Effects of journey duration and temperature during pre-slaughter transport on behaviour of cull sows in lairage

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ABSTRACT

This observational field study investigated the effects of journey duration, temperature, and waiting duration before unloading on the behaviour of 562 cull sows during lairage from 23 commercial loads. Each load consisted of sows originating from more than one herd, thus experiencing variable pre-slaughter transport and management. In lairage, sows were mixed in groups of 25, involving animals from all journey durations (min-max: 0.8–8.4 h) and video monitored for 60 min. At first most sows were in upright position (approximately 80% before unloading), decreasing to 30–40% after 30 min. After 60 min, 42% of the sows had initiated aggression (min-max: 0–43 events/sow), 28% had been subjected to aggressive behaviour (min-max: 0–14 events/sow), and 36% s were observed drinking (min-max: 0–16 events/sow). Several significant interactions were found between journey duration, the average temperature in the vehicle and lairage pen (averages: 4.3–26.2 °C) and waiting duration before unloading (min-max: 3–25 min). For example, after short journeys, sows exposed to higher temperature carried out more aggressive behaviour, while a higher temperature after long journeys was associated with more lying and less drinking. This suggests that the sows prioritised lying behaviour over drinking and establishing a dominance hierarchy. We discuss how the results may be interpreted as behavioural signs of fatigue, but further studies, for example involving quantification of physiological and motivational indicators, are needed to clarify this. Irrespective, the present findings suggest that a stay in a lairage pen, as part of the pre-slaughter logistic chain, involves challenges for the welfare of the cull sows.

1. Introduction

In commercial pig production an annual culling rate of around 50% is commonly practised (e.g., Danish Pig Research Centre, 2020). As mentioned by Herskin et al. (2021), international pig production has undergone structural changes during recent decades, leading to increased herd sizes and fewer, larger abattoirs, thereby increasing the required transport distances. As sow carcasses are often not accepted at modern abattoirs specialised in slaughtering finishers, this trend has had large effects on the pre-slaughter logistic chain of sows (Miranda-De La Lama et al., 2014). Depending on the geographical region, the logistics of transport of sows to slaughter may vary considerably. Recently, Blair and Lowe (2022) described the US cull sow marketing network as consisting of complicated journeys lasting several days. In Denmark, sows may also be transported directly from their farm of origin to an abattoir, or vehicles may pick up sows at several farms on the way to the abattoir as described by Thodberg et al. (2022). Across categories of swine, transport is recognised as a stressful event involving several hazards for animal welfare (EFSA AHAW Panel et al., 2022). Cull sows can in general be considered vulnerable to stress due to their clinical status, including on-farm findings of for example decubital shoulder ulcers, wounds, and udder lesions (Fogsgaard et al., 2018; Grandin, 2016; McGee et al., 2016). In addition to the deteriorated clinical condition, sows may be lactating, as it is not uncommon for farmers to ship sows very quickly after weaning (Fogsgaard et al., 2018; Thodberg et al., 2022). According to EFSA AHAW Panel et al. (2022) the upper threshold of the thermal comfort zone and the upper critical temperature of sows in late lactation were estimated to be 20 °C and 22 °C dry temperature, respectively. The clinical state of cull sows combined with the high sensitivity of sows to heat stress (EFSA AHAW Panel et al., 2022)
Panel et al., 2022) means that sows are probably more vulnerable to transport stress than other categories of swine (Peterson et al., 2017). However, not only factors related to the animals as such, but also factors related to the management of cull sows may challenge their welfare during transport. As part of the preparation for transport, sows are most often mixed with unfamiliar conspecifics. This may happen while the sows are waiting for pick-up at the farm of origin and again when loaded on to the vehicle (Herskin et al., 2020a; Herskin et al., 2020b). Sows tend to fight when mixed (Borberg and Hoy, 2009; Greenwood et al., 2014; Krauss and Hoy, 2011), the consequences of which may pose yet another risk to their welfare.

During the journey to the abattoir, according to EU Regulation (Council Regulation EC No 1/2005), pigs transported for <8 h are not required to have access to water. In Denmark, national legislation (Anonymous, 2020) specifies that cull sows cannot be transported >8 h, thus, they are always transported in vehicles where water is not accessible. For sows, access to water may also be limited during the hours before transport, as many of them are kept in so called ‘pick-up facilities’ before they leave the herd of origin, where water is often not supplied (Herskin et al., 2020a; Herskin et al., 2020b). Hence, for sows the pre-slaughter logistic chain may contain several possible stressors such as temperature changes, limited feed and water access, multiple allocations to novel surroundings and mixing with unfamiliar conspecifics. Thodberg et al. (2019) showed that when sows arrive at the abattoir, their clinical condition had deteriorated as compared to the on-farm situation. The results suggested that temperature in the vehicles, journey duration and waiting duration before unloading were among the risk factors for this deterioration - often in interaction.

When sows arrive at an abattoir, there may be some waiting time (Thodberg et al., 2022) after which they are unloaded into lairage pens, where they are kept until stunned and slaughtered. A lairage pen typically holds more sows than one vehicle compartment, which means that sows most often are mixed upon arrival to the abattoir. Sows in lairage pens have access to water and are fed if they stay for >12 h (Danish Veterinary and Food Administration., 2015). In general, letting pigs stay in lairage pens for a period before slaughter is used for several reasons, such as the opportunity to maintain a buffer for the slaughter capacity, but also to allow the pigs to calm down and rehydrate after transport (as discussed by Faucitano and Raj (2022)). Despite the possibility for pigs to recover from transport stress, the use of lairage has also been discussed as potentially stressful for finisher pigs (Warriss et al., 1994). The need to recover after transport has, however, been questioned in finisher pigs after removal of the stress-sensitive halothane gene (Aaslyng and Gade, 2001).

Recently, Browning and Veit (2020) described the process of slaughter as one of the biggest ethical issues in animal farming, husbandry and agriculture in general. Until now, the process and efficiency of stunning (Atkinson et al., 2020) have received the majority of the scientific attention, whereas far fewer studies have focused on lairage. So far the studies have focused only on finisher pigs from perspectives of meat quality (Costa et al., 2002), behaviour (Brown et al., 1999a, 1999b; Dalla Costa et al., 2016; Fraqueza et al., 1998) and welfare (as reviewed by Brandt and Aaslyng (2015)). For finisher pigs, it has been described how they show a high level of activity when entering lairage pens, including pigs seeking out water nipples (Brown et al., 1999a, 1999b). After arrival in the lairage pens, the proportion of finisher pigs lying increases gradually (Brown et al., 1999b). Finisher pigs show signs of aggression while in lairage, and the development over time has either been described as decreasing over time (Dalla Costa et al., 2016) or as an inverted U-shape (an initial increase followed by a later decrease) (Brown et al., 1999b; Fraqueza et al., 1998; Geverink et al., 1996). To our knowledge, this stage has not been described for sows, and no knowledge is available regarding potential ways to improve the current practice in terms of animal welfare for this category of pigs.

The present study was part of a project examining potential welfare challenges for cull sows in the pre-slaughter logistic chain. As an observational study, we examined whether factors related to the transport to the abattoir – temperature inside the vehicle and the lairage pen and journey duration – affected the behaviour of sows during the initial 60 min upon arrival in a lairage pen. The 1-h observation period was chosen based on the results of a pilot study (reported in a master thesis by Bonnerup (2020)) that involved observation of behaviour of cull sows during an overnight stay in lairage pens. The results suggested a considerable activity level, including drinking and aggression, during the first 1–2 h upon arrival with substantial individual variability among sows.

We hypothesised that within the legal 0–8 h interval for journeys in Denmark, increasing journey duration, increasing waiting duration before unloading and higher temperature would be associated with increased observations of lying and drinking in lairage.

2. Material and methods

2.1. Study design

This observational field study involved behavioural observations the first hour after entering the lairage pen of 562 sows from 23 commercial loads. From the transport company’s journey logs, we selected (as detailed below) 25 focal sows from each load to enter one lairage pen. The 25 sows originated, when possible, from five different herds in groups of five sows per herd. By originating from different herds,
different journey durations were represented. Due to practical reasons outside our control (less sows were sent to slaughter than indicated by the journey log), two loads included only 24 focal sows and one included 15, and for these loads, one or 10 non-focal sows from a different load was introduced into the lairage pen, respectively. The selection of sows was done before the day of data collection and involved no changes from normal practices. Planning of routes, the inclusion of sows from different herds, and the distribution of sows among compartments within the transport vehicles were managed by one anonymous Danish transport company and were outside our control. The sows were transported from their herd of origin to the abattoir according to normal practices. In order to achieve a full vehicle load, the vehicle stopped at more than one herd. Data were collected over two periods; a warmer period, July 20th–30th 2020 (13 loads) and a colder period, November 23th to December 1st 2020 (12 loads).

2.2. Herds and sows

The focal sows originated from a total of 85 herds located in Jutland, Denmark. All herds were specific-pathogen-free (SPF-status). Nine herds delivered sows twice. The median number of focal sows per herd within a load was five (min-max: warmer period 4–20, colder period 1–25 sows). When a load carried more than five sows from the same herd, the focal sows were selected by convenience sampling (Ersbøll and Bruun, 2004). In each of the herds, the staff selected the cull sows, and the staff and the livestock driver checked their fitness for transport according to Danish regulations (Danish Veterinary and Food Administration, 2018). The cull sows were housed and managed at varying conditions at the herds. In this study, we had no control nor any systematic recordings of housing and management prior to the pre-slaughter transport. However, as reported by Herskin et al. (2020b) the typical on-farm management of
cull sows in Denmark involves pre-transport mixing of unfamiliar sows e.g., from different sections in the herd, either in facilities in the herd or on the vehicle.

2.3. Vehicles and journeys

All vehicles used in the study were from the same company, approved for up to 8-h transport with sows and had full air suspension. All livestock drivers held certificates of competence according to Danish legislation (Anonymous, 2020). All vehicles had two decks and were either articulated lorries or a lorry without a trailer. The vehicles had ventilation panels in both sidewalls as required by Council Regulation (EC) No 1/2005. In addition, the vehicles were equipped with mechanical ventilations based on the drivers’ normal practice. All journeys were driven with deck heights of 130–140 cm. The number of compartments per vehicle as well as the number of sows per compartment could vary. This was not recorded systematically in this study, but the body weight of the sow is mainly supported by her hind quarters that are placed on the floor, while the front of the sow is elevated by stretched front legs.

Table 1

<table>
<thead>
<tr>
<th>Behaviour</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lying</td>
<td>Body weight not supported by legs. Can be in lateral, sternal or intermediate recumbency.</td>
</tr>
<tr>
<td>Upright</td>
<td>Body weight supported by all four legs. The sow could be walking or standing still.</td>
</tr>
<tr>
<td>Sitting</td>
<td>The body weight of the sow is mainly supported by her hind quarters that are placed on the floor, while the front of the sow is elevated by stretched front legs.</td>
</tr>
<tr>
<td>Unidentified</td>
<td>The behaviour cannot be identified as lying, upright or sitting.</td>
</tr>
<tr>
<td>Inter-sow aggression</td>
<td>Sow pushing/knocking her head against and/or biting directed at another sow.</td>
</tr>
<tr>
<td>Receiver</td>
<td>Sow is pushed/head-knocked and/or bit at by another sow.</td>
</tr>
<tr>
<td>Drinking</td>
<td>The sow has her snout inside the bowl with water nipples.</td>
</tr>
</tbody>
</table>

1 Behavioural states recorded by instantaneous scan sampling every 5 min.
2 Behavioural events recorded by all occurrences sampling.
3 A new bout was counted if min. 5 s passed since the last bout or if the sow changed (i.e., one in the pair of inter-sow aggression or the one with her snout inside the bowl).

2.5. Data collection

2.5.1. Journey data

Time of departure from the herd was retrieved from the vehicle’s journey log. Technicians standing ready at the abattoir noted the arrival time and the time of unloading of the first and last sow. At arrival, livestock drivers were asked whether they had any breaks during the journey (yes/no), their duration and whether the mechanical ventilation had been on or not during the journey. At the time of arrival, the degree of opening of the vehicle’s ventilation panels was recorded: closed, 1/3 open, 1/2 open, 2/3 open or completely open.

2.5.2. Temperature logging in vehicles and lairage pen

All temperature loggers used in the data collection were Tinytag plus 2 (Gemini Data Loggers Ltd., Chichester, UK). In the vehicles, two temperature loggers were mounted in steel shielding brackets approximately in the middle of the ceiling, one at the upper and one at the lower deck (height: 130–140 cm). Furthermore, a temperature logger was mounted underneath the vehicle’s left side in protection from sunlight. In the abattoir two temperature loggers were mounted approximately 200 cm above the lairage pen (Fig. 2). Temperature was logged every five minutes at a resolution of 0.01 °C. All loggers were calibrated with a Testo 0613 1212 sensor connected to a 925 thermometer (Testo North America, West Chester, US).

2.5.3. Behavioural observations

After unloading, the focal sows were individually spray marked with an individual number on the back and on each side and led through the building and into the lairage pen. Sows were scored as lactating if the mammary glands were engorged or not lactating if that was not the case. The behaviour of the 25 sows was recorded during the first hour, starting when the lairage pen gate was closed behind the last sow (from now on referred to as ‘after unloading’). Instantaneous scan sampling every 5 min (i.e., 12 times during the observational hour) was used to record the following behavioural states for each sow: lying, sitting, upright or unidentified (Bateson and Martin, 2021). Events of inter-sow aggression and drinking were recorded on individual sow level, using all occurrences sampling (Bateson and Martin, 2021). The ethogram is shown in Table 1. One person analysed the video recordings and was blind to the sows’ journey durations.

2.6. Data analysis

The data was analysed in R v. 4.1.1 (R Core Team, 2022) using a 5% level of significance.

2.6.1. Variables

The proportion of scans each sow was observed lying, upright, or sitting was calculated for the observed hour after unloading. Twenty of the 23 video recordings contained the targeted 12 scans, while two had 11 and one contained 10 scans as the sows were taken to slaughter earlier than planned. All recordings were included in the analyses irrespective of the available number of scans. For each sow, the journey duration was defined as the interval from departure from the herd according to the journey log, and until time of arrival at the abattoir as recorded by the technicians. Across sows, the journey durations were categorised into three groups according to the tertiles of 2.75 h and 4.85 h. Thus, short, medium and long journeys refer to the duration being ≤2.75 h, > 2.85 h and ≤ 4.8 h, and > 4.8 h, respectively. The waiting...
The duration was defined as the time from arrival at the abattoir and until the first sow was unloaded.

The average temperature was determined inside (average of the two inside sensors) and outside the vehicle for the last hour before arrival to the abattoir as this temperature was shared by all sows (few sows shared only the last 48–54 min). The temperature measures inside and outside the vehicle were highly correlated (Pearson’s correlation, ρ = 0.98), as was the average temperature in the lairage pen (average of the two sensors in the pen) with the temperature inside the vehicle (Pearson’s correlation, ρ = 0.89). Due to these high correlations, it was not possible to separate effects of the temperature experienced by the sows inside the vehicle and from those in lairage. Instead, averages of temperatures inside the vehicle for the last hour of driving and in the lairage were used as covariates in the analyses. In four of the loads, the temperature recordings were missing for the vehicle, and the average temperature from the lairage pen was therefore used. The time spent waiting at the abattoir before unloading was also included as a covariate in the statistical analysis.

### Table 2: Descriptive data from the 23 loads of cull sows stratified according to period.

<table>
<thead>
<tr>
<th></th>
<th>Warmer period</th>
<th>Colder period</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sows, n</td>
<td>313</td>
<td>249</td>
</tr>
<tr>
<td>Loads, n</td>
<td>13</td>
<td>10</td>
</tr>
<tr>
<td>Durations, median (range)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Journey duration, h</td>
<td>3.6 (0.8–8.4)</td>
<td>4.2 (0.9–8.6)</td>
</tr>
<tr>
<td>Waiting duration, min Unloading</td>
<td>10.4 (5–25)</td>
<td>6.6 (3–19)</td>
</tr>
<tr>
<td></td>
<td>27 (11–77)</td>
<td>22 (9–26)</td>
</tr>
<tr>
<td>Temperature, avg. ± SD (range)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inside vehicle</td>
<td>19.5 ± 2.6</td>
<td>9.6 ± 2.8 (4.3–14.4)</td>
</tr>
<tr>
<td>Outside vehicle</td>
<td>20.1 ± 3.1</td>
<td>8.3 ± 2.4 (3.3–12.0)</td>
</tr>
<tr>
<td>Inside vehicle waiting to unload</td>
<td>19.7 ± 2.5</td>
<td>11.2 ± 2.1 (6.2–14.9)</td>
</tr>
<tr>
<td></td>
<td>(14.2–27.0)</td>
<td>(12.0–20.8)</td>
</tr>
<tr>
<td>Lairage pen</td>
<td>22.0 ± 1.5</td>
<td>16.7 ± 2.1 (12.0–24.7)</td>
</tr>
<tr>
<td>Break, n loads</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>No</td>
<td>13</td>
<td>9</td>
</tr>
<tr>
<td>Mechanical ventilation, n loads</td>
<td></td>
<td></td>
</tr>
<tr>
<td>On</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Off</td>
<td>10</td>
<td>9</td>
</tr>
<tr>
<td>Ventilation panels, n loads</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fully opened</td>
<td>11</td>
<td>2</td>
</tr>
<tr>
<td>2/3 opened</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>½ opened</td>
<td>7</td>
<td>0</td>
</tr>
<tr>
<td>Fully closed</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

1. Unloading refers to the duration from the first to the last sow off the vehicle.
2. The last hour before arrival to the abattoir.
3. Breaks intended to let the driver rest.
4. Mechanical ventilation refers to whether the livestock driver reported to have turned on the mechanical ventilation during the journey.
5. Ventilation panels refer to the setting at arrival at the abattoir.

Fig. 3. The proportion of behavioural states recorded during the 60 min observation period after unloading into the lairage pen, recorded every five minutes irrespective of journey duration. The grey ribbons indicate ±SE. Only values between 0 and 100% are meaningful. ‘Short’ refers to journey durations of ≤2.75 h, ‘Medium’ refers to >2.75 h and ≤4.85 h, and ‘Long’ refers to >4.85 h.

2.6.2. Descriptive statistics

Journey durations, temperature inside and outside the vehicle, temperature in the lairage pen will be presented descriptively as averages ± SD separately for the two sensors inside the vehicle, the sensor outside the vehicle and the two sensors in the lairage pen. Due to skewness of data, percentages for behavioural observations and number of lactating sows will be presented as medians, minimum and maximum. Plots were made using the ‘geom_smooth’ function from the R package ggplot2 v. 3.4.0.

2.6.3. Statistical analyses

The number of scans each sow was lying was analysed by mixed effects logistic regression models using the ‘glmmTMB’ function from the R package glmmTMB v. 1.1.5, i.e., by generalised linear mixed effects model (GLMM) with binomial distribution and logit link function.
Hereby, the logit of the proportion of scans (p) where each sow was identified as lying \[
\logit(p) = \log\left(\frac{p}{1-p}\right)
\] was modelled as a linear function of the explanatory variables. To adjust for the number of sows that could not be identified as lying, sitting or upright, the count of sows with unidentified states was included as a covariate. Initiating aggression and drinking events per sow were analysed by log-link mixed effects Poisson regression models using 'glmmTMB'.

All models included the following fixed effects: the average of the temperatures inside the vehicle and in the lairage pen (min-max: 9.2–24.0 °C), the categorical journey duration (short, medium, long), the duration of waiting in front of the abattoir (min-max: 3–25 min), period (warmer or colder period) and the two-way interactions between temperature and journey duration (temperature × journey), temperature and waiting duration (temperature × waiting) and the two durations (journey × waiting). In all models, journey was included as a random effect. For the binomial models, results will be presented as odds ratios (OR) and for Poisson models as rate ratios (RR) with 95% confidence intervals (CI) and visualised by estimated probabilities and rates, respectively. Pairwise comparisons were calculated and adjusted by the Tukey method using the package emmeans v. 1.7.4.1. Lastly, Spearman's correlation was calculated by use of the base R package stats v. 3.6.2 and used to examine the association between the count of drinking events per sow and the counts per sow of receiving and initiating aggression. Plots were made using the ggplot2 package v. 3.4.0.

3. Results

3.1. Descriptive statistics

The majority of sows were scored as lactating (63% lactating, 19% not lactating, 18% missing score). The temperature inside and outside the vehicle as well as in the pen is shown in Table 2. The proportion of sows performing each of the four behavioural states varied during the 60 min (Fig. 3). Early after arrival, the majority of sows were upright, while the percentage of sows lying increased over time until approximately 75% of the sows were lying after one hour. The frequency of aggression followed a declining trend until 35 min after where the frequency was close to zero (Fig. 4A). The frequency of drinking increased slightly the first 15 min after long and medium, but not after short journeys, followed by a declining trend until 35 min after where the frequency was close to zero (Fig. 4B). The total frequencies of behavioural events and total percentage of states per sow are presented in Table 3. Sixty-four percent of the sows had zero drinking events. Among the sows observed to drink at least once, the median number of events was one. Thirty-six percent of the sows initiated aggression at least once (among those the median was 2 events per sow), while 72% received aggression at least once (among those the median was 2 events/sow). In 12 cases the receiving sow could not be identified. Ninety-one percent of the sows were recorded lying down at least once (among those the median was 6 scans/sow).

3.2. Lying behaviour

There was an interaction for odds of lying between the journey duration and the temperature (p < 0.001, Fig. 5D, Table 1 in Supplementary materials). The interaction was manifested by higher odds of lying with increasing temperature after a long journey, whereas higher temperatures slightly lowered the odds of lying for medium and short journeys.

3.3. Aggressive behaviour

An interaction between the journey duration and the temperature (p < 0.001) was found for the count of aggressions initiated per sow in that after short journeys, the rate of initiating aggression was higher with higher temperature (Fig. 5A, Table 2 in Supplementary materials). There was also an interaction between journey and waiting duration (p < 0.001), which manifest by slightly higher odds of initiating aggression.
with a longer waiting duration after short journeys, and slightly lower odds after long journeys (Fig. 5B, Table 2 in Supplementary materials).

3.4. Drinking behaviour

An interaction between temperature and journey duration was found for the count of drinking events per sow (p < 0.001, Fig. 5C, Table 3 in Supplementary materials). With higher temperature on long journeys, the rate of drinking was lower, while temperature did not affect the rate after medium and short journeys. The rate of drinking tended to increase with a longer waiting duration.

3.5. Correlations between behaviours

Lastly, the number of scans where sows were lying was negatively correlated with events of receiving aggression (ρ = −0.49) and weakly negatively correlated with initiating aggression (ρ = −0.14). The number of drinking events per sow was weakly but positively correlated with aggression (initiating ρ = 0.25 and receiving; ρ = 0.19).

4. Discussion

The present observational field study was part of a project examining potential welfare challenges for cull sows in the pre-slaughter logistic chain. The part presented here concerned effects on the behaviour of sows during the initial 60 min upon arrival in a lairage pen for factors related to the up to 8 h transport to the abattoir.

4.1. Description of cull sow behaviour in lairage

The present study is among the first to describe behaviour of cull sows in lairage. The level of activity was initially high as >90% of the sows were in upright position. After approximately 30 min, half of the sows were lying down, reaching about 75% lying at 60 min. For finisher pigs, a comparable development in the activity level has been described (Brown et al., 1999a, 1999b; Dalla Costa et al., 2016). In the present study, not all the sows were observed lying within the 60 min, which is surprising, as results from another part within the present project (Kobek-Kjeldager et al., 2023) showed that the large majority of cull sows were in upright position during transport to the abattoir (89–92% of observations/h for each duration). Standing upright and keeping balance in a moving vehicle will be associated with a higher energy expenditure than when lying. Since cull sows are generally in a less fit condition than finisher pigs they are expected to have a more pronounced need for resting with increasing transport duration as discussed by EFSA AHAW Panel et al. (2022). Finisher pigs show more drinking behaviour in lairage right after transport (Brown et al., 1999a, 1999b) and increased water consumption with longer journey duration (Warriss et al., 1983), potentially reflecting drinking motivation that could not be fulfilled during the journey to the abattoir. In the present study, almost 2/3 of the sows were not observed drinking during the first hour after arrival and, furthermore, the number of drinking bouts was considerably low for those that were observed drinking (median 2 events/sow). While the individual water intake was not recorded in the present study, Jensen et al. (2016) found loose-housed lactating sows deprived of water for 6 h over-night consume on average 7.5 L water the first three hours after water was re-introduced. In addition, they concluded that with increased water deprivation (0 h, 3 h, 6 h, 12 h), sows showed signs of increased thirst. The majority of the sows in the present study were lactating (63%) and thus may have similar needs for water as found by Jensen et al. (2016). Indicators of dehydration like skin elasticity (Thodberg et al., 2019; Thodberg et al., 2023) or physiological measures plasma albumin, protein concentrations or osmolarity (Brown et al., 1999a; Houpt and Yang, 1995) are needed to clarify this. The latter have been used in a pilot study on cull sows, and higher levels were associated with longer transport duration (Klaaborg and Schrader-Petersen, 2021).

In the current study, the low drinking frequency raises the question whether the sows’ need for water was met. Possible reasons for the low drinking frequency may be too few or unavailable water nipples. In addition, sows prefer walls to lean against when lying down at least in the farrowing pen (Damm et al., 2006), and lying sows could block access to the water nipples.

It is well known that sows fight when mixed (Borberg and Hoy, 2009; Greenwood et al., 2014; Krauss and Hoy, 2011), including cull sows when mixed in so-called pick-up vehicles (Herskin et al., 2016). In the current study, mixing took place to a varying degree (not systematically recorded) in the pick-up facilities at the herd, in the vehicle and when the sows entered the lairage pen (each vehicle compartment held 11–13 sows and the lairage pen held 25 sows). Thus, as expected, aggressive behaviour was observed but with a large individual variation. Also, Bonnerup (2020) described a large individual variation in the occurrence of aggression among sows in lairage pens in the same abattoir as in the present study. Bonnerup (2020) observed the behaviour of sows while in over-night lairage and described how the level of aggression was highest during the initial two hours but continued at a lower level throughout the following 14 h. In the present study, the highest level of aggression was observed right after the gate was closed behind the last sow, followed by a gradual decrease, reaching a plateau at a low level after approximately 35 min. This is similar to findings on finisher pigs in lairage (Dalla Costa et al., 2016). However, several studies on finisher pigs describe the relation between aggressive behaviour and time as an inverted U-shape (Brown et al., 1999b; Fraqueza et al., 1998; Geverink et al., 1996). One explanation for these differences may be related to different methodology across studies e.g., all occurrence sampling (Dalla Costa et al., 2016; Geverink et al., 1996) or scan sampling (Brown et al., 1999b; Fraqueza et al., 1998). Another part of the explanation can also relate to conditions during the pre-slaughter transportation, like those investigated in the present study and discussed below.

4.2. Effects of journey duration, waiting duration and temperature

In the present study, knowledge about transport duration and temperature conditions during transport to the abattoir allowed us to examine whether the individual variation in behaviour was associated with these factors. For the occurrence of drinking, aggression and lying, interactions were found between transport duration and the average indoor temperature in the vehicle the last hour before arrival and the first hour in the lairage pen. After short journeys, aggression increased with increasing temperature whereas lying increased and drinking decreased after long journeys, the higher the temperature. The different behavioural patterns after short and long journeys at higher temperatures may indicate a motivational change as a consequence of the transport factors. As discussed by Brandt and Aaslyng (2015), it is difficult to interpret the underlying motivation of lying behaviour in
Fig. 5. Plots indicating the significant interactions ($p < 0.01$) between journey duration (different line type and colour) and the covariate on the x-axis (temperature average in the last hour in the vehicle and in the lairage or waiting duration before unloading) regarding sow behaviour in the lairage. Journey duration: ‘Short’ refers to $\leq 2.75$ h, ‘Medium’ refers to $> 2.75$ h and $\leq 4.85$ h, and ‘Long’ refers to $> 4.85$ h.
lairage pens simply from behavioural studies. Pigs may simply lie down when they want to, for example when they feel safe and comfortable, which would be interpreted as positive for welfare (Dawkins, 2021). Yet, this is not easily distinguishable from pigs lying down after a period where lying has been thwarted i.e., wanting to lie down but for some reason could not. In the extreme, lying may also be a sign of fatigue and thus could indicate the strain of the pre-slaughter transport. Previous studies on finisher pigs during lairage also found behavioural changes as a consequence of transport factors. In alignment with the present results, Urrea et al. (2021) found a greater proportion of lying and decreased drinking when finisher pigs were transported at a higher stocking density, which had led to less lying during transport. On the other hand, the results on finisher pigs in lairage by Brown et al. (1999a) indicated a preference for drinking over lying when journey duration increased. Fraqueza et al. (1998) found less activity in lairage pens with higher temperature (20 vs. 35 °C), similar to what was observed after long journeys in the present study. The high temperature used by Fraqueza et al. (1998) was more extreme than in the present study, but it should be taken into account that sows are considerably more sensitive to heat stress than finisher pigs (as reviewed by EFSA AHAW Panel et al., 2022). EFSA AHAW Panel et al. (2022) estimated the upper critical temperature of sows in late lactation to be 22 °C. In the present study this was exceeded in the last hour inside the vehicle in two journeys by 1–2 °C, while in lairage this was exceeded after seven journeys by 1–2 °C.

The behavioural prioritisation of lying over aggression and drinking after long journeys at higher temperatures may be interpreted as a sign of lack of energy to perform the natural behaviour of establishing dominance when mixed with conspecifics. Clarification of this hypothesis warrants further study, preferably involving collection of physiological indicators, e.g. plasma concentration of lactate as reviewed by Terlouw and Bourguet (2022) and examination of motivations underlying the behaviour of the sows, as discussed by Weary et al. (2017) for the examination of affective states in general. So far, such studies are not available in culled sows, but earlier studies on finisher pigs have found results that may support the hypothesis of fatigue. Several studies on finisher pigs have used serum creatin kinase activity as a physiological indicator of muscle activity and fatigue, and generally find a positive association with a longer journey duration (Aradom et al., 2012; Sommavilla et al., 2017; Yu et al., 2009) and higher stocking density during transport (Gerritzen et al., 2013). In finisher pigs, the occurrence of non-ambulatory pigs (i.e., not able to walk) has been used as a sign of fatigue and the occurrence increased with journey duration under Southern Brazilian commercial conditions (Dalla Costa et al., 2019). In the present study, none of the sows arrived non-ambulatory and were therefore not subjected to that extent. Nevertheless, the findings of relationships between transport duration and physiological indicators of fatigue in finisher pigs – known to be younger and more physically fit than culled sows – may support that the observed behavioural effects of journey duration (in interaction with temperature) may have been caused by fatigue. Previous results on the clinical deterioration of culled sows after transport have found more relationships with transport factors (journey duration and temperature) than with factors present already before transport (parity, body condition score, gait score) (Thodberg et al., 2019). As seen in both the study by Thodberg et al. (2019) and the present, the effect of temperature is complex and often interacts with journey duration.

According to legislation (Council regulation EC No 1099/2009), animals must be unloaded as quickly as possible after arrival to an abattoir and subsequently slaughtered without undue delay. In the present study, an interaction between journey and waiting duration showed that after an increased waiting duration, sows transported on short journeys initiated more aggression, while the rate of drinking tended to increase with longer waiting duration. Previous results from vehicles transporting sows in Denmark show that temperature increases in stationary vehicles compared to moving ones (Thodberg et al., 2022).

In the present study, there was a subtle increase in the average temperature during the waiting time before unloading which may have been causal in increased aggression and drinking motivation.

5. Welfare challenges and ways forward

Waiting time as a hazard for the welfare of sows has been discussed in several studies of finisher pigs (Faucitano, 2018; Grandin, 2010). Ways to reduce the waiting duration like coordination of vehicle arrivals are discussed by Faucitano and Pedernera (2016), while ways to improve thermal comfort inside vehicles (e.g., forced ventilation and misting) in the case of queuing was investigated by Pereira et al. (2018). Whether such techniques are used or documented to be effective in abattoirs accepting sows is not known.

The present results suggest that for sows the stay in lairage involves welfare challenges including stress due to mixing and indications of unfulfilled drinking and resting motivation. If the use of lairage for culled sows is used to allow them to calm down and rehydrate after transport as discussed by Faucitano and Raj (2022), one hour in conditions corresponding to the present study performed under normal, commercial conditions does not seem to fulfil this.

Possible solutions within the current pre-slaughter logistic chain could be improving the temperature control in the vehicle as well as in the lairage, minimising mixing, lowering stocking density and having more water nipples available per animal. The dimensions of the pen (8.6 × 3.1 m = 26.7 m²) and the lack of partitions should also be considered. In a recent EFSA Opinion (EFSA AHAW Panel et al., 2022) it was suggested that the use of so-called mixing pens, equipped with sufficient space and hiding opportunities, could be one way to mitigate the consequences of mixing of sows in terms of animal welfare. In addition, more walls to lie against may also prevent drinkers being blocked by lying sows. To the best of our knowledge, no studies have documented this yet, but for culled sows in lairage, allowing them space as well as an undisturbed area might also be one way to mitigate the combined consequences of transport stress and mixing in the lairage.

6. Conclusion

This observational field study of the behaviour of culled sows in lairage after transport for up to approximately 8 h showed at first a high level of activity which included aggressive behaviour, but limited drinking in culled sows when mixed in lairage. The results suggest that especially a combination of long journeys and higher temperatures may lead sows to prioritise lying behaviour over drinking, which may be a sign of fatigue. Further studies are needed to clarify this; for example, studies involving quantification of physiological and motivational indicators of fatigue and hydration levels. Irrespectively, the present findings suggest that a stay in a lairage pen as part of the pre-slaughter logistic chain involves challenges for the welfare of culled sows.

Declaration of Competing Interest

The authors confirm they have no conflict of interest and that no financial support has influenced the outcome of this publication.

The data was collected in collaboration with the Danish Meat and Research Institute (DMRI) from the Danish Technological Institute (DTI). The aim of DMRI is to strengthen innovation and competitive ability in the Danish food industry. We declare that the collaboration has not biased the results.

All authors have read and approved the manuscript.

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Appendix A. Supplementary data

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