

Original Research Article

Effect of increasing stocking density on the Welfare of Growing Large White Yorkshire Pigs

Commented [WU1]: Follow the journal template

ABSTRACT

Aim

This study aimed to evaluate the impact of decreasing stocking density on the welfare of growing Large White Yorkshire pigs.

Study Design

The research focused on assessing the effects of space allowance on pig welfare, health, and production performance, addressing the gaps in understanding how pen size, group size, and stocking density influence pig behaviour and welfare. Seventy-four weaned pigs were assigned to four treatments with varying stocking densities, and behavioural observations were recorded using smartphone cameras and CCTV.

Place and Duration of Study

The experiment was conducted from 2020 to 2023 at the All India Coordinated Research on Pig, Piggery Farm, Department of Livestock Production Management, Guru Angad Dev Veterinary and Animal Sciences University, Ludhiana (Latitude: 30°54' North, Longitude: 75°48' East).

Methodology

Behavioural activities were monitored using smartphone cameras and CCTV systems, and statistical analysis using ANOVA was performed to evaluate the impact of stocking density on pig behaviour and growth performance.

Results

The study found no statistically significant differences in growth performance among treatment groups. However, body weight increased linearly over time across all groups. Feed intake and feed conversion ratio (FCR) showed significant variation, with pigs in higher stocking densities consuming more feed and displaying a higher FCR. Negative behaviours, including aggression and tail biting, were more prevalent in higher stocking density groups.

Conclusion

Reducing the floor allowance per pig had minimal impact on growth performance but significantly increased negative social behaviours, such as aggression and tail biting. These findings highlight the importance of optimizing space allowance to improve pig welfare in modern farming systems.

Keywords: Behavioural activity, Feed intake, Growth performance, Pig welfare, Space allowance, Stocking density

Commented [WU2]: It is better if the abstract is made a little more comprehensible

1. INTRODUCTION

Space allowance (or stocking density) for group-housed pigs refers to unobstructed floor area per pig inside pens or the number of pigs per unit pen area. As an important technological index in modern livestock housing systems, it is strongly related to animal health and welfare, production performance and efficiency, as well as producers' profit (NSR Sastry and CK Thomas, 2015). For a better output, the producer usually prefers a relatively higher stocking density. It has been suggested that the reduced productivity caused by inadequate space allowance occurs because of insufficient feeding space or access to the feeder which causes reduced feed intake (Boyd, 2019). An enriched living environment designed to meet the needs of growing-finishing pigs requires more space than under conventional Dutch conditions. According to Indian Standards (IS: 3916-1966), the floor space requirements for weaned pigs is 0.9 to 1.8 m² per pig, and are not suitable for the intensive system of farming. Though variations in pen size, group size and stocking density can have a major impact on farm animal welfare and production, it is still not clear how these factors affect, for example, pig behaviour (e.g., social behaviour and dynamics) and welfare (Camp Montoro et al., 2021). This study aimed to study the effect of decreasing stocking density on the Welfare of Growing Large White Yorkshire Pigs.

2. MATERIAL AND METHODS

Experimental animals and design

On the 60th day, a total of 74 weaned pigs were randomly grouped into 4 treatments (T₁, T₂, T₃ and T₄), each having a similar body weight range and on an average group weight basis. In T₁, the pigs were reared to a standard stocking density of 0.3 m²/pigs. Each treatment's stocking density was increased by 10% (T₂), 20% (T₃) and 30% (T₄). The pen is made available in such a way that the space may decrease according to the stocking density proposed in the plan of work.

Housing

The house of Piggery Farm of the Department of Livestock Production Management, Guru Angad Dev Veterinary and Animal Sciences University, Ludhiana, is 246 x 46.6 feet in dimension and height in the centre is 13 feet and sloping to 10 feet at the side with a centre passage of 6 feet wide. The pens are divided into ten pens of dimensions 10 x 8.9 feet (cover area) and 10 x 8.9 feet (open area) partition of permanent concrete of 4 feet height with an additional 1 feet of steel pipes going across each partition. Each cover area consists of a creep area of 5.4 x 3.4 x 3 feet; combining the manger and watering area, it is 5.1 x 3.1 x 1.5 feet. Guard rail of a steel pipe which is 1.5 feet height around the cover area and distance from the wall is 1 feet. All these arrangements were made to make the pen airtight, and the upper edges of the house provide ventilation. Each pen with a dimension of 89 square feet was utilized to stock the animals with a floor space of 3.2 square feet per piglet.

Feeding

The corn-soybean meal-based basal diet was formulated as per the NRC-2012 grower ratio, and the calculated analyses of the same diet are given in Table 1. Daily feeding record was maintained separately for each group of the managemental weaning system. Feed and water were made available ad libitum all the time. The body weight of all the piglets was recorded individually at weekly intervals.

Behaviour

The behavioural status of the pigs was recorded using a smartphone camera recorder (VIVO Y11 13MP), and with a CCTV (SONY DSC-HX10V), the responses of the piglets in all the treatment groups were examined. Behaviour recordings were taken 3 times at 09.00, 12.00 and 15.00 IST for an hour on the day of weaning/grouping (0th day), 5th, 10th and 15th day. Thus, behavioural activity was recorded 3 times per day X 30 minutes X 4 days = 360 minutes for each pig in each pen during the experimental period. The behavioural activity was analysed by Turpin et al. (2017).

Statistical Analysis

Significance was defined as P<0.05, with tendencies defined as P<0.01. All statistical analysis was carried out using IBM SPSS Statistics 26. The behaviour of focal animals was calculated as a

Commented [WU3]: Introduction: The introduction section can be improved if these steps are followed
Background of the study
Impacts
Existing Review
Importance of study
Gap as well as Objective of the study.

Commented [WU4]: When describing the methodology for a research article you would need to provide a detailed explanation of how the research was conducted. This includes
The research design,
Study Area and Population
Sampling Method
Data analysis techniques.

percentage of the observation time and behavioural data were analysed using mean values per group. The data were normalized by applying square root transformation and analysis of variance (ANOVA) was carried out to examine the effects of the rearing environment on behaviour and performance. The treatment means were compared by Duncan's Multiple Range Test at a 5% level of significance ($P \leq 0.05$). (Snedecor & Cochran, 1994)

3. RESULTS AND DISCUSSIONS

The growth performance reveals that there was no statistically significant between the treated groups, but there was a linear increase in body weight till the end of the study period (Table. 3). Previous studies found that stocking density or group size has been shown to affect the growth performance and health status of pigs (Funk et al., 2007; White et al., 2008). Pigs raised in 1.3 m²/pig showed a better growth performance compared with those in 1.0 m²/pig (Nannoni et al., 2019). In contrast to their finding, we observed that there was no difference in body weight till the end of the study period. The weekly body weight gain and average daily gain (ADG) show no statistically significant among the treatment groups. Though the result reveals no statistical significance there is a numerical change in the daily gain and it was observed that there was a linear increase in the daily gain showing an increasing trend in the weight gain. Overall ADG also reveals no statistically significant but numerical higher body gain was observed in lower stocking rate as compared to pigs at higher stocking rate. Deen, (2005) observed that space allowance treatment had the highest ADG of 0.94 kg/day. Reducing stocking density from 0.93 to 0.66 m²/pig reduced BW by 4.0%, ADG by 17.0%, ADFI by 10.7%, and G: F ratio by 7.8% as observed by White et al. (2008). Similar findings were also reported by Gonyou et al. (2006); Laskoski, (2017) who observed that for every 0.001 decrease in k (approximately 3% of the critical k value), ADG decreased by 0.56 to 1.41%, with an average value of 0.98% for the 5%-based analyses. In contrast to this Li et al. (2020); and Potter et al. (2010) found no significant differences were noted among ADG, ADFI, or F: G ratio of growing pigs 128 after 30 d of treatment ($P > 0.05$).

The ADFI reveals a statistically significant difference ($P < 0.05$) between the treatment groups (Table. 4). We also observed a linear increase in the feed intake where piglets in higher stocking density pigs consumed more feed as compared to the lower stocking animals of 0.3 and 0.27 m²/pig. The increase in feed intake might be due to the high stocking rate as high stocking density may cause a behavioural problem for pigs. At higher stocking densities, the likelihood of developing crowding stress occurs. Also, due to the high temperature and humidity difference during rearing the pigs are subjected to heat stress which results in higher feed intake. In our present study, the ADFI and ADG were increased with increasing stocking density, and it is generally thought that the reduction in body weight gain is the consequence of reductions in feed intake. Breinekova et al. (2007) stated that due to increases in physiological response to stressors (such as heat and spacial restriction) result in activation of the sympathetic nervous system and the release of catecholamines and glucocorticoids reduces body weight. The present finding was in accordance with the findings of Brumm et al. (2001); Gonyou et al. (2006); Kim et al. (2016); and Potter et al. (2010) where they observed that when growing-finishing pigs are given less than optimal space per pig, feed intake always decreases.

The data reveals a statistically significant difference ($P < 0.05$) between the groups, on the first week the pigs under low stocking density (0.3m²/pig and 0.27 m²/pig) were observed to have a statistically better FCR of 1.29±0.13 and 1.27±0.15 as compared to higher stocking density group (0.24m²/pig and 0.21m²/pig) 1.43±0.14 and 1.77±0.14. However, in the second week, it was observed that there was a significant difference ($p < 0.05$) in the FCR where the heavier stocking density group T4 had the best stocking density when compared with the other stocking density. The lower FCR during the first week might be due to the stress of the animals, where animals are new to their surroundings and to their pen mates, which reflects on the FCR as shown by our experiment. Later when the animals get acclimatized, they regain their feed activeness and get less stress which may have resulted in the changes in the FCR.

The overall FCR reveals statistically significant ($P < 0.05$) between the treatment groups; better FCR were observed in pigs under low stocking density and on heavier stocking the FCR increases. This might be due to stress within larger groups reducing growth potential, and hence ADG, which in turn reduces appetite and ADFI. Stress within the group might be the result of physical restrictions, as

Commented [WU5]: The result should be explained with a table

discussed above, or from the social stress inherent to interaction with more pigs. Though there is no significant difference between treatment groups, there was a numerical difference between the treatment groups where T₁ (0.3 m²/pig) had the lowest FCR (3.19). Kim et al. (2016) observed that no significant effect of stocking density on FCR in FP was observed; the FCR was highest in the group (P>0.1). These results suggest that a high density could retard the growth rate due to lower nutrient availability and chronic stress caused by the social hierarchy and interaction among individuals. Similar to our finding, Carpenter et al. (2018); and Zhang et al. (2013) observed a higher G: F ratio reared in pens with a density of 0.48 m²/pig compared to pigs reared in 0.38 m²/pig.

There was a statistically significant difference in the negative behaviour during the day of grouping/mixing (Figure 1). Pigs under T₁ show less activity when compared to those pigs with higher stocking density. On the day of grouping, pigs show more active behaviour in the form of aggression to establish a new social hierarchy. This results in more active behaviour, resulting in less feed intake, but statistically, the present experiment shows no significance in drinking, but drinking water significantly increases due to the high temperature of the macro-environment and micro-environment of the pen. It was also observed that others had more positive social interaction during the first period, this might be due to the are not familiar with the pen mates and the pig identifies its pen mates either by sniffing the underbelly or by pushing gently. Exploratory behaviour was also observed to be statistically significant between the groups which indicates that the pig in their new pen is trying to familiarise themselves with their new surroundings by sniffing and exploring the different corners of the pens. More exploratory behaviour was observed for higher stocking density groups as these animals tried to find the best place for them to settle. During the observation, more negative behaviour was observed on tail biting, as Crowding has been cited as a common cause for tail biting. Similar findings were reported by Prunier et al. (2020); Van de Weerd et al. (2005); Zonderland et al. (2011); and Zupan et al. (2012) observed that aggressive tail biters are from the lower body weight called 'runt' in the litter. These persistent biters, so-called 'fanatical biters', were described as hyperactive pigs going from one tail to another during a biting outbreak.

Towards the end of the observation, it was found that the duration of lying time also increased which indicates a reduction in other activity during the last day of behaviour observation on the 15th day, the piglets in T₁ (0.3 m²/pig) were found to spend more time sleeping/lying down as compared to the higher stocking density. Though it was still observed that a statistically significant difference occurs in some of the actives like positive social behaviour and exploratory behaviour, these actives are found to be more in a heavier stocking density than in the lighter stocking density groups.

4. CONCLUSIONS

In conclusion, decreasing the floor allowance per pig by 0.27 m²/pig (10%) does not greatly affect the growth performance compared to the conventional floor allowance of 0.3 m²/pig. Furthermore, increasing the feed intake is due to the increase in the number of animals and also due to the negative behaviour which increases with eating behaviour. However, it was observed that the negative social behaviour reveals higher activity in the higher stocking density.

ETHICAL APPROVAL

All authors hereby declare that all the guidance on experimental animals of CPCSEA were followed, as well as specific national laws where applicable. All experiments have been examined and approved by the appropriate ethics committee **Regd. No. GADVASU/2021/IAEC/62/15**.

REFERENCES

- Boyd, P. (2019). How stocking density affects feed intake. *Pig Progress*, 35(10), 24–25.
- Breinekova, K., Svoboda, M., Smutna, M., & Vorlova, L. (2007). Markers of acute stress in pigs. *Physiological Research*, 56(3), 323.

Commented [WU6]: The conclusion could be strengthened by clearly summarizing the key implications of the findings for animal welfare and productivity. Highlight how the observed negative social behaviors might impact long-term health or overall farm management. Additionally, consider providing recommendations for optimal stocking density based on the balance between welfare and productivity.

Brumm, M. C., Ellis, M., Johnston, L. J., Rozeboom, D. W., Zimmerman, D. R., Arthur, R. D., Carter, S., Christenson, R. K., Christianson, L., Harmon, J. D., Hines, R. H., Jones, D. D., Leibbrandt, V. D., Libal, G. W., Mayrose, V. B., Moeller, S. J., & Richert, B. (2001). Interaction of swine nursery and grow-finish space allocations on performance. *Journal of Animal Science*, 79(8), 1967–1972. <https://doi.org/10.2527/2001.7981967x>

Camp Montoro, J., Boyle, L. A., Solà-Oriol, D., Muns, R., Gasa, J., & Garcia Manzanilla, E. (2021). Effect of space allowance and mixing on growth performance and body lesions of grower-finisher pigs in pens with a single wet-dry feeder. *Porcine Health Management*, 7(1), 1–8. <https://doi.org/10.1186/s40813-020-00187-7>

Carpenter, C. B., Holder, C. J., Wu, F., Woodworth, J. C., DeRouchey, J. M., Tokach, M. D., Goodband, R. D., & Dritz, S. S. (2018). Effects of increasing space allowance by removing a pig or gate adjustment on finishing pig growth performance. *Journal of Animal Science*, 96(7), 2659–2664.

Deen, J. (2005). Effect of stocking density on the welfare and performance of grow-finish pigs. *Research Report: Animal Welfare. NPB #04-093*, 88, 1–25.

Funk, J., Wittum, T. E., LeJeune, J. T., Rajala-Schultz, P. J., Bowman, A., & Mack, A. (2007). Evaluation of stocking density and subtherapeutic chlortetracycline on *Salmonella enterica* subsp. *enterica* shedding in growing swine. *Veterinary Microbiology*, 124(3–4), 202–208.

Gonyou, H. W., Brumm, M. C., Bush, E., Deen, J., Edwards, S. A., Fangman, T., McGlone, J. J., Meunier-Salaun, M., Morrison, R. B., & Spooler, H. (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(1), 229–235.

Indian Standard (IS: 3916-1966). 1966. Code of practice for pig housing. Indian Standard Institution, Manak Bhavan, 9 Bahadur Shah Zafar Marg, New Delhi. Available at <https://archive.org/details/gov.in.is.3916.1966>

Kim, K. H., Cho, E. S., Kim, K. S., Kim, J. E., Seol, K. H., Sa, S. J., Kim, Y. M., & Kim, Y. H. (2016). Effects of stocking density on growth performance, carcass grade and immunity of pigs housed in sawdust fermentative pigsties. *South African Journal of Animal Science*, 46(3), 294–301.

Laskoski, F. (2017). *Universidade Federal Do Rio Grande Do Sul Faculdade De Veterinária Programa De Pós-Graduação Em Ciências Veterinárias “Desempenho De Leitões Submetidos a Diferentes Espaços De Comedouros Quando Mantidos Em Alta Densidade Na Fase De Creche.”*

Li, X., Xiong, X., Wu, X., Liu, G., Zhou, K., & Yin, Y. (2020). Effects of stocking density on growth performance, blood parameters and immunity of growing pigs. *Animal Nutrition*, 6(4), 529–534. <https://doi.org/10.1016/j.aninu.2020.04.001>

Nannoni, E., Martelli, G., Rubini, G., & Sardi, L. (2019). Effects of increased space allowance on animal welfare, meat and ham quality of heavy pigs slaughtered at 160Kg. *PloS One*, 14(2), e0212417.

NRC. 2012. Nutrient requirements of swine. 11th rev. ed. Natl. Acad. Press, Washington, DC.

Potter, M. L., Tokach, M. D., DeRouchey, J. M., Goodband, R. D., Nelssen, J. L., & Dritz, S. S. (2010). *Effects of increasing stocking density on finishing pig performance.*

Prunier, A., Averos, X., Dimitrov, I., Edwards, S. A., Hillmann, E., Holinger, M., Ilieski, V., Leming, R., Tallet, C., Turner, S. P., Zupan, M., & Camerlink, I. (2020). Review: Early life predisposing factors for biting in pigs. In *Animal* (Vol. 14, Issue 3, pp. 570–587). <https://doi.org/10.1017/S1751731119001940>

Sastry, N.S.R., & Thomas, C.K. (2015). Swine Production. In N.S.R. Sastry & C.K. Thomas (Eds.), *Livestock Production Management* (pp. 506-577). Kalyani Publishers, New Delhi-110002.

Snedecor, G. W., & Cochran, W. G. (1994). *Statistical methods, 8th Edn.* Iowa. State University Press, Ames, Iowa.

Turpin, D. L., Langendijk, P., Plush, K., & Pluske, J. R. (2017). Intermittent suckling with or without co-mingling of non-littermate piglets before weaning improves piglet performance in the immediate post-weaning period when compared with conventional weaning. *Journal of Animal Science and Biotechnology*, 8(1), 1–12. <https://doi.org/10.1186/s40104-017-0144-x>

Van de Weerd, H. A., Docking, C. M., Day, J. E. L., & Edwards, S. A. (2005). The development of harmful social behaviour in pigs with intact tails and different enrichment backgrounds in two housing systems. *Animal Science*, 80(3), 289–298.

White, H. M., Richert, B. T., Schinckel, A. P., Burgess, J. R., Donkin, S. S., & 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(8), 1789–1798.

Zhang, Z. F., Li, J., Park, J. C., & Kim, I. H. (2013). Effect of vitamin levels and different stocking densities on performance, nutrient digestibility, and blood characteristics of growing pigs. *Asian-Australasian Journal of Animal Sciences*, 26(2), 241–246. <https://doi.org/10.5713/ajas.2012.12434>

Zonderland, J. J., Schepers, F., Bracke, M. B. M., Den Hartog, L. A., Kemp, B., & Spoolder, H. A. M. (2011). Characteristics of biter and victim piglets apparent before a tail-biting outbreak. *Animal*, 5(5), 767–775.

Zupan, M., Janczak, A. M., Framstad, T., & Zanella, A. J. (2012). The effect of biting tails and having tails bitten in pigs. *Physiology & Behavior*, 106(5), 638–644.

Table 1: Composition of Grower Ration and its nutrient composition

Ingredient	Grower Ration (10-20 kg) (Kg)
Maize	56.00
Soybean Meal	28.00
Wheat Bran	10.00
Fish Meal/GNC	4.00
Mineral Mixture	1.50
Salt	0.50
Calculated Nutrient Composition	
Moisture %	11.90
Dry Matter %	88.10
Total Ash %	6.05
Acid Insoluble Ash %	0.30
Crude Protein %	22.75
Ether Extract %	3.78
Calcium %	0.63

Phosphorus %	0.49
--------------	------

Table 2: Ethogram of the pig

Item	Description
Lying (duration)	Lying without investigation
Eating	With their head in the feeder
Drinking	Pigs making oral contact with the nipple drinkers
Negative social behaviour	Aggressive behaviour, including social behaviour with fight aggressive or flight reaction of the other pig
Positive social behaviour	Sniffing, nosing, licking, and moving gently away from the pig without an aggressive or flight reaction from this individual
Exploratory behaviour	Floor, wall, and pen fittings investigation
Other active behaviour	Other active behaviour except for the above 6 types

Table-3: Growth Performance of weaned at different stocking densities.

Age (Days)	Treatments				
	Control (T ₁) (N=16)	Stocking Density 10% (T ₂) (N=18)	Stocking Density 20% (T ₃) (N=19)	Stocking Density 30% (T ₄) (N=21)	p-value
Average Body weight, Kg					
Initial (60)	9.31±0.27	9.32±0.36	9.31±0.31	9.32±0.38	1.00
67	10.30±0.24	10.39±0.34	10.74±0.40	10.45±0.60	0.91
74	11.80±0.25	12.18±0.36	11.78±0.32	12.04±0.66	0.86
81	13.73±0.28	14.27±0.38	14.12±0.30	14.56±0.46	0.92
90	16.22±0.23	16.68±0.46	16.55±0.31	16.45±0.51	0.91
Average Daily Weight Gain (g)					
67	179.38±14.51	213.99±22.90	162.84±14.13	160.41±23.04	0.15
74	204.81±9.18	220.32±20.96	197.11±24.88	213.10±10.80	0.53
81	286.50±26.73	300.06±20.32	308.63±26.00	312.26±32.76	0.96
90	342.30±31.04	344.54±35.14	347.25±31.10	328.16±42.52	0.90

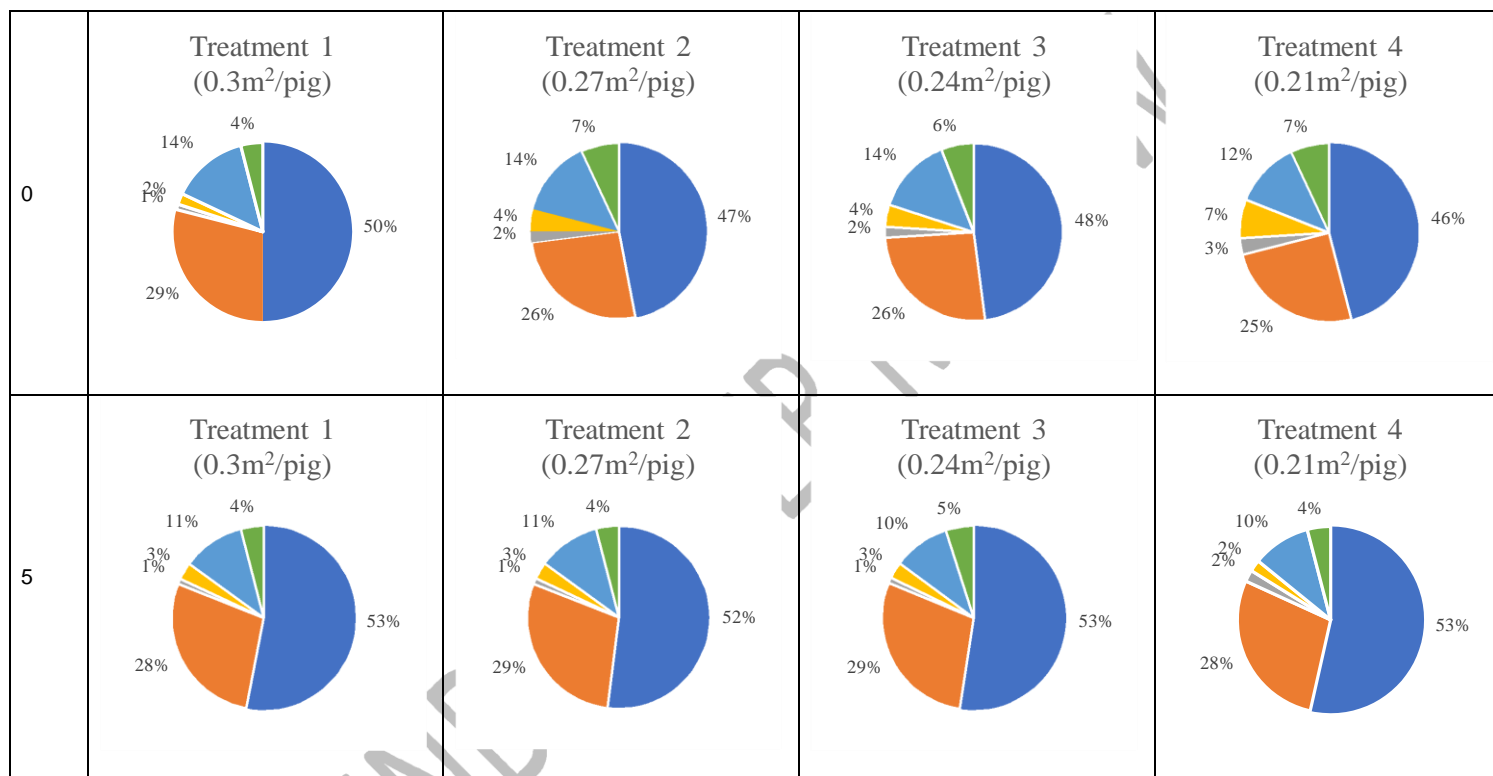
Overall ADG (67-90)	254.07±6.10	262.98±12.89	258.42±11.64	253.25±19.77	0.96
---------------------	-------------	--------------	--------------	--------------	------

Mean values bearing different superscripts in a row differ significantly ($p < 0.05$), SE-standard error

Table 4: Feed efficiency of weaned Piglets when reared at different stocking densities

Age (Weeks)	Treatments				
	Control (N=16)	Stocking Density 10% (N=18)	Stocking Density 20% (N=19)	Stocking Density 30% (N=21)	p-value
	Average Daily Feed Intake, Kg				
10 th week	3.57 ±0.19 ^c	4.29 ±0.15 ^b	4.36 ±0.16 ^b	5.14 ±0.19 ^a	0.00
11 th Week	4.21 ±0.21 ^b	5.79 ±0.23 ^a	5.64 ±0.18 ^a	5.79 ±0.37 ^a	0.00
12 th Week	5.43 ±0.19 ^c	7.50 ±0.11 ^b	7.29 ±0.11 ^b	9.07 ±0.23 ^a	0.00
13 th Week	6.43 ±0.18 ^c	8.43 ±0.09 ^b	8.29 ±0.14 ^b	9.86 ±0.13 ^a	0.00
Total Feed Intake (67-90)	17.19±0.69 ^c	20.22±0.44 ^b	18.85±0.15 ^b	20.90±1.30 ^a	0.00
Average Feed Conversion Ratio					
10 th week	1.29±0.13 ^b	1.27±0.15 ^b	1.43±0.14 ^{ab}	1.77±0.14 ^a	0.05
11 th Week	1.33±0.07 ^b	1.64±0.15 ^{ab}	1.78±0.17 ^b	1.21±0.16 ^a	0.03
12 th Week	1.36±0.15	1.56±0.16	1.41±0.13	1.81±0.26	0.32
13 th Week	1.34±0.16	1.66±0.19	1.47±0.14	2.01±0.27	0.13
Overall FCR (67-90)	2.44±0.06 ^a	2.88±0.17 ^{ab}	2.69±0.11 ^a	3.42±0.34 ^b	0.02

Mean values bearing different superscripts in a row differ significantly ($p < 0.05$), SE-standard error



■ Lying
 ■ Drinking
 ■ Eating
 ■ Negative
 ■ Positive
 ■ Exploratory

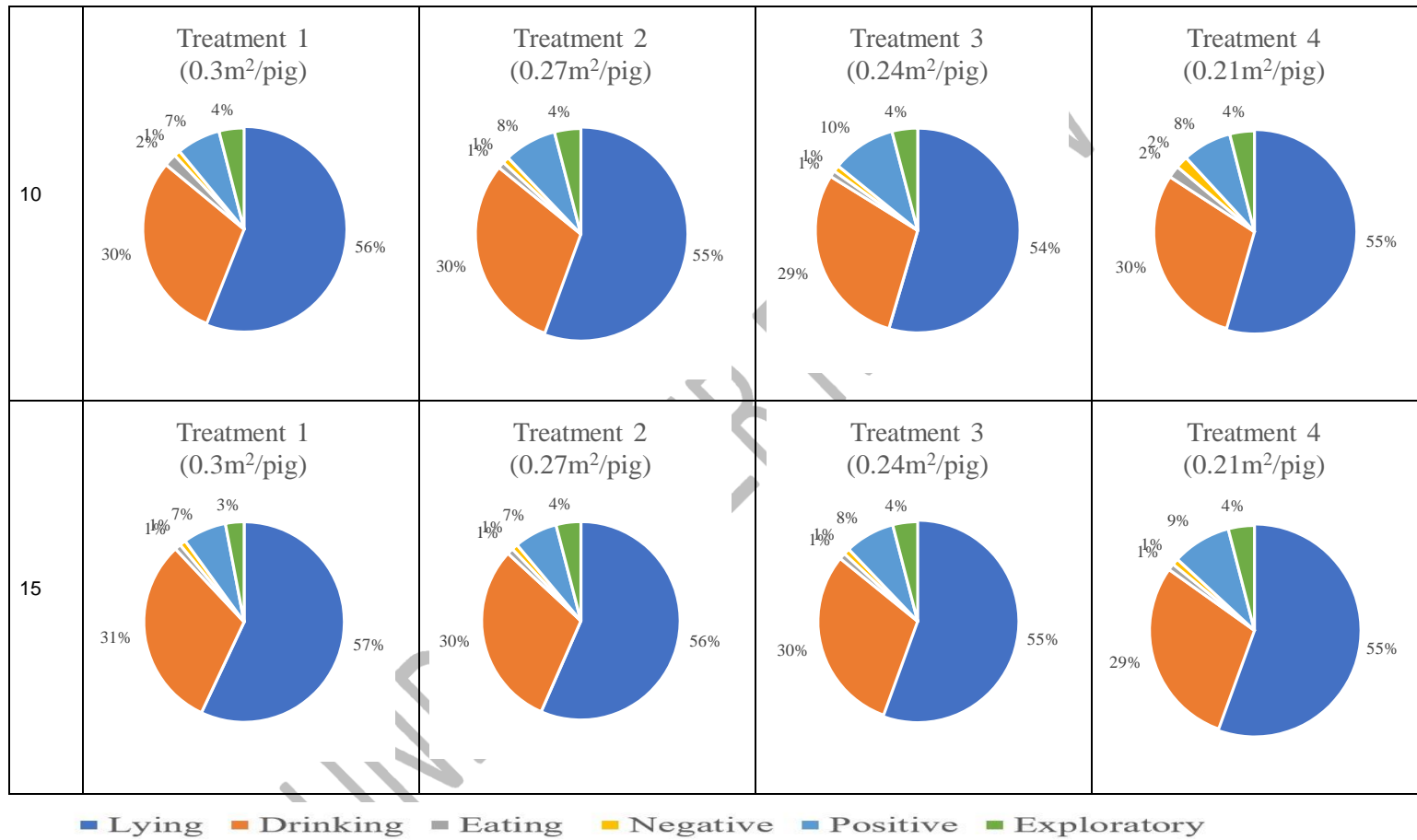


Fig. 1: Pie chart diagram represents Behaviour