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1   **Abstract**
2   In this study, considering the difficulties for all farms to convert farm styles to animal welfare-based housing,
3   an experiment was performed to observe the changes in the behavior and welfare of sows when the slat floor
4   was changed to a collective breeding ground. Twenty-eight sows used in this study were between the second
5   and fifth parities to minimize the influence of parity. Using a flats floor cover, the flattening rates were treated
6   as 0%, 20%, 30%, 40%, and 50%. Data collection was the behavior of sows visually observed using a camera
7   (e.g., standing, lying, fighting and excessive biting behaviors, and abnormal behaviors) and the animal welfare
8   level measured through field visits. Lying behavior was found to be higher ($p < 0.01$) as the flattening rate
9   increased, and sows lying on the slatted cover also increased as the flattening rate increased ($p < 0.01$). Fighting
10   behavior was higher when the flattening rate was 0% and 20%, and chewing behavior was higher ($p < 0.05$)
11   as the flattening rate increased. The animal welfare level of sows, 'good feeding', it was found that all treatment
12   groups for body condition score and water were good at 100 ($p < 0.05$). 'Good housing' was the maximum
13   value in each treatment group was 100, as the percentage of floor increased, the minimum increased from 0%
14   to 78, from 20% to 87, from 30% to 89, from 40% to 94, and from 50% to 96%. The 'good health' was the
15   maximum value of the 0% and 20% treatment groups with the flattening rate was 100, and it was analyzed to
16   be 98 in 30% and 50%, and 99 in 40%. 'Appropriate behavior' was the score was significantly lower than that
17   of other items, but when the flattening ratio was 0% and 20%, the maximum and minimum values were 10. At
18   40% and 50%, the maximum values were 39 and 49, respectively, and the minimum values were analyzed as
19   19 for both 40% and 50%. These results will be used as basic data about sow welfare for farmers to successfully
20   transition to group housing and flat floors.
21
22   **Keywords (5 to 6)**: Behavior, Floor, Group housing, Sow, Welfare
23

Introduction

The Republic of Korea is preparing to introduce animal-welfare-centered breeding standards for pigs to improve the breeding environment of livestock farms [1]. However, farmers are apprehensive of moving from existing stall breeding to group housing because the need to provide bedding materials on the floor increases administrative labor, and economic burden [2]. Stall breeding is a common practice for sow pig farms, except for those that are already domestically certified for animal welfare. The advantages of stall breeding are that the maximum number of breeding heads can be raised in the same space, feed amount can be adjusted by weight, and individual management is easy. It is also effective in protecting weaker sows [3]. However, the productivity of sows under such conditions can be reduced because of pressure and lameness caused by fewer activities during pregnancy [4]. Nevertheless, sows nurtured in group housing during pregnancy show muscle loss and lower skeletal muscle strengthening than in stall breeding [5]. This means a lower rate of accidents, such as crushing piglets or dystocia, owing to a lack of strength in the hind legs at the time of delivery [6]. Consequently, the advantages of transfers from stall breeding to group housing, relative to farm household income, are an increased re-fertilization rate and an increased conception rate in pigs, as well as a rapid recovery of body shape postpartum [7]. These results were obtained from a study of sows nurtured on flat floors and in slat-floor group-housing conditions.

For sows, the type of floor area, floor shape of the pen, and living space, as well as thermal and social environments, are linked to behavior and welfare issues. These factors also affect the quality of the final product [5]. In Korea, slatted concrete floors are commonly used in gestation barns for manure drainage, because farmers prioritize manure management and treatment when designing sow barns [8]. However, slatted concrete floors can cause foot injuries and lameness in sows [9]. By contrast, if the floor of the sow barns is altered with beddings, environmental conditions improve because of reduced emissions of ammonia, hydrogen sulfide, and carbon dioxide, providing a more comfortable environment for the sows [10]. In the case of finishing pigs, characteristics, such as productivity, efficiency, carcass quantities, and feeding activities, improve with a littered floor compared with a slatted concrete floor [11]. Therefore, it is important to provide proper floor facilities suitable for the behavioral and physiological conditions of sows following the transition to group housing. However, from the farmer's perspective, economic losses from the conversion of the existing slat floor to a littered floor are unavoidable, because of the redesign of the barn and change in the floor and manure treatment systems. It is also important to understand how the replaced facilities affect sow behavior and environmental changes. Sow behavior is also related to animal welfare. Animal welfare evaluation depends on various indicators. However, two main questions must be answered [12]: Are animals healthy, and do they get what they require? The behaviors of animals play an important role in answering both questions. Consequently, clinical and preclinical assessments as well as preference testing are needed for existing pain, injuries, diseases, and discomfort in the facility and surrounding environment provided by the breeder [13]. Therefore, from a behavioral point of view, observing wounds on the body and vulva have virus causes, such as abnormal posture, fighting, and abnormal behavior [12].

60 However, no experiment has examined the floors of sows in Korea. Nevertheless, although it is difficult for

61 all farms to convert to an animal welfare-based housing system, research on the process of converting existing

62 farms into animal welfare farms is essential.

63 Therefore, the situation of domestic pigs on several farms was considered in this study. Based on these factors,

64 an experiment was conducted to observe the changes in sow behavior and animal welfare level when the

65 existing slat floor was changed to group housing for sows.

66

Materials and Methods

68 2. 1. Experimental design and animal

69 The study was conducted at an experimental pig farm in Hadong County, Gyeongsangnamdo, Republic of

70 Korea, between April 2020 and February 2021. Twenty-eight Yorkshire × Landrace F2 crossbred sows were

71 used in this study. The sows were between the second and fifth parities to minimize the influence of parity.

72 They entered the group-housing pen 4 weeks after mating and moved to the farrowing crate a week before

73 farrowing. The sows were housed in a group housing pen (measuring 13.5 W × 8 D, with a density of

74 approximately 3.86 m^2/sow) on a partially slatted plastic floor. The pens were equipped with a nipple drinker

75 and an electronic sow feeder (ESF). The sows were managed in compliance with the Korean pig feeding

76 management guidelines (National Institute of Animal Science, 2007)[14], and were fed twice a day. Water was

77 provided ad libitum throughout the study. The sow house temperature varied by an average of 20.5 °C ± 2.1 °C.

78 The sow house used in the experiment was compared by processing the flattening rate simultaneously on two

79 pens with the same structure and area. The floor of the sow group housing pen used in the experiment had a

80 flat floor shape corresponding to concrete sheet width of 850 mm and a gap width of 80 mm (Fig.1). Using a

81 flats floor cover, the flattening rates were treated as 0%, 20%, 30%, 40%, and 50% (Fig. 1-A). The flattening

82 rate area was 108 m^2 at 0%, 21.6 m^2 at 20%, 32.4 m^2 at 30%, 43.2 m^2 at 40%, and 54 m^2 at 50%. Sow density

83 in each treatment was 3.86 m^2/sow. The flattening rate interval was changed every five weeks, considering the

84 sow's adaptation period. The slat floor cover was manufactured by a commercial slats cover company (Bowon

85 ENG, Gimhae, Republic of Korea), with the formworks designed by the research team. Individual slat covers

86 were cast with widths of 700 mm, a depth of 50 mm, and a length of 20 mm (Fig. 1-B).

87

88 2. 2. Measurements

89 2.2.1. Sow behavior

90 The behavior was observed with high-definition (HD) cameras (TC-NCL214S, Tiandy by SICE, Italy)

91 mounted on four sides of the ceiling (2 m above the floor) to capture video (30 frames/s with a resolution of

92 1920 × 1080 pixels). Videos, recoded from April 1, 2020, to February 28, 2021, were saved as avi files in a

93 video recorder (NVR- 4839070, Tiandy SICE, Italy). The behavioral analysis of sows included basic behaviors

94 such as standing, lying, fighting, excessive biting (chewing) behaviors, and abnormal behaviors such as

scratching (Table 1). Among these behaviors, the basic behavior is a time sampling method that collects data every 2 min; when abnormal behavior occurs, the frequency data method is used to compare and analyze each behavioral characteristic. For behavioral monitoring, data were collected for 15 days at an average of 9.5 during the sow's pregnancy stabilization period. The total time required for analysis was 1800 h (15 days × 24 time × 5 treatments).

2.2.2. Animal welfare level

To evaluate the welfare level of sows, the experimental farm's main management (e.g., temperature, humidity, feed, area, and density), and animal welfare level items (e.g., good feeding, good housing, good health, and appropriate behavior; Table 2) were using the assessment protocol [3]. The temperature and humidity diagnoses were measured using a temperature and humidity sensor (HOBO Temp/RH Logger, UX100-011A, HOBO data logger onset, USA).

2.3. Statistical analysis

All data were analyzed using the R package (R version 3.31, R Foundation for Statistical Computing, Tokyo, Japan). The effects of flattening on animal welfare levels and qualitative behavior were analyzed using ANOVA. Data on animal welfare levels were investigated using the mean and standard deviation. The data for qualitative behavior were not normally distributed, as per the Shapiro-Wilk test. To calculate significant differences between the days of observation, the Kruskal-Wallis test was used and confirmed post hoc. Significant results ($p < 0.05$) were examined using post-hoc Scheffé tests to further describe the relationship between the tested interactions.

Results

3.1. Sows behavior

The difference in the behavior of sows according to the ratio of the floor was shown in Table 3. The sows in 0% spent a higher time standing behavior (an average of 39.64%) compared with 26.82%, 20.53%, 19.11%, and 27.84% per day in 20%, 30%, 40%, and 50% flattening rate treatments, respectively. Moreover, sows in the 20% and 50% treatments showed an increased standing behavior compared with the 30% and 40% treatments and the lower standing behavior was observed in the 40% flattening rate treatment. Lying was found to be higher as the flattening rate increased, and sows lying on the slatted cover also increased as the flattening rate increased ($p < 0.01$). Fighting behavior was higher when the flattening rate was 0%, and chewing behavior was increased in the 50% flattening treatment compared with 0%, 20%, and 30% ($p < 0.05$). No significant differences were observed in scratching and grouping behaviors.

3.2. Welfare level of sows

131

132 Table 4 shows the effect of the animal welfare level of the sows based on the flattening rate. In "good feeding,"

133 the maximum and minimum values of all treatment groups for body condition score (BCS) and water were

134 good at 100 ($p < 0.05$). The BCS of the sows was modified by the farmer using a caliper to set the average

135 BCS to 2.5, and the feed was limited to each individual.

136 The welfare principle assessment items 'good housing' were bursitis, shoulder sores, manure on the body,

137 panting huddling, and space allowance ($p > 0.05$). The maximum value in each treatment group was 100, and

138 as the percentage of floor increased, the minimum increased from 0% to 78, from 20% to 87, from 30% to 89,

139 from 40% to 94, and from 50% to 96%, respectively.

140 The 'good health' aspect of animal welfare includes lameness, wounds on the body, vulvar lesions, coughing,

141 sneezing, skin condition, and ruptures and hernias ($p > 0.05$). The maximum value of the 0% and 20%

142 treatment groups with the flattening rate was 100, and it was 98 at 30% and 50%, and 99 at 40%. In contrast,

143 the minimum values were 75 at 0%, 96 at 20%, 95 at 30%, 96 at 40%, and 94 at 50%.

144 Appropriate behavior, which is the last item in animal welfare evaluation, includes social behavior, stereotypes,

145 exploratory behavior, and human fear behavior ($p > 0.05$). The score was significantly lower than that of the

146 other items, but when the flattening ratio was 0% and 20%, the maximum and minimum values were 10. At

147 30%, the maximum value was minimum values were 18 and 22, respectively. At 40% and 50%, the maximum

148 values were 39 and 49, respectively, and the minimum values were 19 for both 40% and 50%. As a result of

149 observing the level of animal welfare, 'Appropriate behavior' for 'fear of humans' involved avoiding people

150 on a flat floor ratio from 0% to 20%, but when it was 30%, animals approached curiously, and when it was

151 40%, the reaction involved running and then approaching again.

152

Discussion

154 The aim of this experiment was to determine the changes in the behavior and animal welfare level of sows

155 when the existing slat floor was changed to group housing. These data will be used as basic data in terms of

156 the health of group housing sows for farms that wish to convert from conventional farms to animal welfare

157 farms and will become the basis for animal welfare farms in South Korea in the future.

158

159 4.1. Sows behavior

160 The sows behavior varied with the proportion of the floor type. According to a previous study [3], as a result

161 of observing the behavior of sows on a concrete floor and a rubber mat, the lying behavior of sows on the

162 rubber mat was longer, indicating that the lying behavior of sows is affected by floor type. This supports our

163 findings. Similar results have been reported in another study [15]. When the floor was flattened in the group

164 housing system, the number of lying and standing positions increased because sows who gained weight felt

165 less discomfort when their feet and legs were fatigued if the mat was flat. In this study, in terms of standing

behavior as a ratio of lying time, as the ratio of the flattening rate increased, standing behavior decreased as lying behavior increased. This is also expected to be significant.

Fighting behavior in sows comes from group housing and food competition during mixing due to limited feeding and competition for positions for sows to rest [16,17]. In this study, it was confirmed that the fighting behavior decreased as the area of flattening rate increased, which is considered to result from the process of competition for a place for sows to rest rather than competition for food. In addition, although not feeding, the behavior of chewing with saliva is a kind of abnormal behavior that occurs when the sow does not consume enough food or is stressed due to dissatisfaction [12]. It is a behavior that can become chronic once started because continuous chewing produces a kind of narcotic morphine in the sow [18]. In this experiment, it was judged to be the behavior of sows that have become chronic about the restricted feeding rather than the effect of the floor.

4.2. Welfare level of sows

The Welfare Quality® protocol was designed to not only reliably assess animal welfare on farm but also provide standardized information about a product and thus to be used for certification purposes [10, 19]. The protocol contains indicators concerning the four Welfare Quality® principles of good feeding, good housing, good health, and appropriate behavior. Therefore, it meets the requirements for studying the effect of flattening rate on the sow animal welfare level test. The Welfare Quality® protocol defines 32 indicators for use with sows. Of these, 81.3% are animal-based indicators, with management-based -and resource-based indicators each accounting for 9.38% of the remainder [19]. Good feeding is an important factor for animals [20]. In particular, sows can enter a negative energy balance during lactation when adequate fat and muscle body reserves are mobilized to support piglet growth through milk production [21]. In this study, we found that proper feed intake, water management, and breeding satisfied welfare standards. It was found this it was not affected by changes in flattening rate.

When evaluating the level of animal welfare, a good housing environment was divided into three welfare criteria. First, items related to animal comfort during rest were bursitis, shoulder sores, and body manure. Second, items related to animals' thermal comfort, that is, neither too hot nor too cold, were panting and huddling. Third, there should be sufficient space for animals to move freely according to breeding density. In this experiment, bursitis and claudication, classed under 'good health', showed no significant difference in the flattening rate. This is consistent with the finding that bursitis is correlated with lameness regardless of production and management systems [22]. However, for shoulder sores, judged as pressure injuries, at 0%, flattening rate, evidence of an old injury (scar tissue formed), evidence of a recent injury that was healing, or reddening of the area without penetration of the tissue was found to be > 30%. Reviews suggest that when sows lie down, the location and anatomy of the protruding tubers put pressure on the tissue above them, making this area prone to pressure sores [23]. This, in combination with other factors within the environment, including the floor surface, environmental temperature, and the health and comfort of the sow [23, 24], can influence the

203 development of shoulder lesions and affect the behavior of sows. This is consistent with the result that the

204 lying behavior of sows also increased as the flattening rate increased in this experiment. Space allowance is

205 related to the size of an animal but includes various factors, such as independent physical space. It is involved

206 in establishing the group size and action space that animals must share for social interaction, that is, a

207 hierarchical structure that can vary depending on the group size and affects wounds and fighting behavior [25].

208 Therefore, in this study, the minimum total floor space of the animal welfare act was based on 3.5 m^2/sow and

209 2.5 m^2/gilt [26].

210 There are two major measures of good health. First, animals should be free of injuries, such as skin damage

211 and locomotor disorders (lameness, wounds on the body, and vulvar lesions). Second, animals should be free

212 from disease; that is, animal unit managers should maintain high standards of hygiene and care (for coughing,

213 sneezing, skin conditions, ruptures, and hernias). We were not specific about the results related to injury

214 according to the flattening rate; however, for skin conditions in the absence of disease, inflammation,

215 discoloration, or spots appeared on less than 10% of the skin when the flattening rate was 0%. This is presumed

216 to be because the conventional slat floor has a greater influence on the development of skin conditions than

217 the flat floor because of the induction of pressure in combination with the weight, leg strength, movement

218 control, and lying behavior of sows [27].

219 Appropriate behavior can be observed in three ways. First, animals should be able to express other normal

220 behaviors; that is, it should be possible to express species-specific natural behaviors such as foraging or

221 exploring (stereotypes, exploratory behavior). Second, animals should be handled well in all situations; that is,

222 handlers should promote good human-animal relationships. This experiment measured only items related to

223 the human-animal relationship (HAR). The condition of a sow when it was placed in its pen and about 0.5 m

224 away from other sows when it was still or its ear was touched was regarded as being caused by the relationship

225 with the existing farm manager rather than the flattening rate. The rationale is that in a study comparing the

226 responses of pigs to two different stock persons with markedly different contact characteristics with pigs [28],

227 the pigs were unable to distinguish the two, and one person's rude treatment made animals fear everyone. This

228 is consistent with the conclusion that because regular positive human contact is a powerful and reliable way

229 to alleviate stress and fear responses in pigs, the key to HAR is closely related to farmers [29, 30]

230

231 **Conclusions**

232 These results can serve as basic data on sow welfare for farmers to successfully transition to group housing

233 and flat floors. However, since this study was conducted on a controlled experimental farm, there may be

234 limitations in drawing firm conclusions about the application of various breeding management methods and

235 environments under diverse conditions according to the characteristics of the farmer. Therefore, to ensure the

236 increased conversion of existing farms to animal welfare farms, it is necessary to study the number of live pigs,

237 weaned pigs, and difficult deliveries through follow-up of the sows used in this experiment. Furthermore,

studies related to the welfare of sows according to the appropriate ratio of flat floor and flooring materials need to be appropriate to the Korean situation.

References

1. Livestock Industry Act of 25 February 2020 amending Chapter Permission for Livestock Farming Business/Article 14/Act No 30477. South Korea.

2. Yang KY, Ha JJ, Kwon KS, Kim, JB, Jang DH, Lee JY, Kim JK. Effect of floor types (slat vs. litter) of group housing systems on sow behavior and environmental levels. J. acad.-ind. technol. 2020; 21(8): 388-394.

3. Elmore MR, Garner JP, Johnson AK, Richert BT, Pajor E A. A flooring comparison: The impact of rubber mats on the health, behavior, and welfare of group-housed sows at breeding. Appl.Anim.al Behav. Sci. 2010; 123: 7-15.

4. Díaz JAC, Boyle LA. Effect of rubber slat mats on the behaviour and welfare of group housed pregnant sows. Appl. Anim. Behav. Sci. 2014; 151:13-23.

5. Friedrich L, Krieter J, Kemper N, Czycholl I. Test–retest reliability of the Welfare Quality Assessment protocol for pigs applied to sows and piglets. Part 2. Assessment of the principles good feeding, good housing, and good health. Sci. J. Anim. 2019; 97: 1143-1157.

6. Vallet JL, Miles JR, Brown-Brandl TM, Nienaber, JA. Proportion of the litter farrowed, litter size, and progesterone and estradiol effects on piglet birth intervals and stillbirths. Anim. Reprod. Sci. 2010;119(2): 68-75.

7. Maes D, Pluym L, Peltoniemi O. Impact of group housing of pregnant sows on health. Porc. Health Manag. 2016; 2: 1-7.

8. Devillers N, Janvier E, Delijani F, Méthot S, Dick KJ, Zhang Q, Connor L. Effect of slat and gap width of slatted concrete flooring on sow gait using kinematics analysis. Animals. 2019: 9: 206.

9. Elmore MR, Garner JP, Johnson AK, Richert BT, Pajor EA. A flooring comparison: The impact of rubber mats on the health, behavior, and welfare of group-housed sows at breeding. Appl.Anim. Behav. Sci. 2010; 123: 7-15.

269 10. Friedrich L, Krieter J, Kemper N, Czycholl I. Animal Welfare Assessment in Sows and Piglets-Introduction of
270   a new german protocol for farm's self-inspection and of new animal-based indicators for piglets. Agriculture.
271   2020; 10: 506.

272 11. Ruff GR, Pairis-Garcia MD, Campler MR, Moeller SJ, Johnson AK. Effect of rubber mats on sow behavior and
273   litter performance during lactation. Livest. Sci. 2017; 204: 65-70.

274 12. Ruff GR. Effects of housing management strategies on performance and welfare in production swine operations;
275   Doctoral dissertation, The Ohio State University: 2017.

276 13. Chapa JM, Maschat K, Iwersen M, Baumgartner J, Drillich M. Accelerometer systems as tools for health and
277   welfare assessment in cattle and pigs–a review. Behavi. Processes. 2020; 104262.

278 14. NIAS (National Institute of Animal Science) 2007. Korean feeding standard for pig. Rural Development
279   Administration Press, Wanju (South Korea), pp. 38–41

280 15. Tuyttens FAM, Wouters F, Struelens E, Sonck B, Duchateau L. Synthetic lying mats may improve lying comfort
281   for gestating sows. Appl. Anim. Behav. Sci. 2008; 114: 76–85.

282 16. Sapkota A, Marchant-Forde JN, Richert BT, Lay JrDC. Including dietary fiber and resistant starch to increase
283   satiety and reduce aggression in gestating sows. Sci. J. Anim. 2016; 94: 2117-2127.

284 17. Verdon M, Hansen CF, Rault JL, Jongman E, Hansen LU, Plush K, Hemsworth PH. Effects of group housing
285   on sow welfare: a review. Sci. J. Anim. 2015; 93: 1999-2017.

286 18. Gregory NG. Physiology and behaviour of animal suffering. Blackwell Science, Oxford, UK, 2008; pp12-21.

287 19. Blokhuis H, Veissier I, Jones B, Miele M. The welfare quality® vision. In Improving farm animal welfare.;
288   Wageningen Academic Publishers: Wageningen, Netherlands, 2013; pp 71-89.

289 20. Martínez-Alvarez O, Chamorro S, Brenes A. Protein hydrolysates from animal processing by-products as a
290   source of bioactive molecules with interest in animal feeding: A review. Int. Food Res. 2015; 73: 204-212.

291 21. Knauer MT, Baitinger DJ. The sow body condition caliper. Appl. Eng. Agric. 2015; 31: 175-178.

292 22. Knage-Rasmussen KM, Houe H, Rousing T, Sørensen JT. Herd-and sow-related risk factors for lameness in
293   organic and conventional sow herds. Animal. 2014; 8: 121-127.

294 23. Rioja-Lang FC, Seddon YM, Brown JA. Shoulder lesions in sows: a review of their causes, prevention, and
295   treatment. J.Swine Health Prod. 2018; 26(2): 101-107.

296 24. Zurbrigg K. Sow shoulder lesions: Risk factors and treatment effects on an Ontario farm. Sci. J. Anim. 2006;
297   84(9): 2509-2514.

298   25. Remience V, Wavreille J. Canart B, Meunier-Salaün MC, Prunier A, Bartiaux-Thill N, Vandenheede M. Effects
299   of space allowance on the welfare of dry sows kept in dynamic groups and fed with an electronic sow feeder.
300   Appl. Anim. Behav. Sci. 2008; 112: 284-296.

301   26. Livestock Industry Act of 25 February 2020 amending Chapter Permission for Livestock Farming
302   Business/Article 14/Act No 30477. South Korea.

303   27. Bonde M, Rousing T, Badsberg JH, Sorensen JT. Associations between lying-down behaviour problems and
304   body condition, limb disorders, and skin lesions of lactating sows housed in farrowing crates in commercial sow
305   herds. Livest. Prod. Sci. 2004; 87:179-187

306   28. Hemsworth PH, Coleman GJ, Cox M, Barnett JL. Stimulus generalization: the inability of pigs to discriminate
307   between humans on the basis of their previous handling experience. Appl. Anim. Behav. Sci. 1994; 40: 129-
308   142.

309   29. Hemsworth PH, Barnett JL, Hansen C. The influence of handling by humans on the behaviour, growth and
310   corticosteroids in the juvenile female pig. Hormones Behav. 1981; 15: 396-403.

311   30. Zulkifli I. Review of human-animal interactions and their impact on animal productivity and welfare. J.
312   Anim.Sci.Biotechnol. 2013; 4(1): 1-7.
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Tables and Figures

A

B

Figure 1. Experimental pen (A: 20%, 30%, 40%, and 50% the flattening rate; Electronic sow feeder (ESF): water cup (WC), B: flattening rate used slat cover.

327   Table 1. Ethogram used to record sow behaviors during the experiment

Category	Behavior	Description
Basic behaviors	**Standing**	The body weight was supported by the 4 legs. Included standing and walking
	Lying	The sow maintaining a recumbent position
	Lying to flattening	The sow lies on the flattening floor while the head is resting on the ground or is erected
Unusual behaviors	**Fighting**	Forceful pushing on other sows
	Chewing	Chewing actions were performed without the presence of food in the oral cavity. If performed excessively, sham chewing may be accompanied by hyper-salivation. Sham chewing occurs most frequently in confined sows fed a highly concentrated diet and is considered to be a vacuum activity
	Scratching	Any repeated or rhythmical rubbing action against objects in the surroundings (e.g., wall, ground surface, etc.) or rubbing action between two parts of a sow's own body.
	Grouping	The formation of a group of sows by natural means (e.g., herd formation as a result of social attraction) or by human action

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330 Table 2. Animal welfare levels items by the welfare quality animal welfare assessment protocol for sows and
331 piglets (WQ) [19]

Measurement items	Welfare criteria	Principal
BCS (Body condition score)	Absence of prolonged hunger	Good feeding
Water supply	Absence of prolonged thirst	
Bursitis, shoulder sores, manure on the body	Comfort around resting	Good housing
Panting, huddling,	Thermal comfort	
Space allowance	Ease of movement	
Lameness, wounds on the body, vulva lesions	Absence of injuries	Good health
Mortality, coughing, sneezing, skin condition, ruptures and hernias	Absence of disease	
Social behavior	Expression of social behaviors	Appropriate behavior
Stereotypies, exploratory behavior	Expression of other behaviors	
Fear humans	Good human-animal relationship	

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337   Table 3. Effects of the flattening rate on sows behavior

	Sow behavior in the ratio of the flat floor						
	0%	20%	30%	40%	50%	*F* value	*p* value
Standing	39.64^a	26.82^b	20.53^c	19.11^d	27.84^b	2.451	0.001
Lying	60.36^d	73.95^c	82.01^b	89.89^a	88.97^a	2.451	0.001
Lying to slat cover	-	12.43^c	17.96^c	38.89^b	56.58^a	2.653	0.001
Fighting	0.03 ^{b}	0.01^a	0.00 ^{a}	0.00 ^{a}	0.00 ^{a}	2.451	0.001
Chewing	0.03^b	0.03^b	0.05^b	0.06^{ab}	0.14^a	2.451	0.016
Scratching	0.10	0.00	0.92	0.00	0.00	2.451	0.074
Grouping	2.28	1.13	19.96	1.26	0.06	2.451	0.062

338   *n.a not assessed. $^{a–d}$ Means with different superscripts in the same column differ significantly ($p<0.05$)

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346   Table 4. Effects of diffrent the flattening rate the welfare quality scores and assessment

Welfare principles assessment		0%	20%	30%	40%	50%	*p* value
Good feeding	Socre min	100	100	100	100	100	
	Socre max	100	100	100	100	100	0.001
	Std.deviation	0	0	0	0	0	
Good housing	Socre min	78	87	89	94	96	
	Socre max	100	100	100	100	100	0.157
	Std.deviation	13.9	7.98	6.75	3.48	2.13	
Good health	Socre min	75	96	95	96	94	
	Socre max	100	100	98	99	98	0.076
	Std.deviation	13.46	2.19	2.02	1.77	2.25	
Appropriate behavior	Socre min	10	15	18	19	19	
	Socre max	10	15	22	39	49	0.240
	Std.deviation	0	0	2.83	14.14	21.21	

347   *n.a not assessed. [a–d] Means with different superscripts in the same column differ significantly ($p<0.05$)
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