFT (Back fat thickness) was taken as the average of 3 measures at the level of the first rib, last rib and last lumbar vertebrae. LEA (Loin eye area) was determined by tracing the cut section of *longissimus dorsi* (LD) muscle between 10th and 11th ribs on butter paper. Estimated lean percentage of carcass was determined using equation of Burson (2001) which includes hot carcass weight, tenth rib fat thickness over the loin muscle and loin muscle/eye area at the tenth rib.

Each half of the carcass was divided into 5 major wholesale cuts viz. boston butt, picnic shoulder, loin, belly and ham in addition to a minor cut i.e. jowl as per Gregory (1998). Weight of trimmed cuts was measured using standard weighing balance and represented as percentage of total dressed carcass weight. Weight of different edible and inedible offal was also recorded.

Composition of pork: Samples of *longissimus* muscle were taken from the carcass after dissection. These samples were sealed in polythene bags and stored at –20°C. Collected samples were analyzed for proximate composition after thawing. Moisture, ether extractible portion and crude protein contents of dissected *longissimus* muscle were determined as per the procedures of AOAC (1995).

Statistical analysis: The data thus obtained was subjected to one way analysis of variance (ANOVA) using the SAS software (version 12.0) package. The data were expressed as mean ± standard error and values were compared between groups for interpretation of results.

RESULTS AND DISCUSSION

After rearing with different floor space allowances up to 29 weeks of age, final body weight of barrows did not differ statistically between the groups. Means of major carcass traits of slaughtered barrows reared with different floor space allowances are shown in Table 2. Values of coefficient *k* for treatment groups T_{IS}, $T_{2/3}$ and $T_{1/2}$ ranged between 0.097 to 0.212, 0.064 to 0.138 and 0.049 to 0.102, respectively during the whole experimental period. Estimated values of *k* coefficient suggests that lowest *k* value (0.049) for lowest floor space allocation group ($T_{1/2}$) in present study is still higher than critical value of *k* coefficient (0.035) as suggested in previous studies conducted in developed countries (AAFC 1993, 2004, Gonyou *et al*. 2006, Anil *et al*. 2007). However, carcass characteristics of pigs in relation to *k* value have not been studied under Indian conditions. Liorancas (2005) found that slaughter weight was higher for pigs reared with higher space allowance (1.2 m^2/pig up to 118 kg BW) than pigs provided with minimum space (0.5 m^2/pig up to 113 kg BW). Similarly, reduction in slaughter weight with crowding has also been recorded in some other studies (Kyriazakis and Whittemore 2006, White *et al*. 2008). Whereas, in present study, reduction in floor space seems to be insufficient to have any adverse effect on slaughter weight of barrows under Indian conditions.

Dressing percentage (with and without head) was also not affected with floor space reduction. Mean carcass length of barrows also did not differ between groups. Similarly, BFT was not influenced by floor space reduction. Fat depth (at 10th rib) of barrows was also not affected with floor space reduction. Effect of floor space reduction on LEA of barrows was not significant. Estimated lean percentage value of carcasses was also not affected by floor space reduction. Though it is not fully justifiable to compare the results with earlier studies as floor space allowance even after 50 % reduction in present study is higher than most of the earlier

Table 2. Major carcass traits of barrows reared with different floor space allowances

Parameters	Group		
	T_{IS}	$T_{2/3}$	$T_{1/2}$
Final weight of pigs (kg)	81.20 ± 2.57	82.38 ± 3.46	81.13 ± 2.77
Final weight of slaughtered pigs (kg)	81.17 ± 5.31	83.85 ± 6.81	82.43 ± 4.75
Fasting weight (kg)	75.97 ± 5.42	79.48 ± 6.31	78.22 ± 4.60
Carcass weight (without head) (kg)	56.13 ± 4.22	59.36 ± 5.30	58.51 ± 3.95
Carcass weight (with head) (kg)	60.68 ± 4.49	64.35 ± 5.54	62.95 ± 4.28
Dressing % (without head)	73.79 ± 0.59	74.45 ± 0.88	74.60 ± 0.70
Dressing % (with head)	79.83 ± 0.62	80.79 ± 0.66	80.25 ± 0.80
Carcass length (cm)	73.00 ± 1.32	73.50 ± 3.11	73.33 ± 1.45
Back fat thickness (mm)	19.89 ± 1.13	23.00 ± 2.71	20.56 ± 1.19
Fat depth (at 10th rib) (mm)	16.67 ± 0.92	20.83 ± 3.28	17.33 ± 1.20
Loin eye area (cm^2)	31.84 ± 2.63	34.47 ± 2.21	33.91 ± 2.27
Estimated lean%	53.83 ± 0.69	52.57 ± 2.36	53.93 ± 1.23

Values are presented as Mean ± S.E.; Values didn't differ significantly ($p<0.05$).

studies, an attempt has been made to do the same to some extent. Regarding carcass traits, Brumm (2010) stated that the effect of floor space restriction is a slight improvement in carcass lean and a slight decrease in carcass back fat depth. Carcass weight (with and without head) of barrows did not differ statistically which is in accordance with findings of Liorancas (2005). Dressing percentage (with and without head) was also not affected with floor space reduction which is in agreement with Leek *et al*. (2004). In contrast, dressing percentage was reduced with space reduction (Morrison *et al*. 2003, Liorancas 2005). Mean carcass length of barrows also did not differ between groups though it could not be compared due to lack of literature in this regard. Similarly, BFT was not influenced by floor space reduction which is in agreement with studies of Brumm (1996) and Wolter *et al*. (2001). Whereas, reduced BFT with reduction in floor space have been reported in few studies (Morrison *et al*. 2003, Brumm 2004, Rossi *et al*. 2008). Morrison *et al*. (2003) found that restricted (0.45–0.74 m^2/pig) pen space for crossbred (Large White × Landrace) pigs of 10 to 23 weeks of age resulted in lower back fat measurement compared to pigs that had unrestricted (0.88 m^2/pig) pen space. They suggested that reduced backfat might be due to social stress resulting from reduced pen space. Brumm (2004) found that in finishing pigs (120 kg BW), back fat increased from 19.4 to 21.4 mm when available space increased from $k = 0.023$ to $k = 0.030$. Similarly, Rossi *et al*. (2008) allotted high (1.4 m^2/pig; $k = 0.047$) and low (1.0 m^2/pig; $k = 0.033$) floor space for (Landrace × Large White) × Duroc pigs of 90–160 kg body weight and found that BFT was higher for higher space allowance. In our study, backfat and dressing % were not affected as even lowest floor space group (about 9 to 80 kg BW, 0.45 to 0.9 m^2/pig floor space, and $k = 0.102$ to 0.049 coefficient) had more space allowance than unrestricted or higher floor space of other mentioned studies. Conversely, Cottrell *et al*. (2007) reported that increasing space allowance was related to a decrease in fat depth, which is a highly desirable characteristic for the producer and the abattoir. Fat depth (at 10^{th} rib) of barrows was also not affected with floor space reduction. Similarly, few studies also found no effect of floor space on fat depth (Brumm 1996, Wolter *et al*. 2001, Hamilton *et al*. 2003, Leek *et al*. 2004). Hamilton *et al*. (2003) reported no differences in fat depth in pigs slaughtered at 120 kg BW and reared in restricted or unrestricted conditions ($k = 0.022$ versus $k = 0.038$), although space allowances were very low in both the groups in comparison to present study. Effect of floor space reduction on LEA of barrows was not significant and literature could not be cited for comparison. Estimated lean percentage value of carcasses was in accordance with findings (Leek *et al*. 2004, Liorancas 2005) which state no effect of space allowance on percentage lean. While, decrease in carcass lean was reported in crowded (Brumm *et al*. 2001) conditions and conversely, in outdoor houses (Bremermann 2001) where more space is available. Similar to present study, Gonyou (2005) also found no effect of

Table 3. Cuts (% dressed carcass weight) of barrows reared with different floor space allowances

Cuts (%)	Group		
	T_{IS}	$T_{2/3}$	$T_{1/2}$
Boston butt	12.66 ± 0.90	12.19 ± 1.16	12.23 ± 0.66
Picnic shoulder	12.17 ± 0.57	14.14 ± 0.58	12.71 ± 0.74
Total shoulder	24.82 ± 1.40	26.33 ± 1.27	24.94 ± 1.09
Ham	27.21 ± 1.06	28.07 ± 1.63	28.05 ± 0.70
Loin	32.42 ± 2.01	29.75 ± 1.90	32.57 ± 1.61
Belly	13.59 ± 0.61	13.95 ± 1.08	12.63 ± 0.37
Jowl	1.96 ± 0.14	1.91 ± 0.15	1.82 ± 0.11

Values are presented as mean ± SE; Values did not differ significantly (P<0.05).

Table 4. Edible and inedible offal (kg) from barrows with different floor space allowances

Parameter	Group		
	T_{IS}	$T_{2/3}$	$T_{1/2}$
	Edible offal		
Head	4.55 ± 0.29	4.99 ± 0.30	4.44 ± 0.34
	(6.04 ± 0.25)	(6.34 ± 0.24)	(5.65 ± 0.15)
Trotters	1.25 ± 0.12	1.49 ± 0.17	1.19 ± 0.080
	(1.65 ± 0.10)	(1.87 ± 0.13)	(1.54 ± 0.088)
Liver	1.28 ± 0.057	1.30 ± 0.14	1.23 ± 0.056
	(1.72 ± 0.10)	(1.62 ± 0.050)	(1.58 ± 0.042)
Heart	0.32 ± 0.031	0.29 ± 0.015	0.30 ± 0.018
	(0.42 ± 0.034)	(0.37 ± 0.014)	(0.38 ± 0.011)
Kidney	0.35 ± 0.026	0.36 ± 0.015	0.38 ± 0.028
	(0.47 ± 0.033)	(0.46 ± 0.028)	(0.49 ± 0.030)
GIT full	8.30 ± 0.36	8.16 ± 0.59	7.69 ± 0.14
	(11.19 ± 0.85)	(10.32 ± 0.31)	(9.97 ± 0.48)
Tail	0.12 ± 0.0031	0.13 ± 0.0043	0.12 ± 0.0033
	(0.17 ± 0.014)	(0.16 ± 0.014)	(0.16 ± 0.011)
Total	16.17 ± 0.69	16.68 ± 1.12	15.32 ± 0.580
	(21.64 ± 1.18)	(21.13 ± 0.43)	(19.76 ± 0.49)
	Inedible offal		
Blood	2.04 ± 0.21)	2.33 ± 0.26	2.35 ± 0.24
	(2.68 ± 0.20)	(2.92 ± 0.19)	(3.03 ± 0.29)
Lungs	0.70 ± 0.043	0.66 ± 0.046	0.68 ± 0.038
	(0.94 ± 0.067)	(0.84 ± 0.045)	(0.87 ± 0.047)
Spleen	0.19 ± 0.014	0.17 ± 0.014	0.18 ± 0.014
	(0.26 ± 0.030)	(0.22 ± 0.018)	(0.24 ± 0.017)
Trachea	0.13 ± 0.0089	0.13 ± 0.0089	0.13± 0.0089
	(0.17 ± 0.013)	(0.17 ± 0.0100)	(0.16 ± 0.018)
Gall Bladder	0.12 ± 0.0069	0.12 ± 0.0069	0.12 ± 0.0069
	(0.16 ± 0.016)	(0.16 ± 0.020)	(0.15 ± 0.014)
Leaf fat	1.58 ± 0.18	1.42 ± 0.25	1.19 ± 0.17
	(2.11 ± 0.21)	(1.74 ± 0.18)	(1.49 ± 0.15)
Total	4.75 ± 0.28	4.83 ± 0.54	4.64±0.38
	(6.30 ± 0.22)	(6.04 ± 0.33)	(5.94 ± 0.32)

Values are presented as mean ± SE and those in parentheses indicates % of pre-slaughter weight; Values did not differ significantly (P<0.05).

space allowance on carcass measurements of pigs. Carcass traits were even unaffected by environment enrichment (Klont *et al*. 2001). Further, performance of these animals in terms of carcass traits were more or less similar to some of the earlier control studies of the same farm (SPF, IVRI, Izatnagar) utilizing same crossbred (Landrace × *Desi*) pigs (Bhar *et al*. 2000, Saikia *et al*. 2009, Kumar *et al*. 2012) irrespective of floor space allowances. Whereas, performance of these crossbred were better than Chinese native crossbred (Landrace × Meishan) in terms of dressing %, BFT, LEA, carcass lean as reported by (Jiang *et al*. 2012) irrespective of floor space allowances.

Major cuts of carcasses as percentage of dressed carcass weight are shown in Table 3. None of the cuts viz. boston butt, picnic shoulder, ham, loin, belly and jowl differ between the groups reared with different floor space allowances. Major cuts of carcasses as percentage of dressed carcass weight are shown in Table 3. None of the cuts viz. boston butt, picnic shoulder, ham, loin, belly and jowl differ between the groups reared with different floor space allowances. Literature could not be cited regarding effect of space allowance on major cuts but it seems to be in proportion to body weight measurements.

Edible and inedible offal of barrows reared with different floor space allowances are shown in Table 4. Gastro-intestinal tract (GIT) and blood contributed maximally among edible and inedible offal category, in all the groups. None of the offal component was influenced by difference in floor space allocations. Edible and inedible offal of barrows reared with different floor space allowances are shown in Table 4. Gastro-intestinal tract (GIT) and blood contributed maximally among edible and inedible offal category, in all the groups. None of the offal component was influenced by difference in floor space allocations. Literature could not be cited for comparison regarding effect of floor space on offal components of pigs.

Composition of pork in the form of ingredients viz. moisture, crude protein (CP) and fat content of pork from different treatment groups are shown in Table 5. Proximate components of pork also didn't differ statistically among the groups. Composition of pork in the form of ingredients viz. moisture, crude protein (CP) and fat content of pork from different treatment groups are shown in Table 5. Proximate components of pork didn't differ among the groups. Similarly, Leek *et al*. (2004) reported that composition of the finished carcass was not affected by stocking density (0·75 m^2 versus 0·45 m^2 per growing pig and 0·88 m^2 versus 0·53 m^2 per finishing pig).

Table 5. Proximate composition of pork

Component	Group		
	T_{IS}	$T_{2/3}$	$T_{1/2}$
Moisture (%)	73.83 ± 0.25	74.80 ± 0.54	73.55 ± 0.26
CP (% DM basis)	81.66 ± 1.74	79.58 ± 2.55	80.05 ± 2.11
EE (% DM basis)	8.45 ± 1.32	9.72 ± 0.93	8.98 ± 0.84

Values are presented as mean ± SE; Values did not differ significantly (P<0.05); CP, crude protein; EE, ether extractible contents.

Insufficient space allowance induces prolonged stress by preventing animals from performing their natural behavior, altering HPA axis secretion, immune function, and performance (Earley *et al*. 2010). The responses to stress factors is the release of neurotransmitters in the brain, which stimulate the nervous system and releases stress hormones into the blood, which might stimulate muscle metabolism negatively in relation to subsequent pork quality (Rosenvold and Andersen 2003). Pigs with inadequate space allowance had poor pork quality (Matthews *et al*. 2001). From the literature cited, it seems that very high stocking density adversely affects carcass traits of pigs. While, in present study, even lowest floor space allowance ($T_{1/2}$ group) is larger than optimum floor space recommended for pigs in most of the other countries. It could be reason for no adverse effect of floor space reduction on carcass characteristics of barrows under Indian conditions.

Carcass characteristics of crossbred barrows reared with reduced floor space allowances in comparison to IS were determined and compared. Major economic carcass traits of barrows were unaffected with floor space reduction in comparison to IS. Similarly, major cuts, offal components and composition of pork also did not alter with reduction in floor space allowances. Floor space reduction (up to 50% of IS) did not have adverse effect on any carcass trait of crossbred barrows. It can be concluded that there is scope of 50 % reduction in quantum of floor space allowance for pig rearing in India.

REFERENCES

AAFC.1993. Recommended Code of Practice for the Care and Handling of Farm Animals: Pigs. Agriculture and Agri-Feed Canada Publication 1898/E, Ottawa, Canada.

Anil L, Anil S S and Deen J. 2007. Effects of allometric space allowance and weight group composition on grower-finisher pigs. *Canadian Journal of Animal Science* **87**:139–51.

AOAC. 1995. *Official Methods of Analysis*.16th edn. Volume. I. Association of Official Analytical Chemists. Washington, DC.

Bhar R, Pathak N N and Paul S. 2000. Performance of crossbred (Landrace × Local Indian) finisher barrows fed maize or wheat based diets: *Asian Australasian Journal of Animal Science* **13**:1429–32.

Bhat P N, Mohan N H and Deo S. 2010. *Pig production*. Studium Press (India) Pvt. Ltd. Darya Ganj, New Delhi.

Bremermann N. 2001. Comparing studies in regard of health, fattening efficiency and meat quality of pigs in the indoor and outdoor keeping respectively. Klinik fur Klauentiere des Fachbereiches Veterinarmedizin der Freien Universitat Berlin: Berlin, Germany. p.116.

Brumm MC. 1996. Effect of space allowance on barrow performance to 136 kilograms body weight. *Journal of Animal Science* **74**:745–49.

Brumm M C, Ellis M, Johnston L J, Rozeboom D W and Zimmerman D R. 2001. Interaction of swine nursery and grow-finish space allocations on performance. *Journal of Animal Science* **79**:1967–72.

Brumm M C. 2004. The effect of space allocation on barrow and gilt performance. *Journal of Animal Science* **82**:2460–66.

Brumm M. 2010. Designing production facilities for pig comfort in Argentinian conditions. Sitio Argentino de Producción Animal. Memorias del × Congreso Nacional de Producción Porcina, Mendoza, Argentina. p. 89–96.

Burson D. 2001. *Procedures for estimating pork carcass composition*. NPB-AMSA Factsheet. Accessed on 14/02/2012 from http:/ /www.extension.org/pages/27311/ procedures-for-estimating-pork-carcass-composition.

Cameron R D A. 2000. A review of the industrialization of pig production worldwide with particular reference to the Asian region. *Animal Health and Area-Wide Integration*. FAO, Brisbane, Australia.

Cottrell T S, Dewey C E, Friendship R M, Ribble C and Carr J. 2007. A study investigating farm-level risk factors for variation in carcass characteristics in pigs in Southern Ontario. *25th Centralia Swine Research Update*. II–18, January 25, 2006 Kirkton, Ontario, Canada.

De Decker J M, Ellis M, Wolter B F, Corrigan B P, Curtis S E and Hollis G R. 2005. Effect of stocking rate on pig performance in a wean-to-finish production system. *Canadian Journal of Animal Science* **85**:1–5.

De Greef K H, Vermeer H M, Houwers H W J and Bos A P. 2011. Proof of principle of the comfort class concept in pigs. Experimenting in the midst of a stakeholder process on pig welfare. *Livestock Science* **139**:172–85.

Earley B, Buckham-Sporer K, Gupta S, Pang W and Ting S. 2010. Biologic response of animals to husbandry stress with implications for biomedical models. *Open Access Animal Physiology* **2**: 25–42.

Edmonds M S, Arentson B E and Mente G A. 1998. Effect of protein levels and space allocations on performance of growing-finishing pigs. *Journal of Animal Science* **76**: 814–21.

FAO. 2009. *Red Meat: Agribusiness Handbook*. Investment Centre Division, Food and Agriculture Organization. Viale delle Terme di Caracalla, 00153 Rome, Italy.

Gonyou H W, Deen J, McGlone J J, Sundberg P L, Brumm M, Spoolder H, Kliebenstein J, Buhr B and Johnson A K. 2004. Developing a model to determine floor space requirements for pigs. *Journal of Animal Science* **82**:34.

Gonyou H W.2005. Floor space requirements for grow/finish pigs in large groups. NPB #04–086, Prairie Swine Centre, Saskatoon, Canada.

Gonyou H W, Brumm M C, Bush E, Deen J, Edwards S A, Fangman T, McGlone J J, Meunier-Salaun M, Morrison R B, Spoolder H, Sundberg P L and Johnson A K. 2006. Application of broken-line analysis to assess floor space requirements of nursery and grower-finisher pigs expressed on an allometric basis. *Journal of Animal Science* **84**: 229–35.

Gregory N G. 1998. *Slaughtering and Slaughterhouse*. Animal Welfare and Meat Science. CABI. p. 298.

Hamilton D N, Ellis M, Wolter B F, Schinckel A P and Wilson E R. 2003. The growth performance of the progeny of two swine sire lines reared under different floor space allowances. *Journal of Animal Science* **81**:1126–35.

Indian Standard [IS: 3916–1966]. 1966. *Code of Practice for Pig Housing*. Indian Standard Institution, Manak Bhavan, 9 Bahadur Shah Zafar Marg, New Delhi.

Jiang Y Z, Zhu L, Tang G Q, Li M Z, Jiang A A, Cen W M, Xing S H, Chen J N, Wen A X, He T, Wang Q, Zhu G X, Xie M and Li X W. 2012. Carcass and meat quality traits of four commercial pig crossbreeds in China. *Genetics and Molecular Research* **11**: 4447–55.

Klont R E, Hulsegge B, Hoving-Bolink A H, Gerritzen M A, Kurt E, Winkelman-Goedhart H A and de Jong I C. 2001. Relationships between behavioral and meat quality characteristics of pigs raised under barren and enriched housing conditions. *Journal of Animal Science* **79**: 2835–43.

Kumar A, Bhar R, Mandal A B and Mendiratta S K. 2012. Effect of low protein diets and lysine supplementation on growth performance and carcass characteristics of growing pigs. *African Journal of Biotechnology* **57**:12128–34.

Kyriazakis I and Whittemore C T. 2006. *Whittemore's Science a Practice of Pig Production*. 3rd edition, Blackwell Publishing Ltd, 9600 Garsington Road, Oxford OX4 2DQ, UK.

Leek A B, Sweeney G B T, Duffy P, Beattie, V E and O'Doherty J V. 2004. The effect of stocking density and social regrouping stressors on growth performance, carcass characteristics, nutrient digestibility and physiological stress responses in pigs. *Animal Science* **79**:109–19.

Liorancas V. 2005. Influence of rearing space on the carcass and meat quality of pigs. *XIIth International Congress on Animal Hygiene ISAH – 2005*, *Warsaw,Poland* **2**:169–73.

Marchant-Forde J N. 2009. The welfare of pigs: *Animal Welfare Series*. 7: Springer Science+Business Media B.V.

Matthews J O, Southern L L, Bidner T D and Persica M A. 2001. Effects of betaine, pen space, and slaughter handling method on growth performance, carcass traits, and pork quality of finishing barrows. *Journal of Animal Science* **79**: 967–74.

Mitchell K G, Keal H D and Pittman R J. 1983. The effect of three stocking rates of pigs housed in identical-sized pens on performance. *Animal Production* **37**:41–43.

Morrison R S, Hemsworth P H, Cronin G M and Campbell R G. 2003. The effect of restricting pen space and feeder availability on the behaviour and growth performance of entire male growing pigs in a deep-litter, large group housing system. *Applied Animal Behaviour Science* **83**:163–76.

Rosenvold K and Andersen J H. 2003. The significance of pre-slaughter stress and diet on colour and colour stability of pork. *Meat Science* **63**:199–200.

Rossi R, Costa A, Guarino M, Laicini F, Pastorelli G and Corino C. 2008. Effect of group size-floor space allowance and floor type on growth performance and carcass characteristics of heavy pigs. *Journal of Swine Health Production* **16**: 304–11.

Saikia P, Chhabra A K, Bhar R and Pragati H. 2009. Performance of crossbred pigs (Landrace × *Desi*) fed on food waste. *Indian Journal of Animal Sciences* **79**:819–23.

Turner S P, Allcroft D J and Edwards S A. 2003. Housing pigs in large social groups: a review of implications for performance and other economic traits. *Livestock Production Science* **82**: 39–51.

White H M, Richert B T, Schinckel A P, Burgess J R, Donkin S S and Latour M A. 2008. Effects of temperature stress on growth performance and bacon quality in grow-finish pigs housed at two densities. *Journal of Animal Science* **86**:1789–98.

Wolter B F, Ellis M, Curtis S E, Parr E N and Webel D M. 2000. Group size and floor space allowance can affect weanling-pig performance. *Journal of Animal Science* **78**:2062–67.

Wolter B F, Ellis M, Curtis S E, Augspurger N R, Hamilton D N, Parr E N and Webel D M. 2001. Effect of group size on pig performance in a wean-to-finish production system. *Journal of Animal Science* **79**:1067–73.