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Floor space requirement for housing and welfare of pigs under Indian perspective

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ABSTRACT

Pork production in India has almost doubled from 0.204 MT to 0.402 MT in last decade (2007–08 to 2017–18). Best utilization of pen space without adversely affecting the productivity and well-being of pigs is crucial for pork sector. Most of the developed countries recommend floor space requirement of 0.15 m^2/pig for weaners and South Asian countries as 0.3 to 0.5 m^2/pig without any provision of open space. In India, very few studies have been carried out on space allowance in pigs. Since, Indian Standards (IS: 3916–1966) for pig housing are very old (1960s), study on the floor space requirement for individual pig in all the stages and different group sizes is very much essential for practical pig rearing. The negative impact of crowding on feed intake and growth is well documented. Higher stocking density may also adversely affect feed conversion efficiency. However, reduction in floor area (33% and 50%) in comparison to IS did not affect major performance traits. Space allowance is one of the important factors in the establishment of social rank. In European countries, the most economical allocation of pen floor space was less than the space needed for optimal performance. Reduced space allowances may lead to amplified aggression-related skin lesion scores. Thus, in space restricted environments, the dominance hierarchy becomes less stable amongst pigs and tail and ear biting are also commonly observed. Based on studies done so far it is concluded that there is scope of reduction in floor space allowance in comparison to IS specifications without compromising welfare status of pigs and further research in this area need to be encouraged.

Key words: Agonistic, Behaviour, Economics, Floor space, Growth, Pig, Welfare

Pork production in India has almost doubled from 0.204 MT to 0.402 MT in last decade (2007–08 to 2017–18) (BAHFS 2018). It indicates huge potential of swine to address nutritional security issues in India as well as in the world. About 20% human population consumes pork in the country today. In India, pig population reduced to 10.29 million from 11.13 million showing annual decline of 8.16% between 2007 and 2012 (BAHFS 2018). This decline might be attributed to a high preference for pork over the years with resultant pressure on the existing population and insufficient attempts to address the challenge. Pig farming has become a profitable enterprise due to possessing several desirable economic traits e.g. high prolificacy, faster growth rate, shorter generation interval, low cost of rearing and high dressing percentage with better feed conversion efficiency (Prasad *et al.* 2011). In India, pig rearing and pork industry is shifting from traditional system to intensive system. Intensive pig production has been grown–up all around the world and has increased with larger pace in Asian countries (Cameron 2000). Keeping in view the increased human population and urbanization, efficient utilization of available land (space) is a matter of utmost concern for majority of pig farmers especially in peri–urban areas. Keeping above points in mind, present review paper highlights various aspects of floor space requirement in pigs.

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Importance of floor space

As housing involves lot of expenditure in the beginning with recommended higher space allowance, it sometime discourages farmers to start pig farming. Higher space recommendations based on old housing specifications for pigs are likely to have negative impact on economic competitiveness of the Indian pork industry. A critical factor in the successful rearing of pigs from three weeks onwards is to have correct balance between the numbers in the group and the space they are allowed (Bhat *et al.* 2010). Efficient utilization of pen space without adversely affecting the productivity and well-being of pigs is important for pork production (Anil *et al.* 2007). Most of the developed countries recommend floor space requirement of about 0.15 m^2/pig for weaners and South Asian countries as about 0.3 to 0.5 m^2/pig without any open space (Oosterwijk *et al.* 2003, Cho and Kim 2011) which is far less than Indian Standards (IS: 3916–1966) recommendation despite the fact that average Indian pigs weigh relatively lesser than world average. Further, in addition to this covered area, almost similar sized open area is also recommended in India. There is no study indicating that absence of open area leads to adverse effects on the performance of pigs except one i.e. Kaswan *et al.* (2017; 2018a) showed that pigs had normal growth, physiological and behavioural status without the provision of open area. Further, in neighboring Asian countries, open area is not recommended for pig housing. In India, very few studies have been carried out on space allowance in pigs and whatever done so far are either with different group size/pen or limited to a particular growth stage only (Sinha *et al.* 1990, Sharma *et al.* 2004). Sharma *et al.* (2004) concluded that 0.9 m^2/pig allowance performed better than 1.2 m^2/pig allowance indicating that extra floor space allowance is not desirable. Since IS recommendations for pig housing are very old (1960s), study on the floor space requirement for individual pig in all the stages and different group sizes is very much essential for practical pig rearing.

How floor space is decided?

Scientific data may indicate that space is not as important for pigs as other resources, viz. food access, if their minimum space requirement is satisfied (Marchant-Forde 2009). The pig's body size proportions are the chief determinants of its static space requirements (Petherick 2007). The relationship between animals and space can be defined in different ways, viz. space allowance per animal (m^2/animal), or stocking density (number of animals/m^2). Both measures are mathematically comparable but may differ substantially in terms of ethological impact. Increased stocking density invariably means increases in group size, and this latter factor is likely to be a significant factor contributing to perceptions of 'crowding' (Petherick *et al*. 1989). As group size increases, free space availability per animal too increases inside the pen. Many researchers (Petherick *et al*. 1989, Gonyou *et al.* 2006, Averós *et al.* 2010) have suggested that space allocations should be based on an allometric equation [$A\ (m^2) = k \times BW^{0.67}(kg)$], which relates total space requirements (A) to average pig weight (BW) by some appropriate factor (k). Lot of values has been suggested for k coefficient, which varies from 0.029 to 0.05 and critical value of k has been suggested as 0.034, below which growth rate of pig retards. If the area occupied by the pig (m^2) is $k \times W^{0.67}$, a change in k value of 0.005 below optimum may be taken to be associated with a 4% change in feed intake (when k = 0.025 there is just sufficient space for the pig to lie down; usually k = 0.040–0.050 is acceptable in intensive housing systems). The association between change in k value and feed intake is expected to be universal for growing pigs (Kyriazakis and Whittemore 2006). Considering average body weight of Indian crossbred weaner pig (2 months) as 9 kg and finisher pig (8 months) as 70 kg and covered area allocations as per IS ranges between 0.9 and 1.8 m^2/pig then k value would be 0.206 and 0.104 respectively, which is 6.1 and 3.1 times higher than recommended critical k value. This clearly indicates that there is huge loss of fixed capital investment which should not be recommended.

From these studies it is clear that floor space allocation to pigs should be based upon their size and body weight. Many studies at pig farms in India (Bhat *et al.* 2010, Prasanna *et al.* 2010, Prasad *et al.* 2011) indicated that body weight of indigenous and crossbred pigs is relatively lower than global average. These results show that body weight and size of Indian pigs is inferior than most of other countries and studies on optimum floor space requirements are necessary. Kaswan *et al.* (2016) reported that even lowest value (0.046) of coefficient (k) for 50% space reduction in comparison to IS was higher than suggested critical k value (0.034) of western countries which clearly suggest that IS recommends much more floor space than western and neighbouring counterparts.

Standards of pig housing

IS suggests covered floor space requirement of 0.96–1.8 m^2 for weaner/fattening pigs with almost same dimensions of open space. Whereas, Bhat *et al.* (2010) suggested covered floor space area of 10–15 sq. ft. (i.e. 0.92–1.4 m^2) for weaner and 12–20 sq. ft. (i.e. 1.12–1.85 m^2) for grower pigs. They also suggested different range of resting space per pig for different categories of pig for low, medium and high stocking densities (Table 1).

Table 1. Stocking density at different stages of production

Category	Body Weight or Age	Stocking density (m^2/pig)		
		Low	Medium	High
Weaner pen	(up to 25 kg or 12 wks)	0.35	0.30	0.25
Growing pen	(up to 40 kg or 17 wks)	0.5	0.45	0.40
Finishing pen	(up to 60 kg or 21 wks)	0.70	0.60	0.50
	(up to 90 kg or 27 wks)	0.90	0.75	0.60
	(up to 120 kg or 33 wks)	1.0	0.85	0.70

Source: Bhat *et al.* (2010)

Over-stocking is deliberately practiced in some pig farms, however, higher stocking density should only be practiced in very well managed finishing units (Bhat *et al.* 2010). Enrichment of pig sties with various inanimate objects can help in maintaining stability within the groups, however such studies are lacking in Indian context. Hence, environment enrichment practices considering natural behaviour of pigs should also be given emphasis while formulating floor space recommendations for pigs.

Effect on growth

Negative impact of crowding on feed intake and growth is well documented (Kornegay and Notter 1984, Kornegay *et al.* 1993, Brumm *et al.* 2001). In weanling pigs housed in groups of four, with 0.28 m^2 to 0.14 m^2 of floor space per pig, the lowest average daily gain (ADG) and average daily feed intake (ADFI) were observed in groups with the least floor space (Kornegay *et al.* 1993). Brumm (1996) recorded a linear improvement in the ADG with escalating space allowance in barrows housed at 0.65, 0.93 or 1.20 m^2/pig from initial weight of 55.5 kg. Similarly, a group of growing pigs with restricted space allowance (0.25 m^2/pig), grew slowly than pigs with a larger space allowance (0.56 m^2/pig) (Hyun *et al.* 1998) for each week of the four weeks study. DeDecker *et al.* (2005) reported that the growth performance of pigs decreased but total live weight produced/pen increased linearly with increasing groups size (2450, 2839, and 3147 kg of live weight produced/pen for 22, 27, and 32 pigs/pen, respectively). Negative impact of crowding on growth is mainly due to a reduction in feed intake. Kyriazakis and Whittemore (2006) observed that in weaner pigs, an increase in space allowance from 0.14 to 0.22 m^2/pig (0.031 to 0.048$W^{0.66}$ m^2) was associated with a 10% increase in feed intake (from 440 to 481 g per pig per day) and suggested 0.4 m^2/piglet for most favourable growth. Further, they concluded that space allowances above/below 0.7 m^2/100 kg of pig live weight in the pen will increase/decrease individual pig growth rate by about 2.5% for every 0.1 m^2 change in space allowed. White *et al.* (2008) observed that reducing stocking density from 0.93 to 0.66 m^2/pig resulted in 4.0% less body weight, 17.0% less ADG, 10.7% less daily feed intake and a 7.8% less Gain: Feed ratio (G:F). Cho *et al.* (2010) also reported that for the six-week nursery period, the crowding reduced ADG of gilts (577: 0.50 m^2/pig, 536: 0.25 m^2/pig, and 558 g/d: 0.25 m^2/pig) and barrows (578, 539 and 527 g/d). When growing-finishing pigs are given less than optimal space per pig, feed intake always decreases (Brumm *et al.* 2001), often resulting in a reduction in ADG, with variable effects on the G:F ratio (Cho and Kim 2011). Conversely, crowding has not been demonstrated to increase the variation in weight within a pen at slaughter (Kornegay *et al.* 1993, Brumm *et al.* 2001, Brumm *et al.* 2003, Brumm 2004). Crowding to a space allowance coefficient of 0.026 resulted in a reduction in ADG (Done *et al.* 2006). An earlier research study suggests that the maximum growth rate for the entire grow-finish period will be achieved at a coefficient (*k*) of 0.0336 where A is m^2/pig and BW is in kg (Gonyou *et al.* 2006).

Kaswan *et al*. (2017) did pioneer work to study the effect of space allocations from weaner to finisher stage without altering group size of pigs. They found that body weight of pigs reared with different floor space allowances did not differ among the treatments (33% and 50% reduced space than IS) for different weeks during weaner, grower and finisher stages. It could be due to relatively higher space allowance (k=0.046) even for 50% reduced space group than suggested critical *k* value (0.034).

Effect on feed conversion efficiency

When group sizes of 6, 18, and 36 were maintained at a constant floor space allowance, group size had no effect on feed intake, but feed conversion efficiency (FCE) was reduced in the larger groups (Petherick *et al.* 1989). Kornegay and Notter (1984) observed that for every 0.1 m^2 increment in space for weaners at a floor space allowance of 0.18 m^2 per pig, for grower at a space allowance of 0.3 m^2 and for finisher at a space allowance of 0.7 m^2 corresponding increases in growth performance equated to 8.6, 5.2, and 2.6% respectively and increases in FCE equated to 1.2, 1.6 and 0.4%, respectively. There is tendency for high stocking density to adversely affect the FCR of finishing pigs (Leek *et al.* 2004). FCE tend to be superior for space (1.4 m^2/pig) than in finisher pigs (1 m^2/pig) up to 160 kg body weight (Rossi *et al.* 2008). Pigs that were crowded (0.52 m^2/pig) had inferior feed efficiency (2.7 vs 2.5 lb feed/lb gain, respectively) than pigs that were not crowded (0.78 m^2/pig), ADG was more in un-crowded, feeding time was lesser in crowded pigs with no difference in ADFI between two groups (Street and Gonyou 2008).

The impact of stocking density on FCE is less predictable (Brumm 2010) most likely when it is near to optimal density. Stocking density has not been known to have an effect on diet nutrient digestibility (Leek *et al.* 2004). Sharma *et al.* (2004) studied floor space requirement for Hampshire grower pigs (12–35 kg BW) in hot humid climate of Guwahati, Assam with 4 different space allocation, i.e. 0.4, 0.6, 0.9 and 1.2 m^2 and group size of 12, 9, 6 and 9, respectively and reported maximum ADG and FCE for 0.9 m^2/pig space. Whereas, Brumm *et al.* (2004) reported that there is no difference in feed conversion as a result of space allocation. It seems that at very high stocking density, FCE is affected adversely while at little higher or other space allocations it is difficult to predict FCE. Kaswan *et al*. (2017) found that dry matter intake (DMI) did not differ significantly among the experimental groups except during a fortnight (22–24 weeks) of finisher stage where it was significantly ($P<0.05$) lower in control (IS) group than treatments (33% and 50% reduced space). Overall mean values of DMI, digestibility (DM) and FCE did not differ at different floor space allowances.

Effect of space allowance on health of pigs

Reduced space allowances causes increased aggression-related skin lesion scores (Turner *et al.* 2000, Anil *et al.* 2007). In addition, Wolter *et al.* (2003) found that low floor space allowance also increased the rate of removal of pigs from pens due to injury, poor health, or death. Lower joint swelling scores and lesions associated with fighting or biting were observed in pens with lesser space (Smith *et al.* 2004). It has been recommended that there is predisposition to disease when less than 0.5 m^2 of lying space and less than 0.8 m^2 of total space is allowed per 100 kg of pig live weight (Kyriazakis and Whittemore 2006). Dedecker *et al*. (2005) concluded that adverse health effects with decreasing floor space are of concern from both animal welfare and economic perspectives, and require confirmation. Kaswan *et al.* (2015) reported marginally higher skin lesion scores in lowest space allowance group with no incidence of lameness, diarrohea, and other diseases in different floor space allowance groups probably due to relatively higher space allocation even in lowest space allowance group.

Effect of space allowance on carcass characteristics: The impact of space allocation on carcass back fat and percentage lean has only been reported in a few trials (Brumm and Miller 1996, Brumm *et al*. 2003, Brumm 2004). In all studies, the leanest carcasses and minimum back fat depth were in those pigs given the lowest space allocation treatment. Based on earlier limited data, it is not possible to predict the impact of space allocation on carcass traits, other than to state that the effect is a slight improvement in carcass lean and a slight reduction in carcass back fat depth as space is restricted with a resulting reduction in daily feed intake (Brumm 2010). A reduction in pen space allowance led to a lower back fat and dressing percentage compared to pigs that had unrestricted pen space (Morrison *et al.* 2003). The increase in social pressure in the pigs with restricted pen space may have resulted in recurrent activation of the sympathetic-adrenal medulla axis or the hypothalamic–pituitary adrenal axis and causing catabolism of protein and adipose tissue (Dubeski *et al.* 1999). Thus, social stress in the restricted pen space may have contributed to the leaner pigs with lower dressing percentage (Morrison *et al.* 2003). Back fat thickness was higher for higher space allowance (1.4 m^2) than lower space allowance (1 m^2) of finisher pigs (Rossi *et al.* 2008). Brumm (2004) found that in finishing pigs (120 kg LW), back fat increased from 19.4 to 21.4 mm when available space increased from k=0.023 to k=0.030.

In contrast, Hamilton *et al.* (2003) reported no differences in fat depth in pigs slaughtered at 120 kg LW and reared in restricted or unrestricted conditions (k=0.022 vs k=0.038). Whereas, Cottrell *et al.* (2007) reported that increasing space allowance led to a decrease in fat depth, which is a highly desirable characteristic for the producer and the abattoir. Kaswan *et al*. (2016) found that major carcass traits including cut of parts, share of edible and inedible offal as well as proximate composition of pork did not differ significantly for different floor space allowances.

Effect on behavioural pattern

Space allowance is an important factor in the establishment of social rank (Baxter 1985). When pigs are housed in space restricted environments, the dominance hierarchy becomes less stable (Jensen 1982). Crowding may aggravate social vices such as tail biting, side nudging, and ear chewing (Bryant and Ewbank 1972). A high correlation between observed incidence of play/fight behaviour and lesion scores has previously been observed. Aggression may crop up in modern pig husbandry due to lack of adequate space to respond submissively to a threat, and to achieve full avoidance action and movement away from dominant counterpart. Thus pigs of low social rank, submitting to aggressive pen mates in competitive situations, will suffer greatly in circumstances where, there is limited living space or limited trough space.

Aggressive behaviour in growing and finishing pigs is considerably increased when space allowance is reduced (Randolph *et al.* 1981, Simonsen 1990, Anil *et al.* 2007). This increased aggression may reflect on many behaviour including an inability of pigs to clearly establish dominance relationships at mixing (Baxter 1987), or a long–term inability to escape aggressors (Turner *et al.* 2000). It is also possible that pigs are more aggressive under restrictive conditions due to increased stress levels (Dantzer *et al.* 1980). Crowding has been cited as a common cause of tail biting (Fritschen and Hogg 1983). Weng *et al.* (1998) concluded that when space allowance decreased, the total number of aggressive interactions increased. In the smallest pen, the number of interactions involving biting was greater than at the other pen sizes, and the avoidance index was lowest, indicating that the animals had difficulty getting away from an aggressor.

Tail and ear biting may also be predisposed by insufficient space allowance. Increased stocking densities among growing pigs where there may be many pigs in a group (more than 10) or limited space per pig (less than 1 m^2/100 kg of pig) or both may lead to stereotypic behaviours and aberrant behaviours such as tail-biting (Kyriazakis and Whittemore 2006). Conversely, the increase in free space associated with increasing group size may contribute to reduced aggression through allowing pigs to perform active behaviours without disturbing other animals in the group and through providing a better ability to escape aggressors (Turner *et al.* 1999). Moinard *et al.* (2003) found that a stocking density of 110 kg/m^2 or greater increased risks of tail biting. Increased tail biting with space restriction was also reported by Jensen *et al.* (2010). Average number of aggressive interactions was higher in lower space per pig (0.64 m^2) compared to higher spaces (0.81 m^2 and 0.88 m^2) (Anil *et al.* 2007). Marchant-Forde (2009) also concluded that amount of space, the quality of the space can also have an effect on aggression and the enrichment reduced aggressive behaviour and injuries. In contrary, two surveys reports that tail biting and various management practices has no association between stocking density and the incidence of tail biting (Kritas and Morrison 2004). A study by Seguin *et al.* (2006) on stable groups also found no effect of space allowance on aggressive behaviour at 2.3, 2.8 or 3.2 m^2/sow, but this was also confounded by different group sizes ranging from 11 to 31 sows. Kaswan *et al.* (2015) observed that skin lesion score of head and ears for weaner pigs was higher in low space allowance groups, whereas, total lesion score and lesion scores for other body parts did not differ among the different space allowance groups.

Young pigs are reported to spend 40–60% of their time lying (Blackshaw 1981). With advancement of age, pigs begin to prefer recumbent lying postures, while pigs of 100 kg body weight may spend up to 87.5% of their time lying (Ekkel *et al.* 2003). Pearce and Paterson (1993) found that finisher pigs housed at low rather than high space allowances spent longer sitting motionless and standing. Pigs showed greater amount of time spent lying in sternal rather than lateral recumbency towards grower–finisher period (Anil *et al.* 2007). Locomotory behaviour was also considerably influenced by pen space availability and reduced with space reduction (Morrison *et al.* 2003). A non-linear relationship was found between space allowance per pig and time spent sitting and lying (Averos *et al.* 2010). Younger pigs spent more time eating. Older pigs spend less of their time eating because they eat faster and consume larger amounts in a single meal (Gonyou and Lou 2000). Pigs with restricted pen space engaged in a greater number of social tactile interactions away from the feeder at 17 and 23 weeks of age, which may lead to greater social stress (Morrison *et al.* 2003).

Pigs prefer to show eliminative behaviour at sites that are wet and where they can have contact with pigs in a neighbouring pen (Mollet and Wechsler 1991, Hacker *et al.* 1994). Kaswan *et al.* (2018a) found that reduction of floor space caused the negative impact on eliminative behaviour which necessitated requirement of frequent cleaning of floor to avoid unsanitary conditions inside the pens. Further, they also reported no difference in agonistic activities with reduction in floor space allowances. Social, exploratory and resting activities of pigs were broadly similar in 33% reduced group than IS group; while in 50% reduction group, pigs showed little deviations of the above said beahviour.

Effect of space allowance on economic efficiency of pig production

In order to maximize production efficiency at lower space allowance per animal strategies such as use of slatted floors, automation of feeding systems, temperature control and ventilation are being explored (Marchant-Forde 2009). Investment cost per animal increases when additional space per pig is provided at any given situation. Therefore, the tradeoff between production efficiency and space allocation becomes critical for maximizing profit and remaining competitive (Powell *et al.* 1993). Edwards *et al.* (1988) showed that for the British market, the most economical allocation of pen floor space was less than the space needed for optimal performance with about 0.6 m^2 of floor space required for the best economic performance versus 0.7 m^2 for best pig performance that sold @ 90 kg/pig. At the same time as daily gain, feed intake and feed conversion were better at the lower stocking density level of 0.81 m^2, the economic benefits were better at 0.49 m^2 (Powell *et al.* 1993). Maximum utilization of pen space is an important economic variable (Anil *et al.* 2007). Research suggests marginal costs increase as stocking densities increase due to reduced growth performance of finishers (Brumm 2004). Input cost of (₹145 and 96 per pig) was saved in addition to 805.4 and 400.1 liters of water per pig production and minor savings of labour at 50% and 33% reduced space allowance than IS (Kaswan *et al*. 2018b).

Conclusion

In view of increased human population and urbanization, efficient utilization of available land (space) is a matter of utmost concern for majority of pig farmers especially in peri-urban areas. Best utilization of pen space without adversely affecting the productivity and well-being of pigs is important for pork industry. Negative impact of crowding on growth, feed intake and FCR is well documented. However, space is not as important for pigs as other resources, e.g. food and environment. Space allowance is one of the important factors in the establishment of social rank. It is concluded that as per existing practices, floor space reduction of more than 33% in comparison to IS specifications can be suggested without compromising welfare status of pigs. Investigations are required to validate the floor space requirement for different categories of pigs, in different group sizes, and environmental conditions.

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