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Effects of nursery and finishing pen shape on pig performance and welfare

Efecte ale formei boxelor din sectoarele creșă și finisare asupra performanțelor și bunăstării suinelor

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ABSTRACT

Modern commercial pig production systems are currently facing several challenges like market prices volatility, high production and environmental costs. Responding to public demand and the legal requirements for improving the welfare standards is leading to further growth of the farming costs and lower profit margins for the pig industry. Due to its impact on key production performance indicators and on welfare, space allowance for nursery and finishing pigs has been the subject of extensive research over the past decades. However, space allowance per pig is just a relative approach, pen side ratio and shape being important as well as it interferes with the free movement and several behaviors expressed by pigs. This study is focused on the impact of pen shape by comparing implications of housing pigs in pens with different perimeter to area ratios at the same level of surface allowed per pig. Results are suggesting that the pen shape design might have an influence on the rearing performance indicators like average daily gain (ADG) and feed conversion ratio (FCR) both in nursery and finishing stages. It seems as well that a welfare indicator, namely the recorded number of skin lesions, differ according to the pen shape, in the favor of pens with lower length to width ratio, even if the pig density per surface unit, feeding, ventilation and enrichment patterns are the same.

Keywords: pigs, welfare, pen shape, growth and carcass performance

REZUMAT

Sistemele moderne ale producției comerciale de carne de porc trebuie să facă față multor provocări actuale cum ar fi volatilitatea prețurilor, costuri de producție și de mediu aflate într-o continuă creștere. Răspunzând cerințelor consumatorului, dar și conformarea la cerințele legale referitoare la îmbunătățirea standardelor de bunăstare conduce implicit la escaladarea necesarului de investiții costisitoare și la erodarea marjelor de profit din industria cărnii de porc. Datorită impactului incontestabil asupra parametrilor productivi esențiali, dar și a bunăstării, spațiul alocat porcilor aflați în creșă și în finisare a constituit o preocupare constantă a cercetărilor din ultimele decade. Cu toate acestea, spațiul alocat per porc ar putea să nu fie un parametru suficient, raportul dintre laturile boxelor și, implicit a designului acestora, ar putea fi importante întrucât acesta poate constrânge libertatea de mișcare și unele comportamente exprimate de către porci. Obiectivul prezentului studiu a fost focalizarea pe influențele raportului dintre aria și perimetrul boxelor asupra unor indicatori de performanță, la aceeași suprafață asigurată per cap de animal. Rezultatele par a sugera că designul dimensional al boxelor ar putea avea impact asupra unor performanțe de creștere cum ar fi sporul mediu zilnic (SMZ) sau rata conversiei furajului (RCF) atât în creșă, cât și pe durata finisării. De asemenea, se pare că un indicator al bunăstării, precum numărul de leziuni cutanate, este diferit în funcție de forma boxelor, fiind favorabil celor cu un raport dintre lungime și lățime mai redus, chiar și în condiții identice de densitate per metru pătrat, sau de furajare, ventilație și materialele ocupaționale oferite.

Cuvinte cheie: suine, bunăstare, forma boxelor, performanțe creștere și abatorizare

INTRODUCTION

In light of the current volatile market conditions for pig meat production, nursery and finishing growth performances on pig farms are crucial to the farm's efficiency and profitability. However, in order to achieve these objectives, a balance needs to be struck between the increasing public pressure regarding the viability of animal agriculture and legal standard requirements of animal welfare that are demanded by contemporary European consumers. As part of its Farm to Fork Strategy, the European Commission is currently conducting a comprehensive evaluation of the welfare laws pertaining to farm-raised pigs (EFSA Panel on animal Health and Welfare, 2022). This includes changing the legal requirements about how to protect animals that are kept for farming (Council Directive 1998/58/EC) and the one that establishes the minimum requirements for pig protection (Council Directive 2008/120/ EC).

It is widely accepted that one of the main animal based welfare markers in pig commercial farming is considered to be the space allowance per pig. As a consequence, in EU this indicator is embedded in the current legal framework requiring minimum surface for all pig groups by age and weight. Due to its undeniable impact on key production performance indicators (ADG - Average Daily Gain; ADFI - Average Daily Feed Intake; FCR - Feed Conversion Ratio) and as well as on welfare, space allowance for nursery and finishing pigs has been the subject of extensive research over the past three decades (Powell et al.,1993; DeDecker et al., 2005; Thomas et al., 2017).

Although there are no solid proofs that the cutoff value for more space allowance affects production performance, it is well known that insufficient individual space influences the behavior of nursery and finishing pigs (Street and Gonyou, 2008; Broom, 2010; Fu at al., 2016; Kim et al., 2017; Vermeer et al., 2017). According to the majority of studies, pigs with low space allowance are unable to engage in certain behaviors, such as exploratory, social, resting, and thermoregulatory behaviors, as well as maintain separate dunging and lying areas (Averós et al., 2010; Vermeer et al., 2017; Ocepek and Andersen, 2022). In addition, growth is harmed, aggression and tail/ear biting are encouraged by a lack of sufficient space (Barnett et al., 1993; Brandt et al., 2020; Montoro et al., 2021).

The two aspects of space that should be reflected on in pen design are quantity and quality. The amount of available space is referred to as quantity while the characteristics of the space that either make it more or less useful to the animal are referred to as its quality. So far many of the studies (Martínez-Miró et al., 2016; Godyń et al., 2019) have focused solely on determining how much space growing pigs require without taking into account the quality of that space. According to some authors (Grandin, 1980), the quality of the space is more crucial to an animal's welfare (Wiegand et al., 1994). Therefore, if we are able to identify the elements that define space quality, it could to be possible to either maintain the well-being of pigs in less space or improve their well-being in the space that is currently available to them.

Optimizing the perimeter to area ratio might be one way to change the quality of a space. A comprehensive study (Stricklin et al., 1979) discovered that groups of cattle use the perimeter of a pen more frequently than the center. It has also been reported that pigs spread out near the perimeter of the pen (Grandin, 1980). Thus, increasing the perimeter may reduce competition for animals that prefer this kind of space.

Therefore, space allowance per pig is just a relative approach, pen sides ratio and shape being important as well as it interferes with the free movement and several behaviors expressed by pigs. According to some European trials (Petherick et al., 1989; Pedersen, 2018), the shape of the nursery and finishing pens should be rectangular with a length to width ratio of 2:1, which can accommodate resting, feeding, and urinating, as well as social activities. Other studies (Spoolder et al., 1999; Wolter et al., 2001) have demonstrated that a group size of 20 to 25 pigs per nursery pen and 15-25 pigs in finishing pens is desired and matches the capacity of most available feeders, providing that water availability is met. Given that a 100-kilogram pig is approximately

130 centimeters long when slaughtered, the pen should be at least 2.2 meters wide to accommodate positive pig behaviors. Regardless of the feeding system, most European finishing pens typically measure 4.5-6.0 meters deep and 2.2-2.6 meters wide (Andersen et al., 2004; Samarakone and Gonyou, 2009).

It is well documented as well that enrichment materials provided to both nursery and finishing pigs have positive impact on key performance indicators and welfare (Jensen and Pedersen, 2008; Barbari et al., 2017; Holinger et al., 2018; Chou et al., 2019). Yet, the most desirable materials like straw or compost are rarely used currently in large commercial farms with fully slatted floors, due to the difficulties connected to the slurry management challenges. Most studies are highlighting that materials like metal, rubber and plastic toys have limited positive effects on pig welfare as the animals lose interest on them, especially after getting dirty on the pen floors.

This study aimed to determine the effects of nursery and finishing pen shape on pig growth performance and welfare.

MATERIALS AND METHODS

Animals, Experimental Design, and Pen Shapes

In total 36 litters were considered as source of pigs for the trial. All pigs were commercial hybrids produced by F1 (Large White x Landrace) sows sired by Duroc terminal semen. Sows were inseminated in the same day and subsequently housed in farrowing pens of two identical rooms in the same building. On the birth day piglets were ear tagged and weighted. Environmental conditions (temperature, ventilation) and feeding regime in both farrowing rooms were the same during lactation. All piglets were tail docked and the males surgically castrated on the 2nd day after birth in accordance with the internal procedures imposed by the farm management team in order to avoid any further rearing associated risks. Commercial pre-starter feed was provided to piglets from day 7 after birth. Sows received standard lactation diet produced within own feed mill, twice a day according to appetite. Piglets were weaned at the age of 29 days and individually weighted in order to estimate the growth performance by ADG assessment. No enrichment material was provided to piglets and sow in the farrowing house.

Due to initial unintended construction constrains both nursery and finishing buildings ended up by having pens with two different shapes based on the length and width ratio but with similar surface (18.0 m^2 in nursery and 38.5 m^2 in the finishing building). Therefore, the main goal of the trial was to identify whether the shape of the pens would have influence on growth, welfare and slaughter performance.

During the rearing and finishing phases enrichment materials were provided to pigs, namely hanging metal chains with wooden sticks, rubber balls and used tires (only in finishing) in each pen. Due to the ASF (African swine fever) positive status in the close proximity - both in backyard pigs and wild boars - and risks associated with it - all enrichment materials were carefully prepared and disinfected prior usage. All four enrichment materials provided were the same in all pens (two of each one). According to the internal management procedures wooden sticks to be connected to the metal chains were heat treated and stored in a safe area while fresh ones were provided to animals on weekly basis. The rubber toys were changed with new ones only when they were considered fully destroyed by the pigs. The hanging wooden metal chains were placed in the vicinity to the water sources.

From the health status perspective, the farm had a long history of being positive for enzootic pneumonia (*Mycoplasma hyopneumoniae*), yet successfully controlled through a vaccination protocol. However, it can be assumed that growth performances were negatively affected by the disease to a certain degree.

Both types of pens had a rectangular shape and showed different values of the five monitored parameters: P:A ratio (perimeter to area ratio), L:W ratio (length to width ratio), D_{max} (maximum distance between two individuals), DW (distance to the nearest wall) and DC (distance to

the nearest corner). Thus, the first parameter determined was the P:A ratio (perimeter to area ratio). Firstly, we calculated the perimeter, and then the area of the pens. After that, the P:A ratio was determined by dividing the perimeter of the pen by its area. The second parameter calculated was "L:W ratio - length to width ratio". Briefly, we determined the length and width of the pens, after which we divided the length by the width.

Regarding the interactions between animals, based on the shape and size of the pens, we calculated three parameters. The first parameter wanted to determine the maximum distance two animals can separate in a pen (D_{max}). Thus, it was calculated using the following equation: $\sqrt{(l^2 + w^2)}$. In this formula, "l" is the length of the pen, "w" represents the width of the pen, and "√" denotes the square root. Briefly, we square the length (l), then square the width (w), after which we added those two squared values together, and then take the square root of the sum.

The next parameter was represented by the distance to the nearest wall (DW), which was calculated by taking half of the width of the pen according to the formula: w/2. So, to find the distance to the nearest wall (DW), we took the width of the pen (w) and divided it by 2. This gives the distance from the center of the pen to the nearest wall. It's a measure used to understand the space available to pigs within the pen, specifically in relation to the distance from their location to the closest wall.

The last parameter calculated was the distance to the nearest corner (DC), was calculated using the following formula: $\sqrt{(l/2)^2 + (w/2)^2}$. Briefly, we took half of the length (l/2), square it, add that to half of the width squared (w/2) and then take the square root of the sum. This gives the distance from the center of the pen to the nearest corner. It is a measure used to understand the space available to pigs within the pen, specifically in relation to the distance from their location to the closest corner.

Pen size and shape for both nursery and finishing, but also the assessment methods of the main parameters related to pen shape are represented in Figure 1.

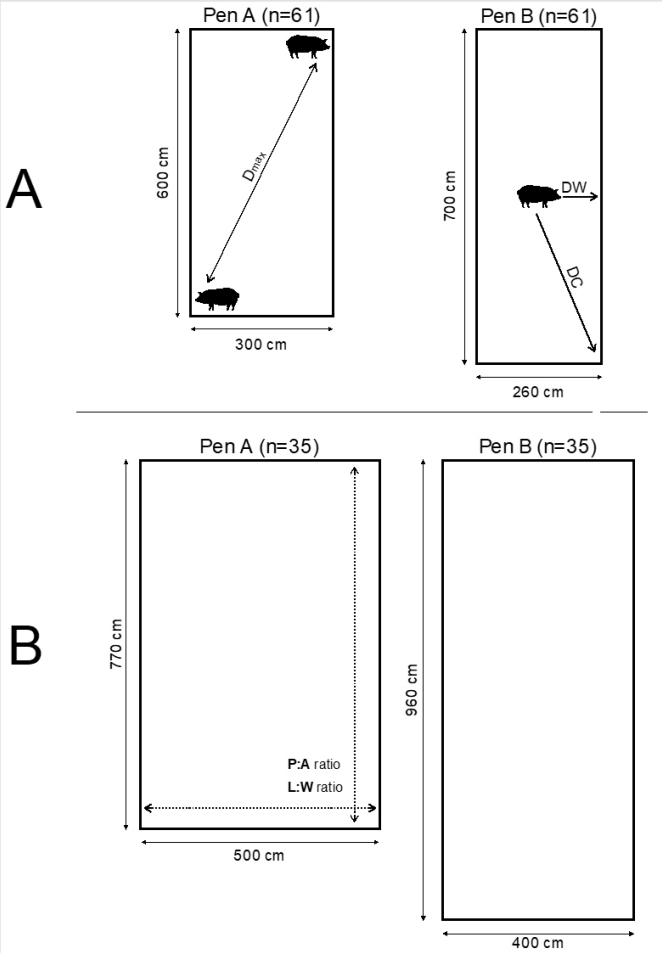

Figure 1. Pen size and shape: (A) Nursery (B) Finishing

Nursery data

At weaning 122 piglets were randomly transferred into the same nursery room and allocated into two differently shaped pens (pen type A and B). Both pen types were fully plastic slatted and no split sex housing was considered. The number of piglets randomly allocated per pen was 61 in both pen A and B type. Both type of pens provided similar space allowance / pig (0.3 m^2/weaner = 18.0 m^2 total net space), same feeding space/pig and constant water access to four nipple drinkers/pen. Therefore, the difference consisted only in the shape of the pens, in terms of: P:A ratio, L:W ratio, D_{max}, DW and DC. The calculated values for these parameters are presented in Table 1, while the shape and dimensions of the pens are shown in Figure 1, both for nursery and finishing. One single ad lib diet was provided to all weaners during the

46 days of this growing phase, with the exception of the first 3 days after the transfer from farrowing when pre-starter feed was provided in order to diminish the weaning related stress. At the end of the nursery stage ADG, ADFI and FCR were calculated and differences were statistically analyzed.

Finishing and slaughter data

Out of the nursery 70 pigs were transferred into the finishing building and randomly allocated into the two differently shaped pens, providing an equal space allowance of 1.1 m^2/pig and 35 pigs/pen (38.5 m^2 netto pen surface).

During the finishing stage ventilation patterns, lighting, feeding regime and access to water were similar in both pen types in order to avoid environmental influences on growth performances and welfare. For growth performance assessment in the finishing stage two measurements were conducted. The first one at 66 days after pigs were transferred from nursery, followed by the second one after 34 days after the first due to diet change for the final finishing phase. All relevant performance parameters were recorded at each growth phase, and data statistically analyzed. At the end of the entire finishing stage all pigs were marked based on the source pen (A and B) and delivered to the nearby slaughterhouse in the same day. Carcass weight and quality parameters were assessed with the Fat-O-Meter (FOM) grading equipment in order to estimate the lean meat percentage (LM%). Overall outcome in terms of LM% and carcass weight results were compared between the two experimental groups.

Skin lesion data

The influence of pen shape on the welfare was related to the score of skin lesions recorded at the beginning and the end of the nursery and finishing stages using a simplified Welfare Quality® assessment protocol. The actual scoring was performed by numbering the pigs with more than 5 visible skin lesions. The percentile skin lesion scores in the nursery phase were recorded at the time of placement (Day 1) and before transferring the piglets into the finishing pens while the ones in Finishing phase were recorded as well at the start (Day 1) and end of the finishing phase.

Pen efficiency in both pen types was calculated by dividing the ADG and FCR to the space allowance per pig (m^2/head).

For the statistical analysis average parameters and significance of differences between the two pen shapes were performed with the t-test.

RESULTS AND DISCUSSION

The current study was built on the hypothesis that pigs raised in identical environments from birth to slaughter might behave differently in nursery and finishing pens with different P:A ratio, L:W ratio, D_{max}, DW and DC, as the shape of the pen could affect the expression of desirable behaviors, thereby hindering the performance of the entire production process.

Main monitored parameters

Numerous previous studies concluded that increased space allowance per pig has a positive impact on their general welfare reducing aggression and vices like tail, ear, and flank biting during the rearing period. Furthermore, pig behavior is improving after adding enrichment items. However, the shape of nursery and finishing pens varies in most farms due to construction constraints, so focusing solely on pen stocking density and enrichment availability can be misleading since it may be more difficult to access feeders, water, or even laying or dunging areas, or because social interactions may be disturbed. The determined values for the main parameters related to pens shape are presented in Table 1.

In both the nursery and finishing stages, pen A exhibited lower values for P:A ratio, L:W ratio, D_{max}, and DC, with the exception of DW, which showed a higher value when compared to pen B.

Table 1. The values of the main parameters for pen A and B, both in nursery and in finishing

Parameter	Nursery		Finishing	
	Pen A	Pen B	Pen A	Pen B
P:A ratio	1.00	1.05	0.66	0.71
L:W ratio	2.00	2.69	1.54	2.40
D_{max} (m)	6.71	7.46	9.18	10.40
DW (m)	1.50	1.30	3.50	2.00
DC (m)	3.35	3.73	4.59	5.41

P:A ratio - perimeter to area ratio; L:W ratio - length to width ratio; D_{max} - maximum distance between two individuals [$\sqrt{(l^2 + w^2)}$]; DW - distance to the nearest wall (w/2); DC - distance to the nearest corner [$\sqrt{(l/2)^2 + (w/2)^2}$]

Production performances

Table 2 displays the weaning results, indicating a notable homogeneity among the piglets at the conclusion of the 29-day suckling period. This weaning age aligns with the current EU legislation regarding weaning practices. Body weight and calculated ADG at the time of transfer from farrowing to nursery was similar and the differences between the groups piglets were not statistically significant. The results were rather expected as cross fostering was performed in day 3 after birth in order to have more uniform litters and to avoid piglet pre-weaning loses. Furthermore, for the same aim high quality pre-starter was provided to all litters starting on day 7 up to weaning.

Out of the weaned piglets groups only two samples were transferred into nursery due to the limited space available in the two differently shaped pens. Piglets in the samples were randomly designated into the pens. Pre-started feeding was continued for 3 days after weaning, followed by a gradual shift to starter diet. On the day 18th of age young piglets were transitioned to the grower diet until the transfer into finishing pens, in accordance with the internal standard procedures. During the nursery test 2 piglets from type A pen and 5 piglets from type B pens were extracted and humanely culled due to health impairment.

Table 2. Average weaning weight and daily gain in weaning

	Farrowing room A	Farrowing room B	Δ	t-test
No. sows	18	18	0	-
No. weaned	178	175	3	n.s.
AWW (kg)	8.17 ± 0.85	8.10 ± 1.09	0.07	n.s.
ADG-W (g)	0.244 ± 0.03	0.242 ± 0.04	0.002	n.s.

Δ - difference between farrowing room A and farrowing room B; AWW - average weaning weight; ADG-W - average daily gain in weaning; n.s. - no significant differences ($P > 0.05$)

At the end of nursery stage (46 days) piglets from pen A weighed 3.10 kg more on average than those in pen B, despite similar rearing conditions. Significant difference was recorded for ADG-N and FCR with pen A being superior with 70 g/day of ADG and 0.30 of FCR than pen B. These advantages corroborated with the lack of significance of differences between pens from the feed intake perspective seems to suggest that pigs in pen A, which was wider than pen B, allowed a better expression of the feeding and other social behaviors (Table 3).

Although P:A ratio was in the favor of type B pen and this should be better from behavioral perspective it seems that the difference was too small in order to influence the productivity or welfare.

Evaluating the pen efficiency of the two pen types in terms of ADG and FCR/m^2 in nursery has led to the conclusion that pen A type was favorable to both absolute performance parameters (+0.004 for ADG and - 0.017 for FCR), confirming the overall relative superiority of the pen A type both in terms of growth and feed efficiency (Table 4).

Phase 1 finishing performances (Table 5) suggest that pigs housed in pen A had a higher ADG (average surplus of 46 g/day) than those raised in pen B, in which the l:w ratio was more extreme. However, differences were not significant when ADFI and conversion were considered. It is worth mentioning that pigs transferred into finishing were provided with the same grower diet as in nursery for the first 3 days and then with finishing diet produced by the farm owned feed mill until the previous day of delivery to slaughter.

Table 4. Pen efficiency parameters in nursery

	Pen A	Pen B	Δ
ADG/m^2	0.022	0.018	+ 0.004
FCR/m^2	0.083	0.100	- 0.017

Δ - difference between pen A and pen B; ADG - average daily gain in nursery; FCR - feed conversion ratio

As in nursery the difference between the two pen types in terms of P:A ratio might suggest a connection with the growth and feed usage parameters without pointing out a significant advantage of the pen A type. However, the calculated pen efficiency differences were limited, suggesting that rearing the pigs in type A pen does not translate into a significant production advantage for the farmer per square meter of investment in the finishing infrastructure (Table 6).

Performances for the second finishing phase were recorded separately because for the last 34 days the diet was adjusted according to internal feeding protocol by limiting slightly the energy content. However, the pigs were kept in the same pens, without any changes related to ventilation, lighting, feeding timing or water availability (Table 7).

Table 3. Growth performance in nursery by pen shape type

	Pen A	Pen B	|Δ|	Δ%	t-test
Days in Nursery	46	46	0	-	-
Heads ON test	61	61	0	-	n.s.
Heads OFF test	59	56	3	-5.08	n.s.
Avg. weight OFF test (kg/head)	26.80	23.70	3.10	-11.57	*
ADG-N (kg)	0.394	0.324	0.070	-17.77	***
ADFI (kg)	0.589	0.584	0.005	0.85	n.s.
FCR (kg/kg)	1.50	1.80	0.30	+20.00	***

|Δ| - absolute difference between pen A and pen B; ADG-N - average daily gain in nursery; ADFI - average daily feed intake; FCR - feed conversion ratio; n.s. - no significant differences ($P > 0.05$); * - significant differences ($P < 0.05$); *** - significant differences ($P < 0.001$)

Table 5. Finishing performance in phase 1 - 66 days

	Pen A	Pen B	|Δ|	Δ%	t-test
Days in finishing	66	66	0	0	-
Heads ON/OFF test	35	35	0	0.0	n.s.
Average weight OFF test (kg)	79.30	77.10	2.20	-2.77	**
ADG phase 1 (kg/day)	0.835	0.789	0.046	-5.51	**
ADFI (kg/day)	2.199	2.112	0.087	-3.96	*
FCR (kg/kg)	2.63	2.68	0.05	1.90	n.s.

|Δ| - absolute difference between pen A and pen B; ADG - average daily gain in finishing (phase 1); ADFI - average daily feed intake; FCR - feed conversion ratio; n.s. - no significant differences ($P > 0.05$); * - significant differences ($P < 0.05$); ** - significant differences ($P < 0.01$)

Table 6. Pen efficiency in phase 1 finishing - 66 days

	Pen A	Pen B	Δ
ADG/m^2	0.021	0.020	+ 0.001
FCR/m^2	0.068	0.069	- 0.001

ADG - average daily gain in nursery; FCR - feed conversion ratio; Δ - difference

Table 7. Finishing performance in phase 2 - 34 days

	Pen A	Pen B	|Δ|	Δ%	t-test
Days in finishing	34	34	0	0	-
Heads ON/OFF test	35	35	0	0	n.s.
Average weight OFF test (kg)	115.14	112.10	3.04	-2.64	**
ADG Phase 2 (kg/day)	1.112	1.025	0.087	-7.82	*
ADFI (kg/day)	3.151	3.345	0.194	6.16	**
FCR (kg/kg)	2.93	3.16	0.23	7.85	***

|Δ| - absolute difference between pen A and en B; ADG - average daily gain in finishing (phase 2); ADFI - average daily feed intake; FCR - feed conversion ratio; n.s. - no significant differences ($P > 0.05$); * - significant differences ($P < 0.05$); ** - significant differences ($P < 0.01$); *** - significant differences ($P < 0.001$)

In this final finishing phase P:A ratio was not calculated as the animals were raised in the same pens as in previous phase.

The minor differences between pens from the pen efficiency perspective seems to suggest that the shape of the two pen types does not have strong connection with the potential economic benefits estimated as production performances per square meter (Table 8). However, the average FCR recorded in both finishing phases is 0.136 in the favor of pen A type pigs and have an intrinsic economic value.

Based on the cost of the finishing diet at 0.22 Euro / kg the estimated financial advantage of raising animals in type A pen would reach a level of 2.65 Euro/pig.

Table 8. Pen efficiency in phase 2 finishing - 34 days

	Pen A	Pen B	Δ
ADG/m²	0.028	0.026	+ 0.002
FCR/m²	0.076	0.082	- 0.006

Δ - difference between pen A and pen B; ADG - average daily gain in nursery; FCR - feed conversion ratio

Slaughter results

Despite that at slaughter differences between the two pig groups are not significant in terms of live and carcass weight, nor for the average lean meat percentage, it should be noted that even limited differences can have economical value for the farmer (Table 9) In this case, the pigs raised in pen A type yielded an extra 1.43 kg of carcass/pig which, in current EU market price conditions at an average 2.4 Euro/kg would bring an extra revenue of 3.43 Euro/pig to the farmer. However, it is difficult to state that the superior production parameters recorded in type A pens could be attributed only to the slightly different shapes.

It should be observed as well that the variability of the average carcass weight was quite high in both rearing pen conditions which might highlight other external influences on the growth parameters like the actual quality of the feed provided or other management issues.

Welfare criteria assessment

As stated above skin lesions were assessed at the start and end of both nursery and finishing rearing phases by recording the percentage of the pigs with visible fighting marks.

As expected, in both situations, the percentage of pigs with such lesions was higher at the start of the phase as a result of mixing the pigs, a new environment (pen) and establishment of a new social (hierarchy) in the new formed group. This outcome is similar irrespective of the shape of the pens. It was expected that by the time of the rearing period - both in nursery and finishing stages - the percentage of pigs with visible skin lesions to significantly decrease as the social order was settled in the first few days (Figure 2). Tail biting attempts were not observed probably due to the preventive docking performed after birth as per the decision taken by farm management staff.

Table 9. Slaughtering parameters for the pigs raised in the two shaped pens

	Pen A	Pen B	t-test
No. of pigs slaughtered	35	35	-
Average carcass weight (kg)	88.88 ± 10.41	87.45 ± 8.94	n.s.
Carcass ADG (kg)	0.434 ± 0.04	0.395 ± 0.04	**
Average LM%	57.99 ± 4.02	57.34 ± 3.17	n.s.
Average live weight (kg)	115.9 ± 13.95	112.1 ± 11.47	n.s.
Live ADG (kg)	0.558 ± 0.06	0.508 ± 0.05	**

ADG - average daily gain; LM% - lean meat percentage; n.s. - no significant differences ($P > 0.05$); ** - significant differences ($P < 0.01$)

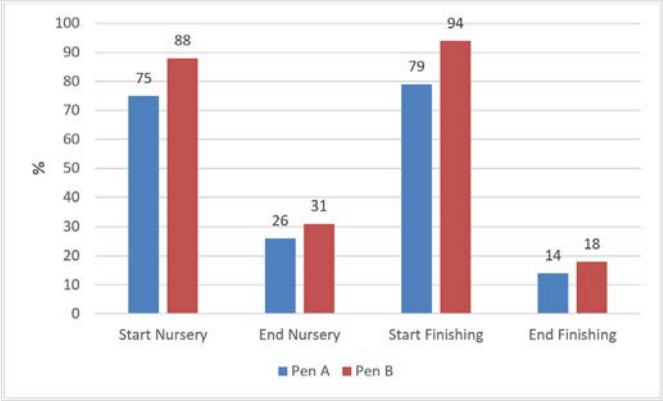

Figure 2. Skin lesion results as animal based welfare parameter

However, it is notable that in nursery the skin lesion percentile scoring was lower in pen A than in pen B type. This might suggest that pen A shape could be more appropriate then type B pen from the welfare perspective despite the similar space allowance per pig. The same outcome seems to be valid for the finishing phase where the differences between scores are even higher when the lesions at start and the end of the rearing period are assessed. Corroborating these findings with the performance indicators in nursery and finishing phases seems to suggest that type A pens might provide a slightly better environment for pigs both from production and welfare perspective.

These results can be attributed to the fact that pen A had a more square-like shape compared to pen B, both in the nursery and in the finishing phases. This statement is also supported by a study conducted by Wiegand et al. (1994), which compared four pen shapes (rectangular, square, triangular and circular) in order to determine their effects on pig behavior and performance and found that aggression was significantly higher in circular pens and lower in square pens with rectangular and triangular pens exhibiting intermediate levels. Regarding pig behavior, they showed that in pens with small D_{max}, pigs lied close together more frequently than in pens with higher D_{max} (Wiegand et al., 1994). D_{max} influences inter-animal distance, pigs in pens with higher D_{max} lie more often at distances greater than 2.5 m, while a lower D_{max} causes pigs to lie within 2.0 m more frequently. Also, D_{max} influenced the formation of social groups, a lower value of this parameter determines the formation of larger social groups (13-15 pigs), while a higher D_{max} determines pigs to form smaller social groups (1-3 pigs) (Wiegand et al., 1994).

Corners are also important because they act as hiding areas, a lower DC will give the pigs a closer place to hide of potential aggressions. Corners also act as dunging areas, a lower value of DC possibly influencing the performance and general cleanliness of the pigs. A squarer shape of the pen, which will determine a lower D_{max} and DC, could improve the use and functionality of designated areas: dunging and resting areas (Ocepek and Andersen, 2022). Guo et al. (2015) showed that once DC increases, elimination decreased and moving and exploring increased. This can result in better growth performance in a pen with a lower DC, thus limiting moving and exploring behavior. Consequently, for a rectangular pen, the shape that leads to a decrease in aggression between pigs should have small P:A ratio, L:W ratio, which will also determine a lower D_{max} and DC for the same area.

CONCLUSIONS

The results seem to suggest that the pen shape design has an influence on the rearing performances even if the provided space allowance, and hence pig density per square meter, feeding, ventilation and enrichment patterns are the same. Therefore, it would be desirable that building new farming facilities should consider not only the EU legal standard or enhanced space requirements per pig but the pen length to width ratios as well as it might have rather significant implications both on production performances and welfare status. However, further studies on larger samples and various length to width ratios are required in order to define the optimum pen shape both from growth performance and welfare perspective.

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