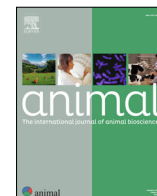




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Investigating the development of piglet feeding behaviour during the immediate postweaning phase using computer vision

T. Van De Putte^a, C. Van Kerschaver^a, M. Hostens^{a,b}, J. Degroote^{a,*}

^a Department of Animal Sciences and Aquatic Ecology, Ghent University, Coupure Links 653, 9000 Gent, Belgium

^b Department of Animal Science, College of Agriculture and Life Sciences, Cornell University, 215 Garden Ave, Ithaca, NY 14850, United States of America



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ABSTRACT

Adequate feed intake is a crucial factor driving piglet health during the weaning transition, and therefore, this study investigated the feeding behaviour in the immediate postweaning period under varying conditions of preweaning socialisation and feed familiarity in a 2×2 factorial design. During the first 3 days postweaning, 288 weaned piglets (21.8 days old), housed in 24 pens ($n = 6$ per treatment) with 12 piglets per pen, were video recorded. Preweaning socialisation involved co-mingling piglets from three litters 10 days before weaning and maintaining these groups after weaning, whereas conventionally reared piglets from three litters were mixed at weaning. Feed familiarity involved providing piglets with supplemental creep feed in an additional feeder after weaning, which was identical to the conditions during the final days before weaning. In contrast, the dry feeder and the weaner diet were unfamiliar to the animals. It was hypothesised that both co-mingling and feed familiarity would promote early postweaning feeding behaviour. To assess feeding behaviour, two image classification models were trained to process the video recordings and predict time spent at each feeder. The models achieved a precision and recall of 0.93 for the dry feeder and 0.91 for the creep feeder. To further explore the behavioural dynamics, including aggression and group hierarchy formation, it was hypothesised that co-mingling would reduce aggressive interactions during the immediate postweaning phase. An aggression detection model was developed using classical motion detection techniques combined with skin lesion scoring as a validation metric. The aggression detector achieved a precision of 0.96 and a recall of 0.71 on a balanced test video. A bi-harmonic circadian feeding pattern was identified, and piglets demonstrated group feeding behaviour shortly after weaning. Co-mingling increased the time spent eating creep feed on day (d) 0 and d1 ($P < 0.019$) and reduced aggression during the same period ($P < 0.016$). Providing additional creep feed increased the total time spent eating on d0 ($P = 0.001$) but decreased time spent eating weaner feed on d1 and d2 ($P < 0.001$). Moreover, increased total feeding time during the first 12–36 h postweaning correlated positively with cumulative feed intake over a longer period (d0–14). To conclude, both preweaning co-mingling and feed familiarity stimulated early postweaning feeding behaviour, while co-mingling also reduced aggression. Feeding behaviour during the immediate postweaning phase appears crucial for promoting adequate feed intake throughout the entire weaning transition.

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Implications

Reducing the number of changing factors at weaning is key to easing the transition, making it essential to understand how each factor individually affects early feed intake behaviour. This study offers practical insights for improving piglet management during the critical postweaning phase. Preweaning socialisation through early co-mingling reduces aggression and promotes early feeding behaviour postweaning. Maintaining feed familiarity by offering the same creep feed and feeder increases eating time immediately

after weaning. Additionally, the computer vision techniques explored show potential to improve understanding and enable practical applications that enhance piglet welfare and farm productivity during this critical period.

Introduction

Understanding the factors that influence the health and growth of weaned piglets is essential to optimise management practices in pig farming. The abrupt weaning process poses a significant challenge, primarily impacting the intestinal tract's ability to adapt to sudden dietary changes. This period often triggers a transient state of anorexia, leading to severe dysregulation of small intestinal

* Corresponding author.

E-mail address: jerdgroo.degroote@ugent.be (J. Degroote).

functionality and adversely affecting gut health and nutritional status in piglets (Boudry et al., 2004; Dong and Pluske, 2007). Research has indicated that specific feed intake patterns in pigs can signal various stressors, including environmental, health, or social challenges (Matthews et al., 2016; Nasirahmadi et al., 2017). Notably, changes in feeding behaviour have been predictive of disease outbreaks such as pneumonia (Brown-Brandl et al., 2013). Real-time feed intake data are particularly relevant for weaned piglets, where both low and high voluntary feed intake during the weaning transition are associated with an increased risk of postweaning diarrhoea (Madec et al., 1998; Spreeuwenberg et al., 2001; Laine et al., 2008). While recent technologies like radio frequency tagging with electronic feeders offer precise monitoring of nutritional and behavioural changes (Marcon et al., 2015; Adrion et al., 2018; Cross et al., 2018), their high cost and application primarily within research settings limit broader adoption. Moreover, electronic feeding stations limit pigs from eating at the same time, which disrupts their natural behaviour. In contrast, camera surveillance coupled with computer vision technology presents a non-intrusive, cost-effective, and objective method for the continuous monitoring of behavioural and feeding patterns (Martínez-Avilés et al., 2017; Nasirahmadi et al., 2017). The presented study employs an experimental design using a 2×2 factorial arrangement, focusing on preweaning socialisation and feed familiarity. Preweaning socialisation considers the practice of co-mingling piglets from different litters prior to weaning (Van Kerschaver et al., 2023a), while feed familiarity refers to the choice of offering creep feed in an extra feeder after weaning (Middelkoop et al., 2020), ensuring that both the feeder type and the creep feed are consistent with the last 4 days preweaning. Many state-of-the-art behavioural studies use object detection and individual tracking. However, tracking individual piglets in an animal-dense environment brings extra challenges and limited accuracy (van der Zande et al., 2021). Therefore, this study explored the application of image classification using a convolutional neural network, inspired by Alameer et al. (2020), to estimate feed intake behaviour at the pen level rather than the individual level. Postweaning feed intake behaviour, measured as time spent eating, was evaluated as a proxy for feed intake. It is hypothesised that preweaning co-mingling and the additional provision of familiar feed in a familiar feeder after weaning will enhance postweaning feed intake behaviour. By introducing significant variability in weaning stressors, this study aimed to identify a potential relationship between early postweaning feed intake behaviour and longer-term feed intake during the weaning transition. Furthermore, through continuous and detailed monitoring using automated image classification, the study aimed to provide insights into the development of piglets' early group feeding behaviour and the potential emergence of circadian feed intake patterns. In addition, aggression at the pen level was measured, offering additional insight into the relationship between the establishment of hierarchical relationships and feeding behaviour. Measurements were performed using a motion detection-based aggression detector, inspired by Costa et al. (2014), who utilised pixel intensity thresholding to detect pig movement. It was hypothesised that preweaning co-mingling reduces aggression postweaning, as aggressive interactions commonly arise after weaning due to regrouping.

Material and methods

Animals and housing

This work builds upon an earlier experiment published by Van Kerschaver et al. (Van Kerschaver et al., 2023b). It provides comprehensive details on the timing of vaccinations, medical treat-

ments, and the composition of diets during both the preweaning and postweaning phases. During the preweaning phase, 8 primiparous and 28 multiparous DanBred sows and their Piétrain \times Danbred litters were observed in two batches. The farrowing pens, each measuring 1.8 m \times 2.8 m, were equipped with a farrowing crate (0.9 m \times 2.5 m, adjustable) featuring a partially solid and slatted floor, a solid heated area for piglet resting, and fully slatted floors in the remaining area. Management practices included cross-fostering, tail docking, toltrazuril treatment to prevent coccidiosis (Cevazuril, 50 mg/ml oral suspension, CEVA Santé Animale N.V., Belgium), iron injection on day (d) 2 postpartum and vaccination of piglets. Sows and their litters were selected and allocated to treatments 10 days before weaning based on litter piglet BW (mean \pm SD, 3.42 \pm 0.42 kg), litter size (mean \pm SD, 12.8 \pm 0.7 piglets), piglet age (mean \pm SD, 11.8 \pm 0.8 days), and sow parity (mean \pm SD, 3.75 \pm 2.27). The sows received a commercial transition and lactation diet. The piglets had access to a commercial milk replacer (CP = 22%, crude fat = 20%, crude ash = 7%, crude fibre = 0.04%, sodium = 0.5%, lysine = 1.8%, methionine = 0.8%; Biggilac Pl+, Aveve Veevoeding, Merksem, Belgium) in a 1:5 powder-to-water ratio, during d-20 to d-17 before weaning, and to a liquid feed (CP = 20%, crude fat = 11%, crude ash = 5%, crude fibre = 1.7%, lysine = 1.60%, phosphorus = 0.60%, copper = 150 mg/kg; BiggiFeed Pl+, Aveve Veevoeding, Merksem, Belgium) in a 1:1 ratio from d-17 to d-10 before weaning. They were offered commercial solid creep feed in a round creep feeder (270 mm diameter) (MS ClickFeeder mini, MS schippers, Bladel, The Netherlands), with five feeder spaces, located at the anterior side of the sow during d-10 to d-4 (creep feed A) and d-4 to d0 (creep feed B) (BiggiFeed Pl+, Aveve Veevoeding, Merksem, Belgium).

After weaning, piglets (21.8 days old) were housed in pens measuring 2.20 m \times 1.32 m, equipped with partially slatted and solid flooring, a nipple drinker, and one or two feeders depending on treatment. A movable chain and a jute rope were provided in each pen, which accommodated 12 piglets. The nursery unit maintained 24 h of continuous light during d0-3 and 8 h of artificial light per day from d4-42 postweaning. There was a minimal amount of natural daylight via an 80 \times 60 cm window. During d0-14 postweaning, piglets were offered a commercial weaner diet (Biggyspeen Balans, Aveve Veevoeding, Merksem, Belgium). Subsequently, piglets received a commercial starter diet from d14-42 postweaning (Biggystart Balans, Aveve Veevoeding, Merksem, Belgium).

Experimental design

The experimental design employed a 2×2 factorial arrangement for the nursery pens. The first independent variable, preweaning management (housing), involved piglets that were either conventionally (CON) reared in separate farrowing pens without contact with other litters, or co-mingled (CO) with piglets from different litters by removing partitions between three farrowing pens starting 10 days before weaning. At weaning, conventionally reared piglets from three unfamiliar litters were distributed across three nursery pens and hence mingled after weaning. Conversely, piglets from the co-mingling system were redistributed with those they had been co-mingled with 10 days prior to weaning. Allocation of the piglets to nursery pens was blocked per litter group, i.e., piglets from three litters were mixed (either at weaning or prior to weaning depending on the treatment) and allocated to three nursery pens while ensuring representation of three to five piglets from each litter in a single pen. Our treatments were evenly distributed over the two farrowing rooms to prevent potential bias introduced by the farrowing room (e.g. pathogen pressure). Allocation further included stratification for BW and sex to achieve three similar pen replicates within each block of three litters. The second independent variable, feed familiarity, determined whether the

same diet was provided before and after weaning. After weaning, all piglets had *ad libitum* access to a three-space dry feeder, which is a standard dry feeder with three distinct feeder spaces for individual piglets (custom-made stainless steel construction, 62 × 25 × 80 cm, l × b × h). This dry feeder contained a commercial weaner diet. Half of the nursery pens were exclusively fed this weaner diet (**NO-CREEP**) while the other half was supplemented with creep feed (**CREEP**). Creep feed was limited to 0.538 kg per piglet, incurring an additional cost of €0.30 per piglet. Both the type of creep feed and the feeder were consistent with the last 4 days before weaning. Details about the composition of the diets can be found in [Supplementary Table S1](#). The experiment was run in two equally sized batches with a 4-week interval, each involving a balanced experimental design as described above.

Measurements

This study builds upon the research conducted by [Van Kerschaver et al. \(2023b\)](#), which investigated 36 pens of piglets (totalling 432 individuals) over a period of 42 days postweaning. Our analysis focuses on a subset of this dataset, comprising 24 pens (288 piglets) with six pens per treatment ($n = 6$), and primarily focuses on feed intake behaviour and aggression during the first 3 days postweaning (d0–d2). In each batch, 12 cameras were strategically positioned above 12 pens, mounted at a height of 2.80 m to offer a complete view of the entire pen, including clear visibility of the dry feeder. Pens selected for camera monitoring ensured a balanced distribution of treatments. Three models were developed to analyse specific behaviours: feed intake behaviour at the dry feeder, feed intake behaviour at the creep feeder, and aggression. Feed intake behaviour was assessed by processing video recordings from the first 3 days postweaning at a rate of one frame per second using the designated image classifier model for each feeder type. The feed intake behaviour was quantified as the time spent eating in seconds, calculated by multiplying the number of animals eating by the duration of eating. Aggressive behaviour was analysed using the aggression detector with both the number of aggressive interactions and the total duration of such behaviour quantified. Additionally, the residual feed in both the creep feeders and dry feeders was manually weighed each day from d0 to d10, and then again on d12 and d14. Fresh skin lesions at the snout, shoulders, and flanks of the piglets were scored at the beginning of d2, using a 0–2 scale or 0–3 scale, depending on the body part, with higher values indicating a greater severity of skin damage ([Parratt et al., 2006](#); [Kutzer et al., 2009](#); [van der Peet-Schwering et al., 2015](#)). Procedural details can be found in [Van Kerschaver et al. \(2023b\)](#).

Equipment and video data handling

The video recordings were captured and stored using a setup consisting of 2-megapixel IP cameras (Hikvision®, China) and a Hikvision DS-7204HQHI-K1/E DVR system. The camera system allowed for continuous recording at a resolution of 1 920 × 1 080. The average video bitrate was 680 kb/s, and the frame rate was fixed at 15 frames per second. The video files were encoded using H265 compression. All video data processing and analysis were performed on a Dell computer with an Intel(R) Core(TM) i7 processor (2.70 GHz). The machine was equipped with an NVIDIA Quadro T2000 graphics processing unit, with 4 GB of GDDR5 memory. The cuDNN 8.0 library and the CUDA toolkit 11.0 were installed. Video processing and analysis were conducted using Python 3.8.8, leveraging the Keras libraries integrated into Tensorflow 2.4.0. Frames were extracted from the video recordings and saved in jpg format. The region of interest within each frame

was cropped using either OpenCV 4.5.1 or FFmpeg 4.4, depending on the specific requirements of the analysis.

Development of an image classifier for the dry feeder

The dry feeders were stationary in all pens, eliminating the need to detect their locations prior to image analysis. To deploy a custom image-classifying neural network to assess eating piglets, a deep learning dataset comprising 400 images was created, using a 75/25 split for training and evaluation. These images, extracted as frames from a subset of the extensive video dataset, were cropped around the dry feeders and sized at 370 × 190 pixels. Specialists manually reviewed these images to annotate if piglets were eating. This labelling task proved challenging, particularly due to the presence of non-nutritive behaviours common in newly weaned piglets. Examples of this behaviour are exploration, hesitation to eat, head lifting, aggression, and piglets entering the feeding zone backwards. Special attention was paid to excluding these non-nutritional feeder visits, and frames were labelled to specifically indicate the number of animals eating. Piglets were considered to be eating when their head and neck extended beyond the edge of the feeder, reaching up to the shoulders, with the head directed downward and the shoulder blades visible. The presence of the front legs inside the feeder was acceptable; however, if the hind legs were also inside the feeder, this behaviour was labelled as a non-nutritional visit. The classification included four classes: 'zero', 'one', 'two', and 'three'. An example of each of the four classes (also referred to as class events) is given in [Fig. 1](#). Frames with zero eating piglets were categorised in class 0 ([Fig. 1a](#)) while class 1 ([Fig. 1b](#)), class 2 ([Fig. 1c](#)) and class 3 ([Fig. 1d](#)) represent one, two and three eating animals, respectively. In [Fig. 1a](#), one piglet is standing in the feeder with the hind legs while the other is too far away from the feeder. Similar non-nutritive visits are illustrated in [Fig. 1b](#) and [Fig. 1c](#) where piglets were not close enough in the feeder and/or lifting their head. In [Fig. 1d](#), a prime example is given where all three piglets are considered eating, with the head directed downward and the shoulder blades visible. Inspired by [Alameer et al. \(2020\)](#), the methodology employed a convolutional neural network as a feature extractor with the addition of custom fully connected dense layers and a prediction layer. ResNet50 without its prediction layer was selected as the base model for the neural network ([He et al., 2016](#)). Employing a pretrained network from 'ImageNet' and enhancing it via transfer learning was not feasible in this situation, so all layers were trained, including the base model, to achieve satisfactory performance on the initial validation set. A global average pooling layer and two dense layers (ReLU activation) were added between the base model and the custom 4-class prediction layer (softmax activation). Each dense layer consisted of 1 024 neurons and was followed by a dropout layer (rate 0.5) to mitigate overfitting, enhance generalisation and improve model performance. In addition to dropout, three techniques were employed to address potential issues of model specialisation and enhance its robustness. Firstly, early stopping callbacks were implemented, allowing for training termination when no significant improvements were observed on the evaluation dataset. Secondly, to increase the diversity and richness of the dataset and enable the neural network to learn robust representations across various variations and conditions, the existing data variability resulting from the 24 slightly different camera viewpoints was artificially augmented. This involved creating copies of the images with slight rotations, varying zoom levels, flipping, and random minor adjustments to contrast. Thirdly, even though frames were collected with a minimum 10-second time interval between them, the imagehash library ([Buchner, 2021](#)) was necessary to detect and discard nearly identical frames, that added no value and could introduce bias. This was especially useful

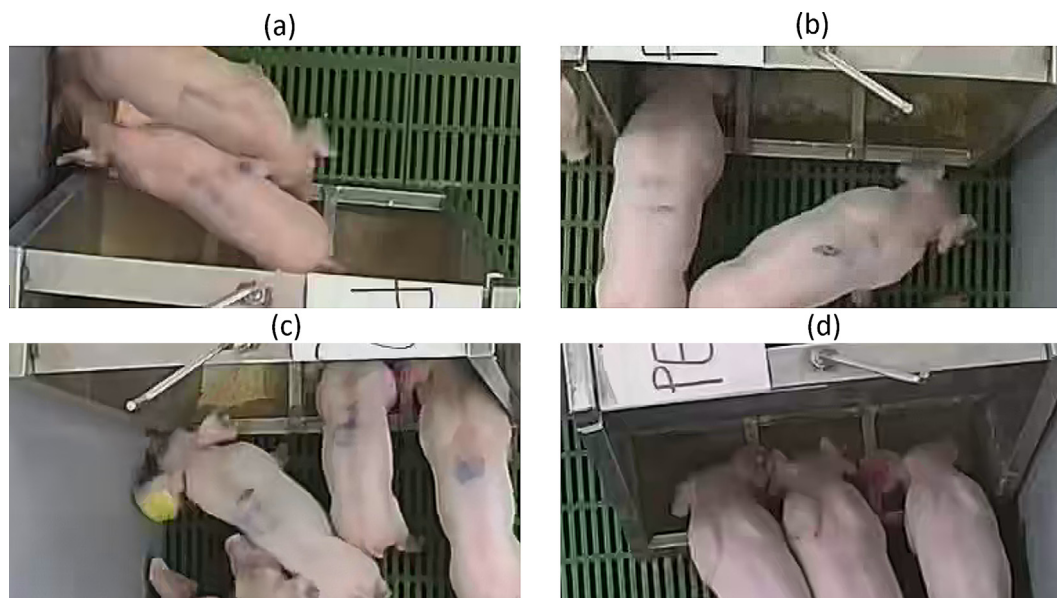


Fig. 1. Example frames illustrating the four classes (0–3) at the three-space dry feeder: (a) class 0 (no piglets eating), (b) class 1 (one piglet eating), (c) class 2 (two piglets eating), and (d) class 3 (three piglets eating).

during periods of minimal activity in the feeding zone. This approach improved annotation efficiency, reduced required training time, and optimised data storage. During the training phase, the Adam optimiser and the sparse categorical cross-entropy loss function were employed, with a learning rate of 10^{-4} and a batch size of 32. A more detailed description of the code can be found in [Supplementary Material S1](#). The trained model proved beneficial in expanding the balanced dataset by extracting additional frames from other sections of the video footage. Frames misclassified by the model were manually relabelled with the correct class, thereby enhancing the dataset with new information. This process of iterative refinement of the dataset through active learning was repeated three more times. As the dataset grew, an additional subset called the test set was created with unseen frames and throughout the development process, a strict separation of the train, test, and validation sets was maintained. The fourth generation dataset consisted of 8 000 images, with a train-, test- and validation ratio of 70/15/15. The fraction of frames used to construct the deep learning dataset from the entire video footage was less than 60 parts per million.

Development of an image classifier for the creep feeder

Similar to the dry feeder, an image dataset was created to train a custom convolutional neural network model to analyse feeding behaviour for creep feed applied in a yellow and round-shaped feeder. Due to potential feeder displacement during manual weighing, the location of the feeder had to be accurately determined before cropping the image. Given the consistent light scheme and intensity during this experiment, colour intensity thresholding, edge detection and circle detection could be used to precisely identify the creep feeder's position. The algorithm first transformed the image from the blue–green–red colour space to hue–saturation–values using the `cvtColor` method from OpenCV, aiding in distinguishing the creep feeder's yellow hue. This was achieved by thresholding with the `inRange` method from OpenCV where only pixels in the hue–saturation–value range of [15, 125, 100] to [30, 225, 255] were kept, excluding irrelevant colours. The algorithm then employed OpenCV's Canny edge detection algorithm to accurately outline the yellow creep feeder's contours. Subsequently, the

HoughCircles method detected circular shapes. To ensure realistic detection, only circles within a predefined radius range, specific to our settings, were considered. These techniques (i.e., colour thresholding, edge detection, and circle detection) effectively located the feeders in video frames. To develop and employ a new neural network for assessing eating piglets at the creep feeder, video frames were specifically cropped to a size of 400×400 pixels around the feeder's identified location. Adequate resizing and pre-processing were applied before input into the network. This model's development paralleled the approach used for the dry feeder model, with one important difference: six prediction classes, instead of four, to account for up to five piglets eating simultaneously at the creep feeder. Piglets were considered eating when their head and neck extended beyond the edge of the creep feeder, with the head directed downward and the shoulder blades visible. An example of each of the six classes is given in [Fig. 2](#). In [Fig. 2b](#), one piglet is turning its head away from the feeder and is considered as non-eating. Situations in which piglets are close to the feeder but in the opposite direction are useful for the model to learn non-nutritive visits. For example, in [Fig. 2c](#), a tail could be observed instead of the neck or shoulders. A piglet's snout becomes visible after the animal lifts its head in [Fig. 2e](#). In [Fig. 2f](#), one piglet enters the feeding zone but it is hindered to get close enough. Another piglet (upper-left in [Fig. 2f](#)) can be considered uncertain based on the distance between the neck and the feeder. However, it was annotated as eating, which means [Fig. 2f](#) is an example of five eating animals (also referred to as a class 5 event). The final dataset for this model comprised 12 468 images with a 70:15:15 split for training, validation, and testing.

Development of an aggression detector

To estimate aggression at the pen level, a motion detector was developed, inspired by [Costa et al. \(2014\)](#), which employed pixel intensity thresholding to generate an activity profile based on the movement of pigs. In our study, the motion detector was specifically tuned to highlight events where animals rapidly accelerated in various directions, a behaviour typical of piglets establishing a new social hierarchy. This development comprised two steps. Initially, a preliminary motion detector was developed using

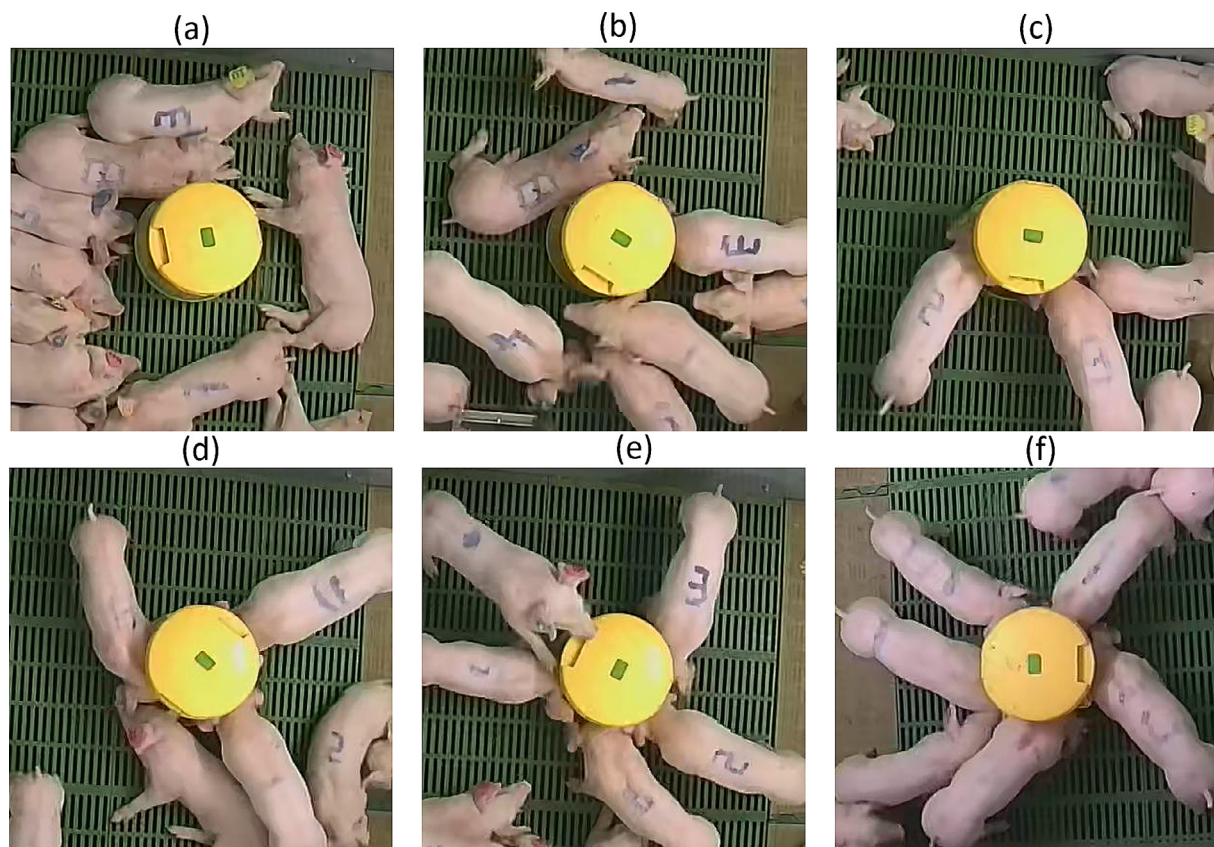


Fig. 2. Example frames illustrating the six classes (0–5) at the yellow creep feeder: (a) class 0 (no piglets eating), (b) class 1 (one piglet eating), (c) class 2 (two piglets eating), (d) class 3 (three piglets eating), (e) class 4 (four piglets eating), and (f) class 5 (five piglets eating).

image blurring and thresholding techniques. The function parameters were empirically determined using a 60-second video clip of sleeping piglets becoming active. This clip was chosen because it captured the transition from inactivity to motion. The red–green–blue colour values of pixels in consecutive frames were averaged to create a motion blur effect, which later helped to highlight significant movements in the video. This operation was efficiently executed using FFmpeg's filter complex (crop, tmix = 2), leveraging the utilisation of the graphics processing unit (h264_nvenc) for enhanced processing speed. The OpenCV library was utilised to process each frame by converting it to grayscale and applying a Gaussian blur filter (27×27 pixels). The intensity of each pixel in the current frame was then subtracted from its counterpart in the previous frame, creating a matrix representing temporal changes. Applying OpenCV's threshold function with parameters (17, 255, THRESH_BINARY), pixels were classified based on their intensity change: values within the range of 17–255 were considered as significant changes and corresponding pixels were set to 255. Pixels that changed less were set to zero. Finally, OpenCV's findContours function, with parameters (RETR_TREE and CHAIN_APPROX_SIMPLE), identified outlines of regions with movements. Outlines exceeding a length of 2 200 pixels were selected, forming connected enclosed areas filled using the drawContours function set to 'Filled'. This approach designated both the outlines and the pixels within as changed. Subsequently, the countNonZero function quantified the number of changed pixels. Applied to consecutive video frames, this process generated a time series with the number of changed pixels representing activities ranging from occasional movements during resting periods to intense and long-lasting aggression. Therefore, in the second step,

it was essential to eliminate low-intensity activities, such as rapid head movements during play (e.g., when interacting with the metal chain) or random explorations, characterised by a minimal number of changed pixels. Additionally, interference, such as video flickering and false detections like insect movements or human activity, needed to be excluded from this activity profile. Rarely observed, very intensive play behaviour, where all 12 piglets were chasing, jumping, and spinning around the pen without showing aggression, is assumed to produce a high activity profile comparable to flies on the lens or video flickering, and would therefore be filtered out. To avoid arbitrary definitions of noise and threshold values, a grid search method was implemented. This approach involved systematically exploring a range of parameter values to pinpoint the optimal settings. Optimal parameters maximised the correlation between the total duration of aggression in the isolated segments and the pen means of skin lesion scores on shoulders and flanks (Van Kerschaver et al., 2023b). A threshold range [T1, T2] was set for the number of changed pixels. Values below T1 were likely due to very low or random activity, while values exceeding T2 are attributed to extreme activity, such as human interventions, or high-intensity interference like video flickering. Next, a moving average filter with a defined window size (W) was used to smooth the data and minimise fluctuations. A threshold value (T3) was established on the smoothed data to identify the minimum intensity necessary to categorise a movement as potentially aggressive. Movements below this threshold were deemed non-aggressive or unrelated to fights. A minimum interval (I) was set between two separate fights. Any aggression occurring within this interval was regarded as part of the same fight sequence. In the final step, a minimum duration (D) was established for a series of fast move-

ments exceeding the minimum intensity threshold. Only series meeting this duration criterion were ultimately classified as aggressive. After analysing the first 48 h of video footage with the aggression detector, the parameters yielding the highest Pearson correlation between the log of total detected aggression during this period and the mean skin lesion scores in the pens 48 h post-weaning were identified. These parameters were T1 = 10 000, T2 = 6 100, W = 149 frames (equivalent to 10 s), T3 = 1 400, I = 63 frames (or 4 s), and D = 135 frames (9 s).

Model validation

To validate the image classification models, the F1 score, recall, and precision for each class in the respective validation sets were calculated, and the mean values of these metrics were used to select the best-performing models for both feeder types. The mean F1 score, mean recall, and mean precision were also calculated for the respective test sets to determine the performance of the selected models. These values are reported in the Results section. The number of images classified as true positive (**TP**), false positive (**FP**) and false negative (**FN**) were used in the equations given by:

$$\text{Precision} = \frac{TP}{(TP + FP)}$$

$$\text{Recall} = \frac{TP}{(TP + FN)}$$

$$\text{F1score} = \frac{2 \times TP}{(2 \times TP + FP + FN)}$$

To evaluate the aggression detector, a test video was compiled from 26 randomly selected instances of fighting piglets from the complete video dataset, representing all 24 pens. This test compilation included various behaviours such as eating, sleeping, and foraging, in addition to the fighting sequences. The exact timings of the fights were annotated by a specialist. Aggressive behaviour was annotated as events involving mutual fighting or unilateral aggression that escalated into spinning movements, collisions, and prolonged interactions between piglets. This yielded a nearly equal distribution of aggressive and non-aggressive behaviours. The test compilation was then analysed by the aggression detector, and the algorithm-detected fight durations were compared against the indicated fighting timings. To determine the algorithm's effectiveness, precision and recall were calculated. The Intersection over Union (**IoU**) was computed as the ratio of the intersection of frames detected as aggressive to the union of detected and indicated aggressive frames.

$$\text{IoU} = \frac{TP}{(FP + TP + FN)}$$

Data analysis

For each pen, the total time spent eating per day at the respective feeders was recorded and used as the independent variable to compare with the respective weighed feed intake in a simple linear regression model. Additionally, a multiple linear regression model was developed incorporating the time spent eating grouped by class to test whether class-level data further improved the feed intake prediction and to investigate whether the feed intake rate per animal depended on the occupancy rate of the feeder. Both simple and multiple linear regression were conducted using the statsmodels library (version 0.14.0) in Python.

Additional calculations were performed on the data from the image classification models and the aggression detector. The mean fight duration was computed, and the feed intake rate was deter-

mined by calculating the ratio of the actual weighed feed intake to the observed feed intake behaviour. In determining the relative class distribution, the percentage of each class was calculated based on the total number of animal-seconds spent eating. Continuous cumulative time spent eating was calculated for each pen during the first 3 days postweaning. Pearson correlations between the mean time spent eating within a centred 6-h rolling window and cumulative feed intake (**CFI**) for various periods were calculated to evaluate the association of early feed intake behaviour and long-term feed intake.

To assess the effect of the treatments on parameters related to total feed intake, weaner feed intake and aggressive behaviour, an ANOVA was conducted by a generalised linear model in R version 4.3.1 (R Core Team, 2023) using the 'lme4' package (version 1.1.34) (Bates et al., 2015). In this model, responses were measured with the pen as a statistical unit. Housing and feed familiarity, along with their potential interactions, were included as fixed factors, while batch was considered as the random factor. All parameters related to creep feed intake were analysed using a generalised linear model with housing as the fixed factor and batch as the random factor. A robust test of equality of means using a Welch's test and the non-parametric Kruskal-Wallis test was applied (R Core Team, 2023) when homoscedasticity and normality assumptions were not fulfilled. To evaluate the impact of the day on feed intake rate and relative class distribution, a non-parametric Friedman test was conducted (R Core Team, 2023). To account for the paired nature of the data by pen, a Nemenyi post-hoc test ('PMCMRplus' package version 1.9.7) (Pohlert, 2023) was conducted for multiple comparisons following the Friedman test. Data normality was assessed using the Shapiro-Wilk test, while homoscedasticity was evaluated with Levene's test ('rstatix' package version 0.7.2) (Kassambara, 2023). A more detailed description of the code can be found in [Supplementary Material S2](#). Statistical differences were considered significant at a *P*-value of less than 0.05. To investigate potential periodic patterns in the data, an autocorrelation analysis was initially performed using the acf function of Statsmodels (version 0.14.0) in Python. Subsequently, a periodic model was fitted to the data using the SciPy library (version 1.10.1).

Results

Evaluation of the computer vision models for feeding behaviour

The performance of both feed intake models on their respective test sets is shown in [Supplementary Fig. S1](#). The model for animals at the dry feeder achieved a mean F1 score, recall, and precision of 93%, while the model for the creep feeder reached 91% for each metric.

The relationship between feed intake behaviour (i.e. time spent eating) and the actual feed intake, as measured by daily manual weighing of the remaining feed, at both feeders is presented in [Fig. 3](#). The differing slopes indicate distinct feed intake rates, averaging 20 mg/s at the dry feeder and 31 mg/s at the creep feeder. The adjusted *R*² values for weaner feed intake and creep feed intake are 0.92 and 0.70, respectively. Multiple linear regression with class-level information did not substantially improve *R*² values compared to the simple linear regressions. The slightly higher Akaike's Information Criterion and Bayesian Information Criterion values observed in the multiple linear regression models ([Supplementary Table S2](#)) indicate that including class-specific feeding behaviour did not necessarily improve predictive performance compared to using total feeding behaviour, despite the increased complexity. Furthermore, isolating the effect of each class would be challenging due to multicollinearity ([Supplementary Table S3](#)).

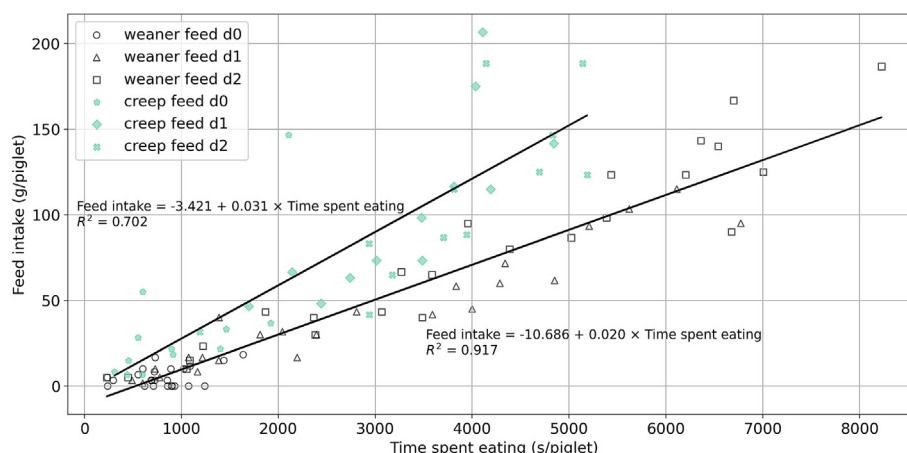


Fig. 3. Simple linear regression assessing the relationship between daily weighed feed intake and daily time spent eating. Data were collected at the pen level ($n = 24$) but are expressed per piglet.

Daily changes in feed intake rates during the early postweaning period were investigated. No differences were found between d0 ($33.4 \text{ mg/s} \pm 7.2$), d1 ($29.7 \text{ mg/s} \pm 2.6$) and d2 ($27.4 \text{ mg/s} \pm 2.3$) for creep feed intake rates or total feed intake rates (d0 = $13.3 \text{ mg/s} \pm 3.0$, d1 = $20.2 \text{ mg/s} \pm 1.6$, d2 = 22.1 ± 1.2). However, the weaner feed intake rate increased significantly from $7.0 \text{ mg/s} \pm 1.4$ on d0 to $18.1 \text{ mg/s} \pm 0.9$ on d2 (Nemenyi $P = 0.038$, following a Friedman test). (On d1, the weaner feed intake rate was $13.5 \text{ mg/s} \pm 1.1$).

The effect of preweaning socialisation and feed familiarity on feeding behaviour

One day before weaning, the mean BW of the piglets was $5.60 \pm 0.05 \text{ kg}$, disregarding treatment. By day 14 postweaning, this increased to $7.15 \pm 0.06 \text{ kg}$. An average daily gain of $102 \pm 3 \text{ g/day}$ was accompanied by an average daily feed intake of $161 \pm 4 \text{ g/day}$. More details and descriptive statistics for animal performance are presented in [Supplementary Table S4](#).

[Fig. 4](#) illustrates the daily progression of the relative class distribution at both feeders and the effect of preweaning socialisation on this distribution. At the dry feeder ([Fig. 4a](#)), a significant decrease in class 1 events and an increase in classes two and three events was observed from d0 to d1 ($P = 0.002$). Although a consistent tendency is visible, preweaning housing conditions did not alter the class distribution postweaning. Regarding the class distribution at the creep feeder ([Fig. 4b](#)), a similar time effect was observed ($P = 0.012$). Additionally, in the first 24 h postweaning (d0), co-mingling increased the occurrence of class 4 (+5%) ($P = 0.039$) and class 5 (+1%) eating events ($P = 0.049$).

[Table 1](#) shows that the effect of feed familiarity on total daily feed intake (weaner diet and creep feed) was significant across all 3 days, while a difference in total daily time spent eating between CREEP and NO-CREEP occurred only on d0 postweaning. Access to familiar creep feed postweaning increased the total feed intake rate on d0 and d2 postweaning and tended to increase this rate on d1. Since there was no effect on the weaner feed intake rate, the observed effect on total feed intake rate was due to the higher intake rate of creep feed. Creep feed intake only tended to be higher in the CO group on d1 while the time spent eating creep feed was stimulated by preweaning co-mingling on d0 and d1 postweaning. Correspondingly, both total feed intake and total time spent eating on d1 were positively influenced by preweaning

socialisation. In contrast, no effects were observed on weaner feed intake or time spent at the dry feeder. Co-mingling did not affect the intake rates of creep feed, weaner feed, or total feed. Data in [Table 1](#) are expressed per piglet, based on a consistent number of 12 piglets per pen. However, data were collected at the pen level.

The mean time spent eating was then analysed using a centred 6-h rolling window, measured in seconds per second per animal, representing the average percentage of time a piglet spends eating during that interval ([Fig. 5a](#)). The results revealed diurnal peaks in the eating behaviour of weaned piglets. The initially low feed intake behaviour reached a notable first peak ($2 \pm 0.5\%$) around 1800 h, 5 h postweaning. This increased to about $6 \pm 2\%$ by the next day, with notable group variations during h12–24 postweaning. Groups with creep feed supplementation spent more time eating during this phase. By 53 h postweaning, mean time spent eating stabilised at around $9 \pm 1\%$. Nighttime feeding behaviour gradually increased from negligible to $4 \pm 1\%$ by the third night. [Fig. 5b](#) shows the cumulative time spent eating. At 4.5 h postweaning, 30% of the pens reached a cumulative time spent eating of 5 min per piglet, while 85% of all pens reached this threshold by 8 h postweaning. The curve is consistently low during h0–18 postweaning for all treatment groups. After this period, the curves diverged until 48 h postweaning, to subsequently tend to progress in parallel. After 3 days, the cumulative time spent eating was the highest for the CO-CREEP group ($227 \text{ min} \pm 6 \text{ min}$), while the CON-NO-CREEP group recorded the lowest ($171 \text{ min} \pm 12 \text{ min}$). Intermediate groups averaged around $192 \text{ min} \pm 13 \text{ min}$. In [Supplementary Fig. S2](#), more detailed information is provided by zooming in on the first 12 h of the cumulative time spent eating curve.

[Fig. 6](#) presents the progression of Pearson correlation coefficients and the associated P -values, evaluating the relationship between mean time spent eating and feed intake over progressively extending periods. A peak correlation ($r = 0.80$) was noted around 18 h postweaning, highlighting the relationship between feed intake behaviour and the cumulative feed intake during d0–1 postweaning (CFI d0–1). The correlation coefficient maintained statistical significance from approximately 12–27 h postweaning. Correlation coefficients were also determined for extended periods of observations where no behavioural monitoring was executed (i.e. d0–4 until d0–14). While there was a gradual decrease in Pearson's r from CFI d0–1 to CFI d0–14, these correlations that peaked around 18 h postweaning remained significant, albeit over a progressively shorter time window. Beyond this period, a general

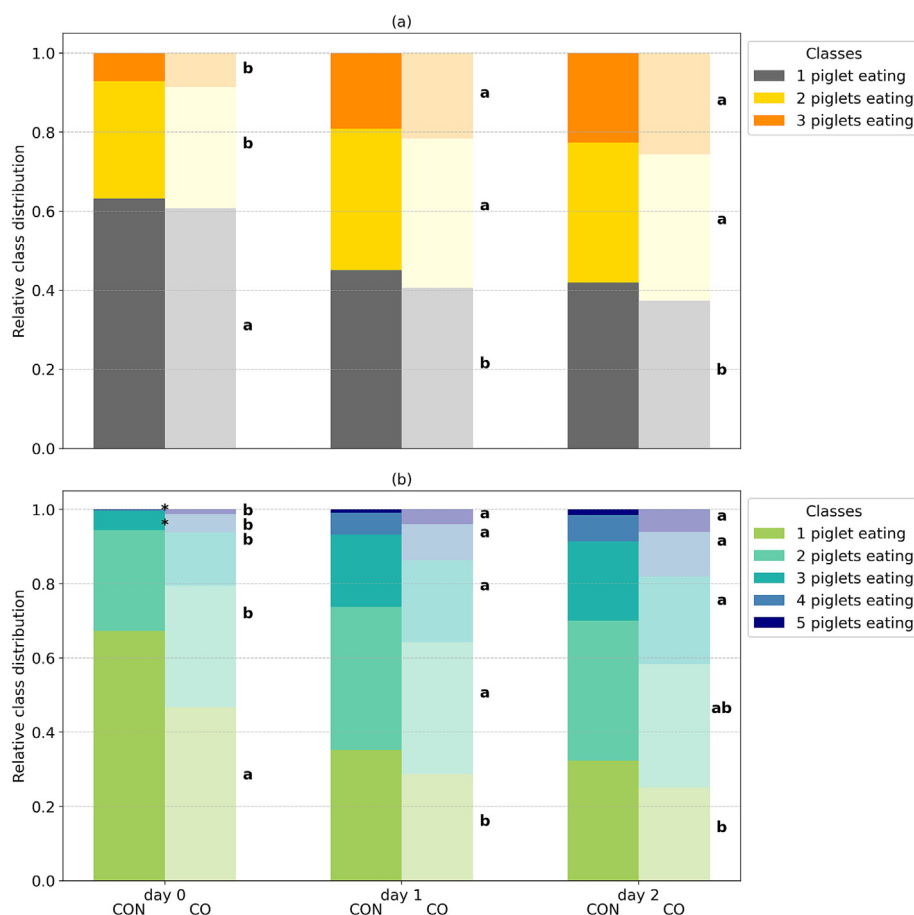


Fig. 4. The relative class distribution for piglets eating weaner feed at the three-space dry feeder (a) and creep feed at the creep feeder (b) on days d0, d1 and d2 postweaning ($n = 6$ pens). * indicates a significant effect of preweaning socialisation (housing) within each class and each day postweaning. ^{a,b} indicate significant differences between days postweaning within each class, disregarding housing. Abbreviations: CON = conventional preweaning housing system; CO = co-mingling during the preweaning period.

downward trend in Pearson's r was observed, with the periods of significant correlation becoming more sporadic.

Estimation of periodic patterns in feeding behaviour

Analysing the time series data, a visual pattern of periodicity emerged in the mean number of feeding animals per pen ($n = 24$), with reduced feed intake behaviour around 1200 and 0000 h (Fig. 7). An autocorrelation analysis (Supplementary Fig. S3) of the time-series data was conducted to explore temporal dependencies and periodic patterns. Peaks in Pearson correlation coefficients at 12 and 24 h lags suggest the presence of a bi-harmonic circadian rhythm in the piglets' feeding behaviour. The mathematical model formulated to depict this observed behaviour is expressed as:

$$Y(t) = \alpha + \beta_0 \times t + \beta_1 \times \cos(2\pi \times f_{\text{circ}} \times t) + \beta_2 \times \cos(4\pi \times f_{\text{circ}} \times t)$$

Here, t denotes the time in hours postweaning, f_{circ} , set at $1/24$ cycles per hour, represents the primary circadian frequency, and the second harmonic is at a frequency of $1/12$ cycles per hour. A linear term, $\beta_0 \times t$, accounts for the overall increasing trend in feed intake. The model fitting yielded the following estimated parameter values: $\alpha = 0.92511$, $\beta_0 = 0.01254$, $\beta_1 = 0.18702$, and $\beta_2 = -0.29605$. The model's fit to the data was evaluated using the coefficient of determination, R^2 , which was 0.5773. Fig. 7 presents both the raw data and the model fit.

The effect of preweaning socialisation and feed familiarity on aggressive behaviour

The aggression detector achieved a precision of 0.96, recall of 0.71, and IoU of 0.69 on the test video. It underestimated the mean fight duration by 26% compared to the ground truth. These results are shown in Supplementary Fig. S4.

Table 2 summarises the effects of preweaning socialisation and feed familiarity on aggression parameters. The number of fights and the time spent fighting were measured at the pen level. Housing conditions preweaning influence both the number of fights and the time spent fighting on d0 and d1 postweaning. In the CON group, 2.63 fights per piglet, (about 32 fights per pen), were observed on d0, which is eightfold higher than in the CO group. In the CON group, fights totalled about 10 min per pen (or 52 s per piglet) on d0, compared to a mean of 6 s per piglet in the CO group. Similar differences between these two groups were observed on d1 postweaning. Both the number of fights and the duration of fighting increased four-fold in the CON group compared to the CO group. Notably, the mean fight duration differed between groups on d2 postweaning, with the CON group having shorter fights (13 ± 0.6 s) than the CO group (16 ± 0.8 s). Feed familiarity had no effect on aggression-related parameters from d0 to d2 postweaning.

As shown in Fig. 8a, the CON-CREEP and CON-NO-CREEP groups exhibited similar patterns in the number of fights across 6-h intervals, with substantially higher counts compared to both the CO-

Table 1

The effect of preweaning socialisation, feed familiarity and their interaction on feed intake, time spent eating and feed intake rate of piglets (n = 6 pens).

		Prewaning socialisation		Feed familiarity			Prewaning socialisation	Feed familiarity	Interaction
	Day	CON	CO	CREEP	NO-CREEP	SEM	P-value	P-value	P-value
Daily feed intake (g/animal) ³									
Weaner feed	d0 ¹	5	5	7	4	1	0.767	0.058	–
	d1	39	46	19	66	7	0.450	0.000	0.069
	d2	73	80	41	113	11	0.685	0.000	0.637
Creep feed	d0 ¹	23	43	–	–	11	0.470	–	–
	d1 ¹	79	125	–	–	15	0.055	–	–
	d2 ²	94	119	–	–	15	0.426	–	–
Total	d0 ¹	17	27	40	4	7	0.861	0.000	–
	d1	78	108	121	66	9	0.048	0.001	0.725
	d2	121	140	148	113	9	0.212	0.033	0.763
Daily time spent eating (s/animal) ³									
Weaner feed	d0	849	790	758	881	69	0.691	0.405	0.844
	d1	2662	3064	1474	4251	393	0.456	0.000	0.126
	d2	3982	4014	2279	5717	479	0.962	0.000	0.853
Creep feed	d0	618	1323	–	–	176	0.019	–	–
	d1	2678	3986	–	–	271	0.007	–	–
	d2	3627	3990	–	–	331	0.597	–	–
Total	d0	1158	1452	1729	881	144	0.202	0.001	0.163
	d1	4001	5057	4806	4251	255	0.038	0.256	0.692
	d2	5795	6009	6088	5717	258	0.697	0.501	0.574
Feed intake rate (mg/s)									
Weaner feed	d0	7	7	10	4	1	0.971	0.133	0.569
	d1	14	13	12	15	1	0.640	0.285	0.363
	d2	17	19	17	20	1	0.378	0.275	0.848
Creep feed	d0	38	29	–	–	7	0.493	–	–
	d1	28	31	–	–	3	0.590	–	–
	d2 ²	26	28	–	–	2	0.681	–	–
Total	d0 ¹	14	13	23	4	3	0.818	0.000	–
	d1	19	21	25	15	2	0.515	0.067	0.830
	d2 ²	21	23	25	20	1	0.424	0.028	–

Abbreviations: CON = conventional preweaning housing system; CO = co-mingling during the preweaning period; CREEP = provided with additional creep feed postweaning; NO-CREEP = no additional creep feed provided postweaning.

¹ Effect of preweaning socialization and feed familiarity were evaluated separately using a Kruskal-Wallis test due to non-normal data distribution.

² Effect of preweaning socialization and feed familiarity were evaluated separately using Welch's test due to heteroscedasticity.

³ Daily feed intake and daily time spent eating were measured at the pen level but are expressed per piglet.

CREEP and CO-NO-CREEP groups, which showed consistently low and nearly identical fight frequencies. Approximately 48 h postweaning, all four curves intersect and subsequently level off. Fig. 8b demonstrates the cumulative number of fights over the postweaning period, highlighting the contrast in aggression levels between piglets from the two distinct preweaning housing conditions. By the end of the observation period, the total number of fights in the CON group was three-fold higher than in the CO group.

No significant correlations between time spent eating and fighting within each day were found. Detailed data on the association between aggressive behaviour and nutritional parameters are presented as a correlation matrix in Supplementary Fig. S5.

Discussion

Piglets develop a bi-harmonic circadian feeding pattern and group feeding behaviour

A daily feeding pattern in weaned piglets has been identified as a bi-harmonic circadian pattern. The observed peaks in time spent eating were approximately at 0600 and 1800 h. Continuous artificial lighting was available until 72 h postweaning, suggesting that ambient light was not the main factor enforcing a circadian rhythm in feeding behaviour. Our observations align partially with the findings of Besteiro et al. (2021), who monitored the general activ-

ity of weaned piglets using passive IR sensors in environments lit by natural light. Although these authors observed two or more peaks of daily activity in different rounds and on various days, the model that best described their data depicted a circadian pattern with only one daily activity peak around 1200 h. The wavelet analysis conducted by Besteiro et al. (2021) demonstrated that more than two harmonics may be present. In contrast, our autocorrelation analysis detected no more than two periodic patterns. Consequently, there is likely further scope to refine and improve the current model. The longer-term observations of Besteiro et al. (2021) were conducted at barn level with twice the piglet density of this study and did not involve feeding activity. De Haer and Merks (1992) observed a bimodal circadian rhythm in grower-finisher pigs reared under limited natural light conditions and fed through automated feeding stations. These authors observed peaks in feed intake and time spent eating at approximately 1100 and 1600 h. The proportion of time that piglets spent eating alone decreased from d0 to d1, while the proportion of time with multiple piglets eating together at the feeder increased correspondingly. This pattern of group behaviour, which seems to develop throughout the weaning period, may be partially explained by piglets learning from each other how to locate potential feeding sites, as suggested by Nicol and Pope (1994) and Oostindjer et al. (2014). Additionally, Nielsen et al. (1996) found that when groups of pigs had access to multispace feeders, the pigs

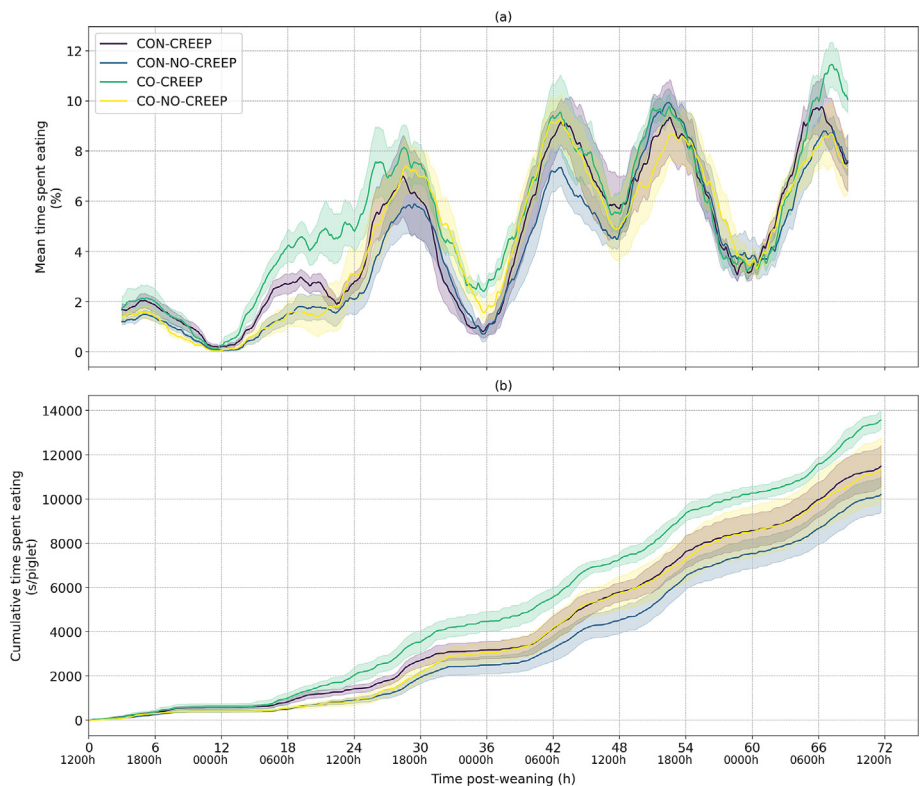


Fig. 5. The effect of preweaning socialisation and feed familiarity on piglet feed intake behaviour during the first 72 h postweaning (n = 6 pens). Data were smoothed using a centred rolling average with a 6-h time window. Treatment means are plotted with their SE bands. (a) Mean time spent eating, expressed in s/s per piglet, equivalent to the proportion of time spent eating. (b) Cumulative time spent eating, expressed in seconds per piglet. Abbreviations: CON = conventional preweaning housing system; CO = co-mingling during the preweaning period; CREEP = additional creep feed provided postweaning; NO-CREEP = no additional creep feed provided postweaning.

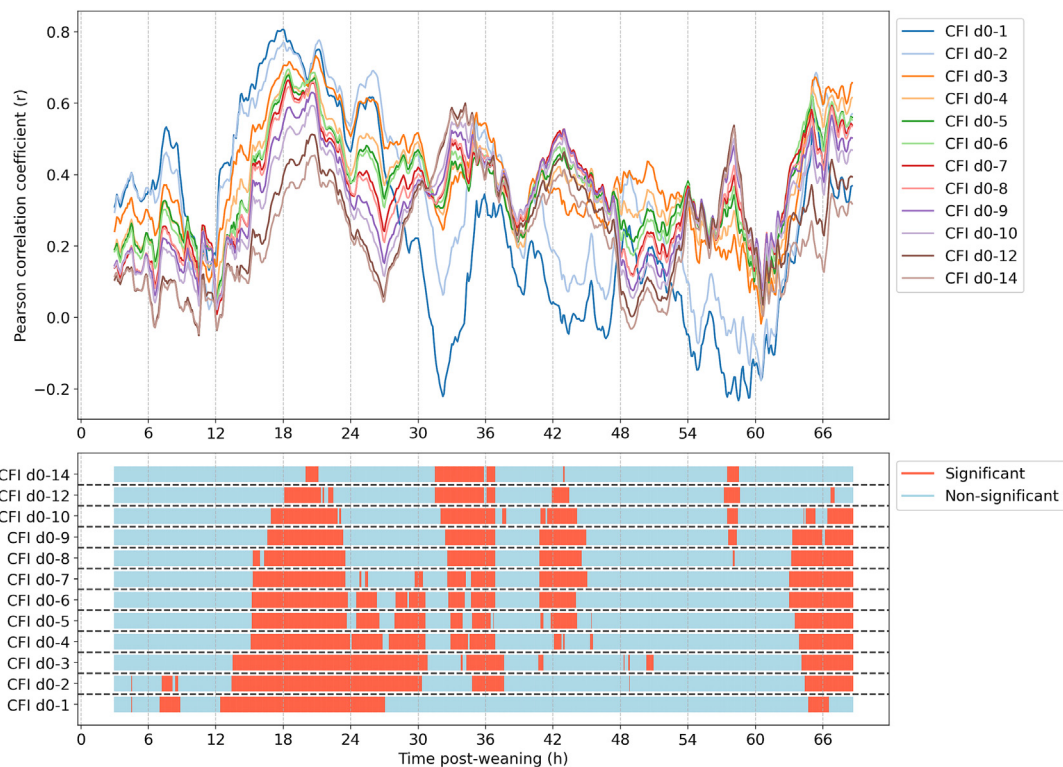


Fig. 6. Progression of Pearson correlation coefficients (r) between mean time piglets spent eating (measured at the pen level during the first 72 h postweaning) and their cumulative feed intake over increasing postweaning periods (from days 0–1 to 0–14) (n = 24 pens). Corresponding P-values are shown in the adjacent plot, indicating the significance of the correlations over time. $P < 0.05$ is shown in red, while $P \geq 0.05$ is shown in blue. Abbreviation: CFI = cumulative feed intake (weaner feed and creep feed, if supplied).

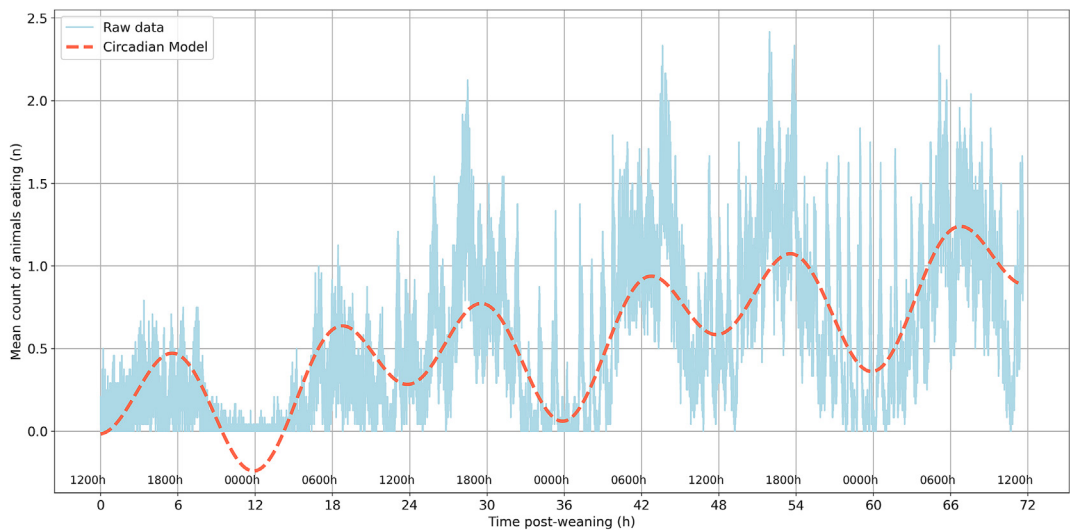


Fig. 7. Time series plot illustrating the mean number of piglets feeding per pen (n = 24), without distinction of feeder type over the first 72 h postweaning. The raw data are represented in blue, while the fitted trended two-harmonic circadian model is displayed in red.

Table 2
The effect of preweaning socialisation, feed familiarity and their interaction on number of fights, time spent fighting and mean fight duration of piglets during the first 3 days postweaning (n = 6 pens).

	Prewearing socialisation		Feed familiarity			P-value		
Item	CON	CO	CREEP	NO-CREEP	SEM	Prewearing socialisation	Feed familiarity	Interaction
Number of fights per piglet (n) ¹								
d0 ²	2.63	0.33	1.56	1.40	0.38	0.000	0.451	–
d1 ³	1.54	0.44	0.83	1.16	0.22	0.016	0.731	–
d2	0.85e	0.84	0.85	0.85	0.09	0.945	1.000	0.763
Daily time spent fighting per piglet (s) ⁴								
d0 ⁵	52.25	5.71	31.75	26.21	7.80	0.000	0.686	–
d1 ⁶	27.68	6.78e	13.49	20.97	4.14	0.013	0.381	–
d2	11.94a	13.85	13.18	12.62	1.62	0.580	0.871	0.574
Mean fight duration (s/n)								
d0	19.53	15.25	17.03	17.75	0.90	0.011	0.645	0.201
d1	17.02	14.62	14.97	16.67	0.82	0.144	0.295	0.830
d2	13.03	15.96	14.71	14.28	0.61	0.015	0.702	0.934

Abbreviations: CON = conventional preweaning housing system; CO = co-mingling during the preweaning period; CREEP = additional creep feed provided postweaning; NO-CREEP = no additional creep feed provided postweaning; d0 = first 24 h after weaning.

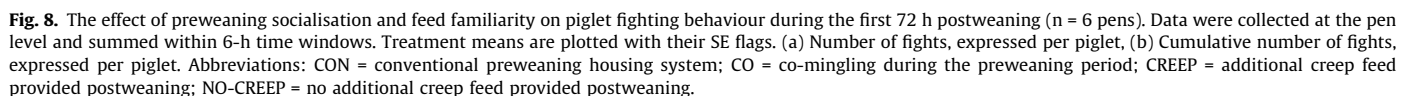
^{1,4} Number of fights and daily time spent fighting were measured at the pen level but are expressed per piglet.
^{2,5} Effects of preweaning socialisation and feed familiarity were evaluated separately using a Kruskal-Wallis test due to non-normal data distribution.
^{3,6} Effects of preweaning socialisation and feed familiarity were evaluated separately using Welch's test due to heteroscedasticity.

demonstrated a distinct preference for feeding simultaneously and in proximity to other feeding pigs. This is in accordance with the findings of Hsia and Woodgush (1984). Group feeding behaviour at both the creep feeder and the dry feeder is more pronounced in co-mingled piglets than in those from the conventional housing system. However, this was only observed on d0 when four or five piglets were eating simultaneously at the creep feeder. An increased feeder space could possibly have contributed to this effect. However, the standard feeder for the weaner diet, which contained three feeder spaces for 12 piglets, is generally considered sufficient and unlikely to limit feed intake (Laitat et al., 2004; Mesarec et al., 2021). Since piglets can learn to eat solid feed from one another (Morgan et al., 2001), co-mingled piglets may have developed preweaning feeding partnerships, leading to familiar piglets spending more time eating together on the day of weaning (Li and Johnston, 2009). Alternatively, co-mingling may have

enhanced the piglets' social learning skills (Canario et al., 2017). It is possible that, in conventional housing, unstable social hierarchies triggered more agonistic interactions at the feeder, thereby discouraging group feeding. Additionally, the proportion of eaters and non-eaters may influence the apparent group feeding behaviour. In future research, advancing feed behaviour measurements from pen level to individual level will be crucial for gaining a deeper understanding of this relationship.

Computer vision-based estimation of piglet feed intake

Our approach enabled continuous monitoring of the piglets' feeding time. The daily time spent feeding aligns with findings by Cox and Cooper (2001) and Worobec et al. (1999). Moreover, these observations correlated well with the measured feed intake, with R2 values of 0.917 and 0.712 for the dry feeder and creep feed



ronmental constraints that influence feeding motivation. Additionally, piglets in larger groups have a strong preference to eat together at the same time and place, which can override their individual feeding preferences. This collective behaviour leads to competition and alterations in feed intake rates (Nielsen, 1999).

During the first 3 days postweaning, the mean duration of individual fights was consistent with the findings of [Li and Johnston \(2009\)](#) and [Mei et al. \(2016\)](#), suggesting that, despite limitations in distinguishing aggression from other intense behaviours like playing, the data likely reflect the overall frequency of fighting. Careful interpretation of our results is warranted, as fight durations in our test set were underestimated by 26%, due to difficulties in accurately identifying the precise start, end, and temporary interruptions of fights. Besides reducing aggression between piglets, co-mingling also increased feeding time at the creep feeder during d0 and d1, resulting in a significant rise in total feeding time and total feed intake on d1. However, the effect was not observed for the time spent at the dry feeder. These findings indicate that a more stable social hierarchy (through co-mingling) likely increases the intake of familiar feed resources (i.e. creep feed) but does not impact the exploration of novel feed resources (i.e. weaner diet). Feed palatability and digestibility may have contributed to this

effect. While Pluske and Williams (1996) found that mixing piglets at weaning increased feed intake, the current results better align with Bruininx et al. (2001) who argued that social hierarchy establishment might reduce initial intake. In some cases, it was observed that aggression is common during feeding (Hansen et al. 1982). However, McGlone (1986) suggested that fights are more about social hierarchy than competing for feed. Future improvements for the aggression detector to identify the exact location where a fight initiates, whether near the feeder or elsewhere, could provide clarity on this matter.

Temporal changes in early feed intake behaviour relate to intake on a longer term

Feeding behaviour on a given day was linked to feed intake on that same day. Interestingly, we observed changes in feed intake behaviour, i.e., a steeper increase in the time spent eating within the first 24 h postweaning, to correlate with the total amount of feed consumed over an extended period. This highlights the importance of early feed intake behaviour to cope with the weaning transition, especially as initial feed intake represents only a small fraction of the total intake over the first 2 weeks postweaning. Indeed, earlier studies have indicated that adequate early postweaning feed intake is pivotal in reducing the vulnerability to weaning-induced gut health issues (Pluske et al., 1997; Spreeuwenberg et al., 2001; Bruininx et al., 2002a). Similarly, Fabà et al. (2024) demonstrated that piglets with higher feed intake within the first 3 days postweaning exhibited faster feed consumption rates and increased feed intake later in the nursery phase. The use of the automated methodology as an indicator of early feed intake contributes to a more precise estimate of piglets' eating behaviour, and thus may reveal more precise findings on any relationship between pre- and postweaning feed intake.

Conclusion

Based on the computer vision analysis of animal behaviour, this experiment suggests that preweaning socialisation through early co-mingling likely reduced aggression and enhanced early feeding behaviour in weaned piglets, while feed familiarity also increased the time spent eating immediately after weaning. However, an increase in feeder space may also have contributed to this effect. The piglets developed group feeding behaviour following a circadian pattern, even under the continuous lighting conditions of this experiment. Finally, early feed intake behaviour in the immediate postweaning phase seemed to be crucial for promoting adequate feed intake throughout the entire weaning transition.

Supplementary material

Supplementary Material for this article (<https://doi.org/10.1016/j.animal.2025.101524>) can be found at the foot of the online page, in the Appendix section.

Ethics approval

This study was conducted at a commercial pig farm located in Bissegem (Belgium), in accordance with the EU Directive 2010/63/EU on the protection of animals used for scientific purposes and by the Belgian royal decree (KB29.05.13) on the use of animals for experimental studies. It was approved by the Ethics Committee for Animal Research of the Faculty of Veterinary Medicine and Bioscience Engineering of Ghent University, Belgium (Ethical Approval Code: 2020-028).

Data and model availability statement

Models were not deposited in an official repository but are available upon request.

Declaration of Generative AI and AI-assisted technologies in the writing process

During the preparation of this work the author(s) did not use any AI and AI-assisted technologies.

Author ORCIDs

T. Van De Putte: <https://orcid.org/0009-0006-8947-9960>.

C. Van Kerschaver: None.

M. Hostens: <https://orcid.org/0000-0001-5376-976X>.

J. Degroote: <https://orcid.org/0000-0002-8139-8799>.

CRediT authorship contribution statement

T. Van De Putte: Writing – original draft, Methodology, Formal analysis, Data curation. **C. Van Kerschaver:** Writing – review & editing, Methodology, Data curation. **M. Hostens:** Writing – review & editing, Methodology, Software. **J. Degroote:** Writing – review & editing, Supervision, Methodology, Formal analysis, Funding acquisition.

Declaration of interest

None.

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