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ABSTRACT

In groups of gestating sows, accessing feed supply may be a source of tension and induce aggressiveness and fights. Using electronic sow feeders (ESF) could help to ensure that each sow eats its entire ration in a group-housed pen. The objective of this study was to evaluate the impact of a competitive feeding situation related to the management of the ESF, on the overall behaviour, physical activity, and energy requirements of gestating sows. A total of 32 sows, divided into two groups, were involved in the study. The feed competition was created by closing the access of one of the two feeders available in each gestation room for 5 consecutive days. This situation was repeated twice, each time preceded by one control week during which both feeders were available. Automatons, accelerometers and manual video analysis recorded each sow's feeding, drinking and social behaviour, their physical activity, occupation and location in the pen. Linear mixed effect models were used, including the fixed effects of treatment (feed competition or control), repetition (first or second period), group (2 modalities), social ranking (3 modalities), their interactions, and the random effect of sow. During competitive feeding situations, the number of negative interactions doubled ($P < 0.001$), the sows spending more time standing in the morning ($P < 0.001$) and in the areas located further away from the feeder ($P = 0.005$). The number of and time spent for nutritive visits were not affected by treatment, whereas the number and duration of non-nutritive visits decreased ($P < 0.001$) during feed competition. This later effect was more marked in low- and high-ranking sows (interaction, $P < 0.01$). During feed competition sow spent less time sleeping ($P < 0.01$) and more time exploring the feeder ($P < 0.001$), these effects being less marked in period 2. The calculated metabolizable energy (ME) requirement, and therefore the quantity of feed required, increased during feed competition ($P < 0.001$), the effect being greater during the second period than the first (interaction $P = 0.04$). Moreover, ME requirement was greater for higher compared to lower-ranking sows ($P < 0.001$). The treatment had no significant effect on body weight and back-fat-thickness, neither on health criteria. To conclude, these results indicate that short-term dysfunction of ESF affect the overall behaviour of sows and increase negative interactions and energy requirements, without affecting their performances or health.

1. Introduction

In Europe, sows are group-housed during most of their gestation, according to European Union Legislation (Council Directive, 2001). Unlike individual stalls, loose housing systems modify the level of physical activity, by alloing freedom of movement and social interactions (Spoolder and Vermeer, 2015; Koketsu and Lida, 2017). Moreover, as pigs are social animals, a hierarchy naturally emerges each time the sows are mixed. This hierarchy is influenced by many factors such as the composition and size of the group, as well as the availability of equipment of interest to sows in the pen (Verdon and Rault, 2018a). Aggression between sows due to the new hierarchy may cause sow culling (due to severe injuries like lameness or spinal cord injuries) and reduce reproductive performance (Hemsworth, 2021). Access to feed is mainly influenced by the hierarchical order of the group, the order of visit to the feeder may therefore be a precise indicator of hierarchy (Lanthony et al., 2022). Moreover, 69% of aggression and intimidation behaviours occur near the feeding area instead of the resting area

Abbreviations: C, control; ESF, electronical sow feeder; HR, high ranking; IR, intermediate ranking; LR, low ranking; ME, metabolizable energy; R, restricted; RMSE, root mean square error.

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(Norring et al., 2019). This point is particularly important due to the restricted rations fed during gestation, which are lower than the voluntary consumption of sows (D'Eath et al., 2018). Many research projects have focused on finding solutions based on nutrition or pen equipment to reduce aggression and ensure adequate feed supply to each sow. In this context, feeding technologies were developed, such as Electronic Sow Feeders (ESF), which offer new feeding strategies based on a better adjustment of feed supply to the nutritional requirements of individual sows (precision feeding). The ESF allows subordinate sows and gilts to eat their own entire ration, without pressure from dominant sows. The data recorded by the ESF may also be used to detect potential changes in feeding behaviour patterns that may for example point to health disorders (Vargovic et al., 2021).

The nutritional model developed by Gaillard et al. (2019) for estimating daily requirements and feed allowance is based on the characteristics of gestating sows (age, parity, body weight), and also recently integrated the level of activity per day for the calculation of estimated metabolizable energy (ME) requirements. The level of physical activity may be influenced by the characteristics of the sows and the housing system (Gaillard et al., 2021), but also by different events that may occur during gestation, for example, thermal conditions (Abarnou et al., 2023) or noise.

The objective of this study was to evaluate the effect of two consecutive induced competitive feeding situations during short periods on the behaviour (feeding, drinking, social interactions, behaviour, location in the pen, physical activity) of gestating sows and their impacts on nutritional requirements. The hypotheses were that feed competition would induce a higher interest in the feeder, an increase in agonistic behaviours and in the time spent in a standing position, which may increase daily ME requirements (Durand et al., 2021). Repeating the feed competition situation may decrease agonistic behaviour and the level of activity, due to the habituation of the sows.

2. Materials and methods

This study was carried out from July to November 2020, at the Pig Physiology and Phenotyping Experimental facility (doi: 10.15454/1.5573932732039927E12) of the French National Research Institute for Agriculture, Food and Environment located in Saint-Gilles (France). Ethical approval concerning the French legislation on experimental animal care was approved by the Ethics Committee in Animal Experimentation in Rennes, France (authorization on living animals No. 25883–2020070711528084).

2.1. Animals and management

A total of 32 crossbred gestating sows (Large White x Landrace) were involved in the experiment between the third and the eighth week of gestation. The 24 multiparous (parity rank between 2 and 9) and 8 primiparous sows were divided into two groups (A: 17 sows with 4 primiparous, and B: 15 sows with 4 primiparous). Sows were at five weeks of gestation in group A and three weeks in group B. At the start of the experiment, in group A and B, the mean body weight was 244.7 ± 39.0 kg and 223.3 ± 41.0 kg, respectively; and the mean backfat thickness was 17.2 ± 2.7 mm and 15.1 ± 2.9, respectively. No animals have been removed and the groups remained stable during the experiment.

Each group of sows was housed in a room of 7.2 m by 8.2 m, on a concrete floor enriched by the addition of straw (in areas A2, A3 and A4, Figs. 1 and 2) and the presence of two "playing" chains. The space allowance in the gestation room was 3.6 m^2/sow. The bedding was fully replaced daily in the straw-covered areas. Each room was equipped with two self-locking ESF (Gestal, JYGA Technologies Inc, Québec, Canada) and two electronic drinkers (Asserva, France) offering ad libitum access to clean water. Each sow was equipped with two Radio Frequency Identification tags: one to be identified by the feeders and one by the drinkers.

Feed was delivered daily and individually at the ESF in doses of 300 g available every 1 min and 30 s to avoid leftovers. Sows could eat their entire ration in one visit, provided they stayed inside the ESF long enough for the next portion to be delivered. The ration was a blend of two diets (one with a Low and one with a High nutrient content, Table 1) whose ingredients are presented in Gaillard and Dourmad (2022). The blend of the two diets was calculated daily and individually to meet the SID lysine requirements. This was achieved using the nutritional model previously revised by Gaillard et al. (2019). The quantity of feed supplied was determined individually and was stable during gestation (2.73 ± 0.79 kg/day), except for a bump feeding of 500 g/d starting at 85 days (i.e. after the end of the experimental period). Under routine farm conditions, ESFs remain open at all time, and feeding starts at midnight, to reduce levels of social tensions and aggressions.

Two RS-CCPOE280IR4-DH cameras (Ro-main Inc., Québec, Canada),

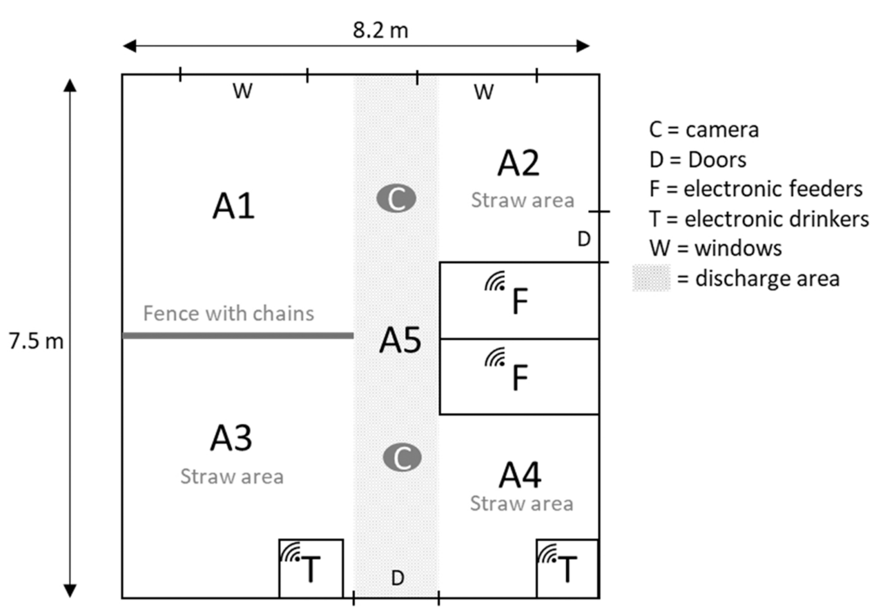

Fig. 1. The organization of the gestating sow pen including the automatons and sensors.

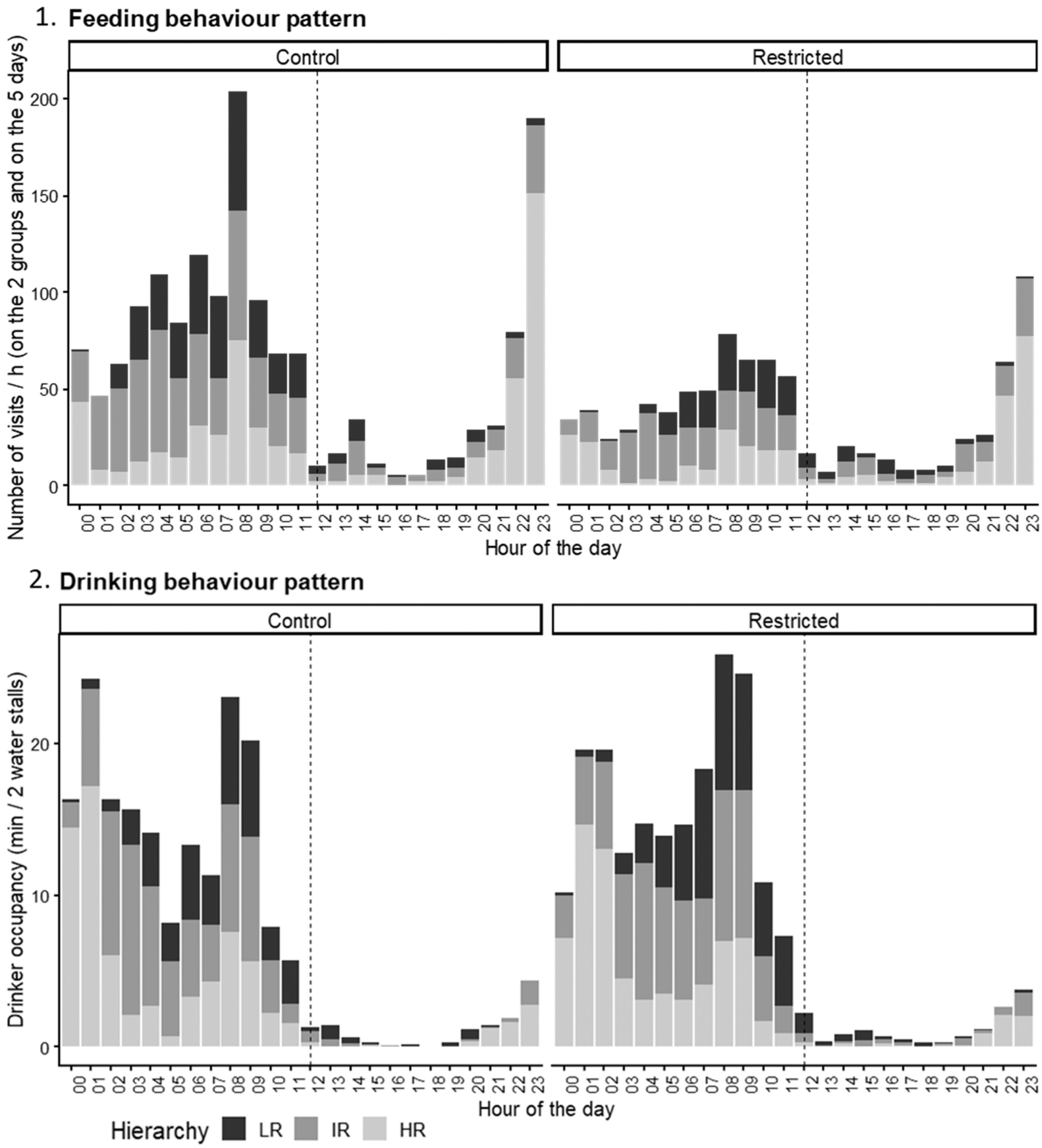

Fig. 2. Effect of the experimental treatment (Control vs. Restricted access to the feeder) and the social ranking (low (LR), intermediate (IR) and high ranking (HR) sows, on the feeding (1.) and drinking (2.) behaviours patterns, as a mean on the five experimental days.

were mounted on the ceiling of each room and recorded the sows continuously, day and night (Fig. 1).

2.2. Feed competition

The competitive feeding situation was created artificially by closing one of the two available ESF (used routinely in this farm) for 5 days (from Monday 12:00 h to Friday 12:00 h). This short-term period was chosen to represent a dysfunction of an ESF without a quick repair. Doubling the number of sows per feeder did not prevent any sows from accessing the feed.

This was performed twice during gestation; one ESF was closed during period one ("Restricted" treatment: R, Period 1) and the other during period two (R, Period 2). During each week preceding a "Restricted" week, the two feeders were opened and these weeks were used as control weeks (Control: C, periods 1 and 2). The two groups of sows were not exposed to the restriction at the same stage of pregnancy: group A was restricted at weeks six and eight after artificial insemination, and group B at weeks four and six.

2.3. Data collection and calculations

Feeding and drinking behaviours were automatically recorded using automatons. Daily time spent at the feeders, the number of visits with ("nutritive visit") or without ("non-nutritive visit") feed consumption, and the amount of feed consumed were determined based on ESF records. Daily time spent at the troughs, the number of visits and water consumption were determined based on the electronic drinker records. The sow order of visits to the feeder for the first nutritive visit of the day was used as an indicator of hierarchical status within the group, with the method developed by Lanthony et al. (2022). The social ranking was initially identified based on the data obtained during the entire

Table 1
Composition of the two diets (low and high nutrient content) used for feed allowance, expressed in g per kg of feed.

g/kg of feed	Low nutrient content diet	High nutrient content diet
Analysed levels		
Dry matter	897	892
Crude Protein	110	155
Crude fat	38.5	39.0
Crude fibre	47.4	39.9
Neutral Detergent Fiber	160	138
Acid Detergent Fiber	53.8	45.2
Acid Detergent Lignin	8.9	8.4
Lysine content	4.21	8.43
Phosphorus content	4.42	5.55
Gross energy, MJ/kg	16.3	16.3
Calculated contents[a]		
ME[b], MJ/kg	12.7	13.0
SID[c] lysine,	3.30	8.50
Digestible Phosphorus	2.31	3.27
Total calcium	7.38	9.79

[a] Calculated according to INRA-AFZ, 1984
[b] Metabolizable energy
[c] Standardized ileal digestible

gestation. Three categories were created according to the first and third quartiles: low (LR), intermediate (IR) and high (HR) ranking sows. The social ranking throughout the entire gestation was compared to the ranking observed each day during the experiment, and to the mean ranking over the 4 weeks of the experiment.

Manual video analysis was carried out by three trained observers using the Observer software (Noldus, Wageningen, The Netherlands) during the first 36 h of each period. The observers were trained to have the same labelling on a sample of videos. Within each repetition and group the videos from the C and R weeks were analysed by the same observer. Each sow was individually marked on her back to follow it during the behavioural sampling. The location of the sows in the pen was recorded continuously (areas 1–4, A1 to A4, Fig. 1). A sow was considered to be in an area when it had both anterior legs in that area. The sow's occupation (the behaviour performed by the sow at a given time) and social interactions were also recorded (Table 2, adopted from Velarde and Geers, 2007).

Every Monday morning during the gestation, the sows were transferred to another room for a few minutes to measure their body weight with a scale (Schippers, The Netherlands, precision ± 0.5 kg), and their back-fat thickness on both right and left sides using an ultrasound portable device (Imago, ECM, France), 65 mm from the midline, behind the last dorsal rib, on the back of the animal, by the same person each time. Skin lesions (severity and frequency), as well as health problems, were also simultaneously recorded. An index was calculated as the sum of skin lesions pondered by their severity (1: for lesions under 5 cm, 5: for lesions over 5 cm, 10: for bloody or deep lesions). Skin lesions were divided into two categories for two different indexes: the scratch index (for long and straight lesions) and the wound index (round lesions). Only skin lesions without sign of healing process (thick, solid crust, no bloody or weeping, no redness/heat or open wounds) were counted, to avoid old lesions from the previous week. The data collected on Monday were linked to the previous period to see the effect over the time.

Twenty-five sows (12 in group A and 13 in group B; 7 in LR sows, 10 in IR sows and 8 in HR sows) were equipped with a randomly functional accelerometer fixed on an ear tag (RF-Track, Rennes, France) in order to continuously record the number of position changes, the daily time spent lying down (flank fully on the ground or not), standing (all 4 legs standing still), or walking (1 or more legs active) and therefore to recalculate *ex-post* the ME requirements for maintenance. The accelerometer's specificity and sensitivity measured in similar straw-bedding conditions were 75.9% and 67.5%, respectively, based on Marcon et al. (2017). The coefficient of 0.30 kJ ME.kg$^{-0.75}$.d^{-1}.min^{-1} for the activity maintenance (standing posture) and 440 kJ ME.kg$^{-0.75}$.d^{-1} for total maintenance (for 4 h/d standing activity) were used for determining ME requirements for maintenance (Noblet et al., 1993). ME for maintenance did not integrate the requirements for litter and placenta growth.

Table 2
Description of the sows' behaviours recorded manually from videos.

Behaviour	Description	
Occupation		
Exploring the ESF	explores the ESF (contact with the snout).	
Exploring the floor	explores the floor, contact with the snout or digs with paws.	
Sleeping	lies without moving (during more than 30 s) body or eyes	
Observing	raises her head and may move.	
Social interaction		
Positive	Lying in body contact	lying in contact with the body of another sow (legs, back, shoulders, …)
	Snout to snout	touches another sow's snout with her snout
	Sniffing	sniffs or licks the body of another sow
Negative	Head knocking	knocks against another sow with a quick vigorous upward thrust of the head
	Pushing	uses shoulders or another part of the body (except the head) to move another sow aside while putting pressure on the body
	Biting	with the mouth open, and contact with the body of another sow
	Threatening	stares at another sow and walks away
	Fleeing	avoids another sow
	Attacking	runs into another sow

2.4. Statistical analysis

The statistical analyses were carried out using R studio software (version 4.1.2, R Foundation, Vienna, Austria). Due to the lower number of primiparous, the hierarchy ranking of every sow were used instead of the parity for the rest of the statistical analysis to obtain three balanced groups. To verify that the hierarchy ranking is indeed linked to the age of the sow, correlations of Pearson between the different hierarchy rankings, the age and parity of the sows were calculated using the "cor.test" function of the "stats" package (Best and Roberts, 1975).

Linear mixed-effects models were used with the "lme" function of the "nlme" package (Pinheiro et al., 2022). The models included the fixed effects of the treatment (C. vs. R.), the period (1 vs. 2), group (A vs. B), social ranking (LR vs. IR vs. HR), their two-way interaction with the treatment and the random effect of each sow. The feeding and drinking behaviours were analysed as a daily average, over the 5 experimental days. The occupation, location, and social behaviours were analysed as an average of the first 36 h of the experiment. The physical activity data were analysed as a daily average over the 5 experimental days. The nutritional requirements were analysed as a daily average of the 5 experimental days. The "performance" package (Lüdecke et al., 2022) made it possible to choose the best model, by potentially removing some non-significant interactions or factors, based on multiple indices of model quality and goodness of fit (r-squared, root-mean-square error (RMSE), intraclass correlation coefficient). A < 0.05 *P*-value was considered significant. For each model built, every hypothesis (normality of predicted variable and normality of model residues) were validated.

3. Results

3.1. Hierarchy status

Significant correlations appeared between the ranking established over the entire gestation and the ranking established during the 4 weeks of the experiment (correlation coefficient - $R^2 = 0.91$; $P < 0.001$); and between the ranking observed throughout the entire gestation and the one determined each day of the experiment ($R^2 = 0.83$; $P < 0.001$).

Throughout the entire gestation, the social ranking was correlated with the parity of the sow ($R^2 = 0.76$, $P < 0.001$), and with its age ($R^2 = 0.75$, $P < 0.001$). These results showed good stability of the social ranking throughout the entire gestation and allowed its use as a fixed effect (LR, IR, and HR) in the statistical models.

3.2. Feeding behaviour

The total number of visits per day (Table 4 and Figure 2.1.) was lower for treatment R compared to treatment C, by 28% for LR and by 34% and 37% for IR and HR sows, respectively ($P = 0.004$), and greater in period 2 compared to period 1 ($P < 0.001$). The number of nutritive visits was 1.0 time/d on average (Table 3), regardless of the treatment, period, group, or social ranking, while the number of non-nutritive visits was significantly affected by all factors (Table 3). The difference between treatments R and C for the non-nutritive visit was lower for LR sows (−35%, P = 0.004) compared to IR and HR sows (−41 and −43%, respectively, $P = 0.004$). The sows from group B made more non-nutritive visits during treatments C than R (6.35 and 3.90 visits/day, respectively), and than group A despite treatments C or R (4.01 and 2.30 visits per day, respectively, $P = 0.08$). The number of non-nutritive visits was greater during the second period compared to the first ($P < 0.001$, Table 4), and increased with the social rank of the sow ($P = 0.006$, Table 3).

The treatment, period, group or social ranking had no significant effect on the total duration of the visit to the feeder (Table 3). The time spent at the feeder for nutritive visits was, during the first period, longer by 1.32 min/d with treatment R than with treatment C, while during the second period it was shorter by 4 min/d ($P = 0.009$). The time spent at the feeder for nutritive visits decreased with the social ranking ($P = 0.04$, Table 3) but was not affected by the group. The treatment showed a significant effect on the time spent at the feeder for non-nutritive visits (28.4 vs. 16.3 min/d with treatments C and R, respectively; $P < 0.001$). The feeder occupancy was higher with treatment R compared to treatment C ($P = 0.009$) and for group B compared to group A ($P < 0.001$, Table 4). It was also higher for IR compared to LR and HR sows ($P < 0.001$, Table 3).

The treatment, period or group did not have any effect on the amount of feed distributed (Table 3). The amount of feed distributed increased with the social ranking ($P = 0.006$, Table 3).

3.3. Drinking behaviour

The interaction between the treatment or group and the number of visits to the water troughs was significant ($P = 0.03$), with more visits for group A with treatment R compared to treatment C (11.1 vs. 10.1 times/d), and less for group B (12.9 vs. 14.3 times/d, Table 3). The interaction between the treatment and social ranking was significant ($P = 0.003$, Figure 2.2.). Only HR sows had a lower number of drinking visits with treatment R than with treatment C, compared to the two other sow categories. The period tended to have an effect on the number of visits ($P = 0.06$), with less visits in the second period (Table 3).

The treatment, group and social ranking did not affect the time spent at the drinking trough and the amount of water drunk. The time spent at the trough was only influenced by the period ($P < 0.001$), which also affected the amount of water consumed (8.2 and 9.0 L/d in period 1 and 2, respectively, $P = 0.01$). Only LR sows decreased their water consumption with treatment R compared to treatment C (by 1.36 L/d, $P = 0.03$).

3.4. Social behaviour

The total number of positive interactions (Table 3) was influenced by the period ($P < 0.001$) and social ranking ($P = 0.03$), but not by the treatment ($P = 0.11$) or group ($P = 0.81$). The level of lying in body contact behaviour was lower with treatment R than with treatment C (13.6 vs. 14.2, $P = 0.04$). It was also lower during period 1 compared to period 2 ($P = 0.003$), for group A compared to group B ($P < 0.001$), and for HR and IR sows compared to LR sows ($P = 0.006$, Table 3). The treatment and social ranking had no significant effect on the number of snout-to-snout or sniffing interactions (Table 3). The number of snout-to-snout and sniffing interactions were lower during period 2 than period 1 ($P < 0.001$, Table 3). Group B presented more snout-to-snout interactions than group A (7.37 vs. 4.60, $P = 0.003$).

The number of negative interactions was 2.6-fold greater with treatment R compared to treatment C (Table 5, $P < 0.001$). It was also greater during period 2 compared to period 1 ($P < 0.001$) and in group A compared to group B ($P < 0.001$, Table 3). The total number of negative interactions decreased with the social ranking ($P = 0.04$, Table 3). More precisely, the sows showed 1.1 more head-butting ($P < 0.001$), 2.9 more pushing ($P < 0.001$), 1.2 more biting ($P = 0.005$), and 1.6 more fleeing ($P < 0.001$) interactions with treatment R compared to treatment C. The treatment had no significant effect on the number of threats and attacks (Table 3). All the negative interactions were significantly more frequent in group A compared to group B ($P < 0.01$, Table 3). The number of pushing ($P = 0.01$), biting ($P = 0.007$), threatening ($P = 0.002$) and attacking ($P = 0.04$) interactions increased with the social ranking (Table 3). During period 2, more head butts ($P < 0.001$), fleeing behaviour ($P < 0.001$), and attacks ($P = 0.03$) were observed, but less threats ($P < 0.001$) than in period 1 (Table 3).

3.5. Occupation time

Over the 36 h of observation, the time spent sleeping was longer by 48.0 min (P = 0.008), and the time spent exploring the ESF by 42.6 min (P < 0.001) with treatment R compared to treatment C (Table 3). During period 2 compared to period 1, the time spent sleeping was longer (P = 0.03) and the times spent observing and exploring the ESF were shorter by 2.07 h and 0.79 h, respectively (P < 0.001). The time spent observing was not significantly affected by the treatment, but was longer for group A than for group B (P < 0.01). The time spent exploring the feeder was longer for group A than for group B (P < 0.001). The time spent exploring the floor tended to decrease with the social ranking (P = 0.08) but it was not significantly affected either by the treatment, the group or the period. The social ranking had no significant effect on the time spent sleeping, observing or exploring the feeder.

3.6. Location in the pen

The treatment, period, group or social ranking did not have any significant effect on the time spent in the areas next to the feeder (A2 and A4).

IR sows stayed less time in the area in front of the feeder (A5), compared to LR and HR sows ($P = 0.03$). The time spent in the A5 area was longer for the sows from group A compared to sows from group B (4.31 vs. 3.05 h over 36 h, $P = 0.03$). The treatment and period had no significant effect on the time spent in A5.

Regarding the areas further away from the feeder (A1 and A3), with treatment R, the sows spent more time in area A1 ($P = 0.005$) and less time in area A3 ($P = 0.07$) on average, than with treatment C: the lower the social ranking, the higher the time spent in the A1 area ($P < 0.001$). Indeed, LR sows spent 15.7 h in area A1 compared to 8.6 h and 4.9 h for IR and HR sows, respectively. The period and group had no effect on the time spent in area A3. LR sows tended to spend less time in area A3 (7.46 h) compared to IR and HR sows (11.76 h and 11.35 h, respectively; $P = 0.07$). In period 1, the sows spent 0.81 h more over 36 h in area A1 compared to period 2 ($P = 0.03$).

3.7. Body condition, sow performance, and health

Sows had 15.03 ± 3.48 piglets born alive and 1.42 ± 1.86 stillbirths on average, for a litter weight of 23.17 ± 3.87 kg at farrowing. The

Table 3

Effect of the experimental treatment[a], period[b], group[c] and hierarchical status of sows[d], on the feeding and drinking behaviour (number and duration of visits, and the amount of feed and water consumed), on the social behaviour (number of positive and negative interactions) and on the occupation.

	Treatment[a]		Period[b]		Group[c]		Hierarchy[d]			Statistical analysis[e]							
	C	R	1	2	A	B	LR	IR	HR	RMSE	T	P	G	H	TxP	TxG	TxH
Number of sows	32	32	32	32	17	15	10	13	9	-	-	-	-	-	-	-	-
Feeding behaviour																	
Visits to feeders, nb/d[f]																	
Total	6.12	4.07	4.68	5.51	4.16	6.15	4.24[a]	4.69[a]	6.57[b]	2.2	0.004	< 0.001	0.003	0.006	-	0.07	0.004
Nutritive visit	1.02	1.02	1.02	1.00	1.01	1.02	1.00	1.01	1.04	0.305	1.00	0.60	0.64	0.49	-	-	-
Non-nutritive visit	5.11	3.05	3.66	4.50	3.16	5.12	3.24[a]	3.68[a]	5.53[b]	2.215	< 0.001	< 0.001	0.003	0.006	-	0.08	0.004
Time in the feeder, min/d																	
Total	57.4	46.8	50.8	53.1	56.1	47.5	58.6	55.8	39.6	30.64	0.19	0.12	0.28	0.63	0.24	0.18	0.40
Nutritive	32.3	30.9	32.5	30.6	35.5	27.3	38.4[a]	35.3[a]	17.4[b]	12.14	0.22	0.56	0.37	0.04	0.009	-	-
Non-nutritive	28.4	16.3	20.9	23.8	24.1	20.4	20.1	19.7	28.9	30.86	< 0.001	0.25	0.52	0.50	-	-	-
Feeder occupancy, h/d	7.22	12.3	6.56	6.81	7.53	5.86	4.33[a]	6.35[b]	2.64[c]	0.71	0.009	0.54	< 0.001	< 0.001	-	-	0.12
Amount of feed, kg/d	2.72	2.72	2.72	2.72	2.68	2.76	2.49[a]	2.80[b]	2.82[b]	0.03	-	-	0.41	0.006	-	-	-
Drinking behaviour																	
Visits to troughs, nb/d[f]	12.2	12.0	12.4	11.7	10.6	13.6	10.3[a]	11.0[a]	15.3[b]	5.10	0.11	0.06	0.14	0.07	-	0.03	0.003
Time in the stall, min/d	7.42	7.65	6.99	8.07	6.19	8.99	6.26	6.69	10.0	2.515	0.23	< 0.001	0.13	0.17	0.13	0.28	0.12
Amount of water, L/d	8.53	8.67	8.24	8.96	6.69	10.7	7.23	7.62	11.4	2.887	0.37	0.01	0.11	0.23	-	-	0.03
Positive interactions[g]																	
Total, nb over 36 h	33.9	27.4	32.7	22.8	29.4	29.9	33.8[a]	26.6[b]	29.9[a]	7.57	0.11	< 0.001	0.81	0.03	-	-	-
Lying in body contact, nb over 36 h	14.2	13.6	13.5	14.5	11.7	16.4	15.3[a]	14.3[a]	11.6[b]	3.63	0.04	0.003	< 0.001	0.006	-	-	-
Snout to snout, nb over 36 h	8.84	4.69	7.97	2.00	7.37	4.60	7.48	5.33	5.92	3.45	0.08	< 0.001	0.003	0.10	-	-	-
Sniffing, nb over 36 h	10.8	9.10	11.2	6.24	10.3	8.96	11.0[a]	6.96[b]	12.3[a]	4.99	0.36	< 0.001	0.14	0.008	-	-	-
Negative interactions[g]																	
Total, nb over 36 h	4.90	12.6	9.81	10.3	15.4	3.26	6.74[a]	10.0[a]	13.1[b]	8.02	< 0.001	< 0.001	< 0.001	0.04	-	-	-
Head butting, nb over 36 h	2.22	3.27	3.70	1.12	4.47	0.99	2.18	3.18	3.24	3.37	< 0.001	< 0.001	< 0.001	0.50	-	-	-
Pushing, nb over 36 h	1.13	3.99	2.54	4.02	4.67	0.95	0.92[a]	3.49[b]	4.39[c]	2.49	< 0.001	0.69	< 0.001	0.01	-	-	-
Biting, nb over 36 h	0.25	1.45	0.73	1.72	1.68	0.24	0.25[a]	0.67[a]	2.37[b]	1.78	0.005	0.26	0.006	0.007	-	-	-
Threatening, nb over 36 h	0.06	1.16	0.23	2.00	1.25	0.19	0.29[a]	0.64[a]	1.47[b]	1.40	0.19	< 0.001	< 0.001	0.002	-	-	-
Fleeing, nb over 36 h	0.81	2.46	2.17	1.26	2.82	0.75	2.96[a]	1.67[b]	1.13[c]	2.30	< 0.001	< 0.001	< 0.001	0.03	-	-	-
Attacking, nb over 36 h	0.43	0.30	0.42	0.17	0.51	0.14	0.11[a]	0.38[a]	0.53[b]	0.64	0.79	0.03	0.005	0.04	-	-	-
Occupation																	
Sleeping, h over 36 h	26.0	25.2	25.3	25.8	25.4	25.5	25.5	25.8	24.9	2.78	0.008	0.03	0.70	0.37	-	-	-
Observing, h over 36 h	4.73	3.53	4.58	2.51	4.40	3.39	4.14	3.75	4.02	1.07	0.15	< 0.001	0.005	0.38	-	-	-
Explore the ESF, h over 36 h	1.05	1.76	1.76	0.97	1.88	1.06	1.57	1.62	1.30	0.57	< 0.001	< 0.001	0.001	0.72	-	-	-
Explore the floor, h over 36 h	2.77	2.86	2.83	2.83	2.80	2.87	3.37[a]	2.70[b]	2.46[c]	0.75	0.36	0.63	0.73	0.08	-	-	-

[a] Treatment (T): C=Control; R=Restricted access to the feeder

[b] Two 5-day periods (P, period 1 and period 2) of restricted access to the feeder

[c] Two groups (G) of sows (A and B)

[d] Hierachy (H) ranking of sows: LR=low, IR=intermediate, HR= high

[e] RMSE= Root Mean Square Error. P values of fixed effects and TxP, TxG and TxH interactions (when there are significant) on a generalized linear model with a random sow effect. Letters (a, b, c) were add to significant difference ($P < 0.05$) between the modality of the hierarchy.

[f] Nb/d = number per day

[g] Nb = number

Table 4
Effect of the experimental treatment[a], period[b], batch[c] and hierarchical status of sows[d], on the body condition (body weight and backfat thickness gain), on the skin lesions (scratch and wound index), on the posture and on the nutritional requirements.

	Treatment[a]		Period[b]		Group[c]		Hierarchy[d]				Statistical analysis[e]						
	C	R	1	2	A	B	LR	IR	HR	RMSE	T	P	G	H	TxP	TxG	TxH
Number of sows	32	32	32	32	17	15	10	13	9	-	-	-	-	-	-	-	-
Body condition																	
Body weight gain, kg	4.03	3.82	3.85	4.00	4.29	3.52	4.56	3.90	3.39	4.88	0.81	0.86	0.41	0.62	-	-	-
BT[10] gain, mm	0.59	0.37	0.54	0.42	0.36	0.62	0.50	1.00	0.49	1.19	0.31	0.58	0.25	0.98	-	-	-
Skin lesions[6]																	
Scratch index	22.2	29.8	25.8	26.2	24.1	28.2	50.0[a]	19.5[b]	12.9[c]	18.6	0.82	0.91	0.33	0.02	-	-	0.005
Wound index	3.27	2.63	4.17	1.68	3.14	2.75	3.33	3.06	2.47	6.53	0.08	0.04	0.12	0.83	-	0.05	-
Number of sows	25	25	25	25	12	13	7	10	8	-	-	-	-	-	-	-	-
Posture in the morning **(00:00–11:59)**																	
Lying, h/12 h	7.08	6.53	6.72	6.90	6.89	6.70	6.74	6.71	6.98	0.88	< 0.001	0.04	0.31	0.46	< 0.001	< 0.001	-
Moving, min/12 h	52.9	59.4	56.7	55.9	39.7	72.0	52.7	52.5	58.4	11.7	0.01	0.04	0.05	0.92	< 0.001	< 0.001	0.008
Standing, h/12 h	4.02	4.46	4.29	4.20	4.41	4.10	4.37	4.30	4.03	0.73	< 0.001	< 0.001	0.20	0.86	< 0.01	0.003	-
Position change, nb/12 h	26.4	28.8	26.8	28.4	26.4	28.9	27.2	28.7	26.7	7.39	< 0.001	< 0.001	0.39	0.91	0.001	< 0.001	< 0.001
Posture in the afternoon **(12:00–23:59 h)**																	
Lying, h/12 h	10.7	10.8	10.7	10.6	10.5	10.9	10.4[a]	10.9[b]	10.7[a]	1.62	0.30	0.98	0.007	0.004			
Moving, min/12 h	10.8	10.7	10.0	11.3	8.62	12.6	13.4	8.1	11.6	6.17	0.002	0.18	0.028	0.21	< 0.001	0.004	-
Standing, h/12 h	0.72	0.66	0.66	0.71	0.74	0.63	0.82[a]	0.50[b]	0.83[a]	0.35	< 0.001	0.19	0.36	0.002	< 0.001	0.003	0.003
Position change, nb/12 h	13.0	12.7	12.3	13.3	13.7	12.1	15.3[a]	11.7[b]	11.8[b]	6.08	< 0.001	< 0.001	0.88	0.02	-	0.007	< 0.001
Nutritional requirements for maintenance[8]																	
ME, MJ/d	30.7	31.1	30.5	31.3	31.6	30.3	27.1[a]	31.5[b]	34.4[c]	0.45	< 0.001	< 0.001	0.05	< 0.001	0.04	-	-
Feed, kg/d	2.34	2.37	2.32	2.39	2.41	2.30	2.06[a]	2.40[b]	2.62[c]	0.03	< 0.001	< 0.001	0.05	< 0.001	0.04	-	-

[6] Index created as the sum of skin lesions pondered by their severity (1: for lesions under 5 cm, 5: for lesions upper 5 cm, 10: for lesions with blood or deep). Skin lesions were divided in two categories for two different index: scratch index (for long and straight lesions) and wound index (round lesions).

[7] BT = Backfat thickness

[8]Estimated metabolizable energy (ME) for maintenance (MJ/d) = ((0.30 *BodyWeight$^{0.75}$ *Activity) + (440 *BodyWeight$^{0.75}$))* 0.001 where BodyWeight is in kg and Activity is the time in standing position (min /d). Feed allowance is the ME for maintenance with a diet of 13.14 MJ of ME /kg.

[a] Treatment (T): C=Control; R=Restricted access to the feeder

[b] Two 5-day periods (P, period 1 and period 2) of restricted access to the feeder

[c] Two groups (G) of sows (A and B)

[d] Hierachy (H) ranking of sows: L=low, M=intermediate, H= high

[e] RMSE= Root Mean Square Error. P values of fixed effects and TxP, TxG and TxH interactions (when there are significant) on a generalized linear model with a random sow effect. Letters (a, b, c) were add to significant difference ($P < 0.05$) between the modality of the hierarchy.

social ranking or group had no significant effect on the litter size ($P = 0.79$ and $P = 0.46$, respectively) and weight at birth ($P = 0.81$ and $P = 0.70$, respectively).

The period, group or social ranking had no effect on the body weight and back-fat thickness gains of sows (Table 4). LR sows had a greater scratch index with treatment R compared to treatment C (63.4 vs. 36.5, $P = 0.02$). The scratch index was greater for LR sows compared to IR ($P = 0.002$) and HR sows ($P = 0.008$, Table 4). The period and group had no significant effect on the scratch index (Table 4).

The wound index was higher with treatment C than treatment R for group A (4.57 vs. 1.69, interaction $P = 0.05$), while the opposite was observed for group B (1.79 vs. 3.75). It was lower in period 2 than in period 1 ($P = 0.04$, Table 4). The social ranking had no significant effect on the wound index (Table 4).

There were no problems of health detected during all the experiment (control and competitive situation for feed).

3.8. Physical activity

As shown in Fig. 3, physical activity was strongly affected by the time of day, as most of the activity occurred in the morning after the start of a new "feeding day" (at midnight). In the morning (00–00–11–59 h) and afternoon (12–00–23–59 h) respectively, the sows spent 6.80 vs 0.10.73 h/12 h lying down ($P < 0.001$), 4.25 vs. 0.70 h/12 h standing ($P < 0.001$), 56.3 vs. 10.7 min/12 h moving ($P < 0.001$), and changed posture 27.7 vs. 12.9 times/12 h ($P < 0.001$), on average.

In the morning, the difference between treatments R and C was greater for period 1 than period 2 for the time spent lying down (−21 vs. −5%, $P < 0.001$), the time spent moving (+16 vs. +9%, $P < 0.001$), the time spent standing (+18 vs. +5%, $P < 0.01$), and the number of position changes (+11 vs. +8%, $P < 0.001$, Table 4). The differences between treatments R and C were greater for group B than for group A regarding the time spent lying down (−10 vs. −6%, $P < 0.001$), the time spent moving (+22 vs. +1%, $P < 0.001$), and the time spent standing (+12 vs. +9%, $P = 0.003$), except for the difference in the number of position changes which was greater for group A than for group B (+11 vs. +7%, $P < 0.001$). The number of position changes was higher with treatment R compared to treatment C, and for HR and LR sows compared to IR sows (+17 and +11 vs. +3%, respectively, $P < 0.001$). With treatment R, the sows spent less time lying down ($P < 0.001$), more time moving ($P = 0.01$), more time standing ($P < 0.001$), and changed positions more often ($P < 0.001$) than with treatment C.

In the afternoon, the time spent moving and standing was lower with treatment R compared to treatment C in period 2, while the opposite was observed for period 1 ($P < 0.001$, Table 4). With treatment R compared to treatment C, the time spent moving was greater for group A (8.7 vs. 8.5 min over 12 h) and lower for group B (12.5 vs. 12.8 min over 12 h, interaction, $P = 0.004$). With treatment R compared to treatment C, LR sows were the only ones with a reduced number of position changes compared to IR and HR sows (−17 vs. +4 and +8%, respectively,

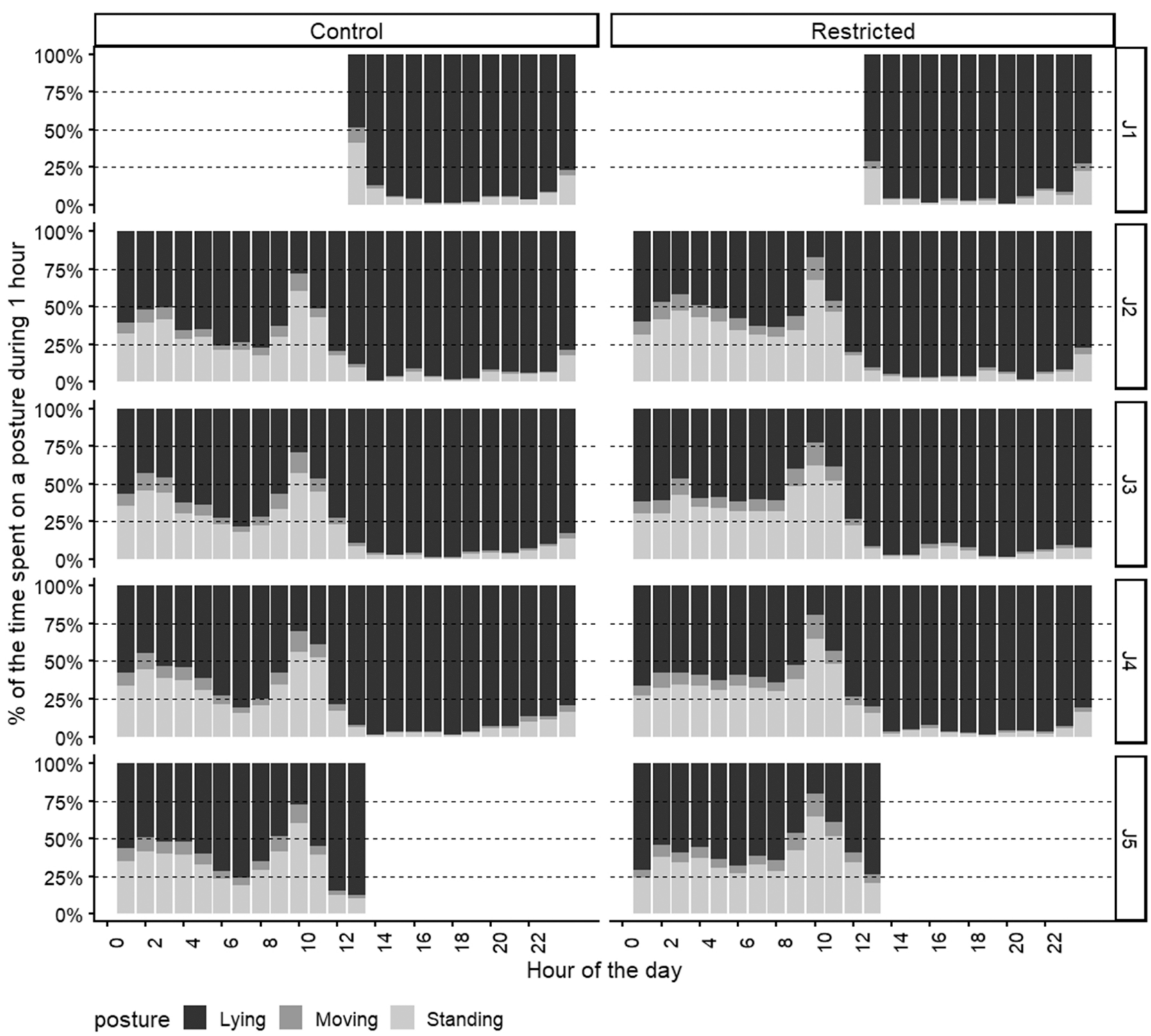

Fig. 3. Effect of the treatment (Control vs. Restricted access to the feeder) on the time stamp of the posture (lying, moving and standing) during the 5 days of the experiment.

$P < 0.001$). The difference between treatments R and C was greater for the time spent standing for group B than for group A (−14 vs. −4%, $P = 0.03$), while the opposite was observed for the number of positions changes, which was greater for group A than for group B (−4 vs. −3%, $P = 0.007$). Regarding the time spent standing, the difference between treatments R and C was greater for HR sows than for LR and IR sows (−12 vs. −8 and −6%, respectively, $P = 0.003$). With treatment R, the sows spent less time moving ($P = 0.002$) and standing ($P < 0.001$) than with treatment C, and the number of position changes was lower ($P < 0.001$).

3.9. Nutritional requirements for maintenance

When calculating *ex-post* nutritional requirements for maintenance while considering the effect of the treatment on physical activity, ME and feed requirements for maintenance were greater by 0.4 MJ/d and 50 g/d (for a diet at 13.14 MJ/d) with treatment R compared to treatment C ($P < 0.001$, Table 4). The treatment and period interaction had a significant effect (P = 0.04). ME requirements were greater during period 1 compared to period 2 with treatments R (31.5 vs. 30.8 MJ/d) and C (31.3 vs. 30.2 MJ/d). They were also greater for group A compared to group B ($P = 0.05$). ME and feed requirements for maintenance increased with the social ranking ($P < 0.01$, Table 4).

4. Discussion

4.1. Feeding behaviour

The short-term feed competition also affected feeding behaviour and the way sows used the feeder. In restricted access situations, sows spent more time exploring the ESF, but the total number of visits, of non-feeding visits and time at the ESF decreased. This decrease in non-feeding visits with the increase in sows per ESF is in accordance with the results of Olsson et al. (2011). The queue to access the ESF is longer with one feeder open instead of two, leading to a greater interest in the feeder (Bench et al., 2013). Moreover, Olsson et al. (2011) showed that more than half of the sows entering the feeder were attacked, which explains the aggressiveness of sows. This is probably related to the occupancy rate of the feeder which significantly increased during the restricted treatment. By changing the timing of feeding, behavioural changes can be observed, more specifically in a small group of sows where there is more fighting compared to a large group (Hemsworth et al., 2013). However, in this study, the number of sows per ESF was quite low during the control and restricted treatment periods, compared to the literature (40–60 sows per ESF, Bench et al., 2013) or commercial sow farms. Therefore, we would have expected limited or no changes in behaviour to take place because of the small numbers of sows per ESF. Thus, the results of this study highlighted that only considering the number of sows per feeder is not sufficient, and it is important to ensure stability in the number of functioning feeders.

4.2. Feeding and drinking patterns

During the day, the feed competition had an impact on drinking and feeding behaviour patterns, with a time lag of visits to the automatons in the morning. Junge et al. (2012) showed that the daily pattern of drinking behaviour was similar to that of feeding. Sows eat and drink in the morning, a period with a higher level of activity. Due to the fact that the feeding period was extended for the entire group, the drinking period was also extended. Verdon et al. (2018b) also showed the impact of social rank on the feeding pattern. Even if the feeder was mostly occupied in the morning, lower-ranking sows ate later, around midday. Even though the feed competition did not have an impact on water consumption, this could be linked to the fact that during the experimental days, the daily quantity of feed supply was the same (restricted feeding).

4.3. Aggressiveness and lesions

During the short-term feed competition, sows were more aggressive toward each other with an increase in agonistic interactions but without any consistent effects on skin lesions. Verdon and Rault (2018a) explained that aggression may occur when accessing or defending a restricted resource. Moreover, agonistic interactions during the control weeks were lower than in other studies (Anil et al., 2006), maybe due to the stability over the experiment of the group composition, which is known to reduce aggression (Campler et al., 2019; Lagoda et al., 2021; Jowett and Amory, 2021). Skin lesions may be an indicator of direct aggression (Verdon and Rault, 2018a) but they do not reflect agonistic interactions without contact, such as threats and avoidance behaviour (Turner et al., 2006). That is why in the present study, the ethogram contains aggressive behaviours representing non-physical aggression (" threat based") as pushing or fleeing behaviour that are significantly affected by the feed competition. These results indicate a clear increase in social tensions in the context of reduced accessibility to the feeder, with marked effects on behaviour, especially for low-ranking animals.

4.4. Physical activity

In situations of short-term feed competition, sow activity increased by around 8% (with less time spent sleeping or lying down), even during the control treatment the daily standing time was around 20% higher than that reported in the literature (Anil et al., 2006; Boyle et al., 2002). This longer time spent standing might be related to the composition of the group, with rather low average parity, the pen design, with the provision of straw, and the type of equipment. The lower specificity and sensibility of the accelerometer used, could also be an explanation. Mc Glone (2013) suggested that posture could be used as an indicator of sow welfare, reduced access to the feeder (i.e. increased number of sows per feeder) therefore having a negative effect on the welfare of group-housed gestating sows fed with an ESF. The increased standing activity is due to the longer time spent waiting to enter the ESF, in line with the increased time exploring it, and the tendency to spend longer time in the area close to it observed in the present study. It may also be caused by unrest due to aggression in the pen, which disturbs more sows causing them to stand for longer periods of time in between meals. This is corroborated by the increased frequency of negative interactions while the frequency of skin lesions was only slightly affected and mainly in low-ranking sows. Physical activity was highly influenced by agonistic behaviours as seen in the results with more position changes in the restricted group, and especially for the high and low ranking sows, which is indicative of more interactions between the highest and lowest ranked sows. This is also a typical cause of distress which inflicts the entire group, prompting less rest and more standing time. It can also be indicative of lower ranked sows pulling the average activity levels up as they try to access resources more frequently the more hungry, thirsty or tired they get. These results suggest that some behavioural adaptations occurred to response to the potentially stressful situation induced by the restricted access to the ESF.

The results also suggest that overall sow comfort decreased. They spent more time in the only area without straw and made more frequent position changes. According to Bench et al. (2013), competition for straw may appear in a group of sows raised on straw bedding. This is confirmed by the present results that indicate that low-ranking sows spent more time in area without straw to avoid the competition and associated aggressions for this resource, given that tensions were already heightened in the pen due to restricted feeder access.

4.5. Energy requirements

The study's results show that in the situation of restricted access to the feeder, sows spend more time standing, which increases their energy requirements. Therefore, the *ex-ante* estimation of sow feed requirements indicates that they were underestimated. In fact, during the 4 weeks of the experiment, sows spent one additional hour standing compared to the 4 h usually used to calculate the maintenance energy requirements (Dourmad et al., 2008). This underestimation may have had consequences for foetal growth or body reserves for some sows. These results highlight the need of real time technologies to follow the level of activity of sows during the gestation and consequently adapt the supply of energy. However, this did not significantly affect their body weight and back-fat thickness gain, maybe due to the duration of the feed competition period induced being too short. The increase in ME requirements with the social ranking of sows could be accounted for by the greater body weight of dominant sows, which were also mostly multiparous (Kranendonk et al., 2007). The restricted access to the feeder also increased the number of posture changes during the morning and the afternoon. The accuracy of the requirements calculation could be improved with the inclusion of energy lost during posture changes, as showed by Labuissiere et al., (2022)

4.6. Social ranking

Access to the pen resources appeared to be facilitated with increased ranking. Indeed, the time spent by sows in the area without straw decreased with their ranking, while the time spent in the quiet resting area with straw and close to the drinker increased. Strawford et al. (2008) failed to prove that hierarchy influences the preference for lying-down area, but they suggested that sows limit their interaction with others by going to non-favourite places as done by the present low-ranking sows. This confirms the results of Verdon et al. (2018b), which show that lower-ranking sows avoid the feeding area.

Time spent at the drinker and the amount of water drunk increased with social rank. Conversely, low-ranking sows spent more time eating than the others, in agreement with the results of Vargovic et al. (2021) who measured a lower feeding speed in young sows, compared to older ones, to get away from their pen mates during feeding times. The present results indicate a lower scratch index, less fleeing behaviour, but more agonistic interactions when the ranking increased. Pierdon and Parsons (2018) and Brajon et al. (2021) also showed that lower-parity sows faced a higher risk of lesions due to aggressions. Our results agree with Verdon et al. (2016) and Brajon et al. (2021), who showed that dominant sows were responsible for the majority of aggressions. The time spent exploring the floor decreased with the increasing rank. These results contradict the results of Chapinal et al. (2010), who report that gilts had lower activity than older sows. However, this study showed a different size and group composition compared to the present paper, with more gilts (30% compared to 23–26% of gilts in the group).

4.7. Group effect

This study highlighted behavioural differences between groups. In particular, group B seemed to be calmer than A with less time spent moving, observing and exploring the ESF, but showed more negative interactions and a greater wound index (especially during the control treatment). The experiment started at different gestation weeks (three vs. five for B and A, respectively) for these two groups, which may partly explain the different behaviours. The establishment of hierarchy when sows enter the group pen may lead to aggression and fights between sows and the number of injuries decreased following mixing and hierarchy establishment (Greenwood et al., 2019). In both groups, the hierarchical order was stable according to the order of access to the feeder, but in group B the hierarchy was probably not completely established, as according to literature, the time required for its establishment varies between three (Verdon et al., 2016) and nine weeks (Hulbert and Mc Glone, 2006). Despite the two groups were stable and the number of primiparous was the same, group B had lower number of sows and consequently a higher percentage of primiparous sows. Maybe this could be an explanation regarding the higher activity and agonistic behaviour observed in this group, as showed Greenwood et al. (2019) and Lagoda et al. (2021).

4.8. Repetition effect, habituation or reinforcement?

During the repetition of the feed competition situations, the effect of the treatments on the time spent active and the time spent in the area without straw was less marked during the second than during the first period, which may point to the habituation of sows to feed competition. Conversely, during the second period compared to the first one, the number of positive interactions (such as oral-nasal interactions) decreased and the number of negative ones (such as attacks or fleeing behaviour), as well as the number of position changes increased significantly, thus suggesting a reinforcement of the effect of feed competition. Even though welfare was not measured in the present study, oral-nasal-face behaviour could be used as an indicator of welfare as suggested by Mc Glone (2013). Therefore, the present results may suggest a deterioration of the welfare status in the second competitive feeding situation compared to the first one. Some physiological or stereotypic measurements on sows, such as cortisol (Murphy et al., 2021) could help to draw conclusions about the habituation or reinforcement effect of the repetition of feed competition.

5. Conclusion

This study found that a competitive feeding situation using ESF increase physical activity and aggressiveness without increasing skin lesions. They also increase estimated metabolizable energy requirements in the first days after the event. The social ranking had a huge impact on the overall behaviour enhanced by feed competition, particularly on the lowest- and highest-ranking sows. The habituation, or not, of sows to feed competition later in the gestation is unclear. In practice, when gestating sows have access to at least two ESF, a short-term dysfunction of one ESF has therefore detrimental effects on the behaviour of the sows with potential effects on their welfare, but without affecting their performance.

Conflict of interest statement

The authors disclose any actual or potential conflicts of interest that may affect their ability to objectively present or review research or data.

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