What makes a good mother? Maternal behavioural traits important for piglet survival

Marko Ocepek[*], Inger Lise Andersen

Norwegian University of Life Sciences, Department of Animal and Aquacultural Sciences, PO Box 5003, 1432 Ås, Norway

[*]Corresponding author: Marko Ocepek, e-mail: marko.ocepek@nmbu.no, Tel: +47 41430972, Fax: +47 64965101

Abstract

The primary aim of our work was to find maternal behaviours important for piglet survival and to develop qualitative scores of those traits. Second, we studied the relationship between maternal behavioural scores, piglet mortality and the number of weaned piglets in sows of three different sow breeds (Norsvin Landrace (n=12), Norsvin Duroc (n=12) and crossbred Norsvin Landrace × Yorkshire (n=14)). The following qualitative maternal behaviours were scored as follows: nest building activities prior to farrowing, sow communication (q_SC), and carefulness (q_SCR) on while sows were standing, moving and just before lying down. We also continuously recorded maternal care behaviors (nest building activities (c_NBA) and sow communication (c_SC; while standing/moving, before lying down) to test the relationship with the respective qualitative scores. There was a moderate positive correlation between the continuous measured c_NBA and the qualitative score for nest building q_NBA ($r = 0.469$) as well as between the qualitative score for communication, q_SC and the continuous, video-based measure of communication while standing, c_SC ($r = 0.439$), and the qualitative and quantitative scores similarly affected piglet survival. Since q_SC and q_SCR were highly correlated ($r = 0.883$), we tested the effect of those behavioural scores separately on production parameters (proportion of dead piglets and number of weaned piglets) using two models (model 1: q_NBA, q_SC; model 2: q_NBA, q_SCR), and compared their relative predictive accuracies using Akaike information criteria (AIC) and AIC weights. In models 1 and 2, piglet mortality decreased with higher q_NBA ($P = 0.004$; $P < 0.001$; respectively) due to less crushing ($P < 0.001$; $P < 0.001$, respectively) and, thus, more weaned piglets ($P = 0.043$; $P = 0.035$; respectively). Increases in both q_SC and q_SCR were associated with lower overall piglet mortality ($P < 0.001$; $P < 0.001$, respectively), fewer crushing incidences ($P < 0.001$; $P = 0.002$, respectively) and, therefore, more weaned piglets ($P = 0.004$; $P = 0.030$; respectively). Additionally, higher q_SC in model 1 was associated with a lower proportion of starved piglets ($P = 0.002$). Model 1 had better predictive accuracy than model 2 for all productive parameters. Our results demonstrated that our three defined maternal behaviour scores had a significant impact on piglet survival, and therefore we would like to

proceed with testing of these scores in nucleus herds of Norsvin Landrace sows to further calculate heritabilities and potentially implement the most successful behavioural trait in the breeding program.

Keywords: Piglet mortality; Nest building; Sow carefulness; Sow communication; Breed

1. Introduction

Although the domesticated pig differs in productive and reproductive efficiency compared to its wild ancestor, their behavioural repertoires have remained similar, especially around parturition (e.g. Jensen, 1986; Gustafsson et al., 1999). A day or so before parturition, domestic and wild sows engage in nest preparation to provide shelter and warmth for the newborn piglets (Wood-Gush and Stolba, 1982; Jensen, 1993). From the onset of parturition, sows spend the majority of their time in the nest with the piglets (Stangel and Jensen, 1991). Social contact encourages sows to interact with their piglets, establishing mother-young bonds and providing warmth and nutrients from the udder (Fiala and Humik, 1983). Sows communicate with piglets through olfactory (sniffing), vocal (grunting) and tactile (nudging) cues (Jensen and Redbo, 1987), mainly during the first few days after parturition when piglet survival is most crucial (Andersson et al., 2011). It is well established that communication between sows and piglets is tightly synchronized during short nursing intervals (Algers and Jensen, 1985; Algers and Uvnäs-Moberg, 2007). However, less attention has been given to the significance of sow communication over longer periods between nursings. During that time, sows communicate while standing and lying, and the relative costs and benefits of sow-piglet contacts may help to explain why communication is performed more in some situations but less in others. We think that a sow's motivation to care for her offspring is likely to manifest in how she communicates with offspring during others activities, outside nursing bouts. Until now, previous studies have focused on sow communication before lying down because it is at this point that piglets are at higher risk of being crushed. However, the results of the effect of sow communication have been inconsistent regarding whether nosing or sniffing before lying down improves piglet survival (Marchant et al., 2001; Valros et al., 2003; Andersen et al., 2005; Pokorná et al., 2008). According to Melišová (2011), sow communication should attract piglets to the sow without increasing mortality. In fact, the only logical explanation for the evolution of sow communication is to keep the piglets in close proximity and protect them from danger.

Piglet mortality is still a major welfare issue as approximately 15% of live born piglets die (Ocepek et al. 2016b) and crushing and starvation constitute more than 60% of all piglet deaths in loose-housed sows (e.g. Andersen et al., 2006; Vasdal et al., 2011). Both causes mainly occur during the first few days of life and increase in larger litters (Weary et al., 1998; Andersen et al., 2011; Vasdal et al., 2011). The sows highly motivated to nest build before parturition are more protective towards their piglets (Andersen et al., 2005; Yun et al., 2014). Differences in maternal care behaviours are likely to reflect different selection pressures (Knap and Merks, 1987; Canario et al., 2009) and primiparous sows appear to show better maternal behaviour skills than multiparous sows. Primiparous sows invest more in their present litter than more experience sows, because breeding goals have shifted the balance towards greater investment earlier in life (Ocepek et al., 2016b).

For maternal behaviour, the best method to obtain precise measures is from continuous video recordings. However, such methods are time consuming and costly. Under commercial conditions, we need to develop simple qualitative scorings of important maternal care behaviours and that is possible for the farmers to understand and implement in an efficient way into the breeding goals. Although many attempts have been made to develop valid scores of maternal behaviour characteristics, this has often been difficult due to methodological challenges related to how these traits are measured (Grandinson et al., 2002, 2003; Lovendahl et al., 2005; Vangen et al., 2005; Gäde et al. 2008). Thus, it is essential to understand the significance of sow communication (while standing and lying) for piglet survival and to develop and verify precise and simple direct measures of maternal behaviour (sow communication, sow carefulness), as well as for other maternal characteristics (e.g. nest building activities). Parity may be an important mediating factor affecting maternal behaviour, in addition to breed, since breeds have been subjected to different selection pressures for litter size. It is, thus, crucial to identify the relationships between maternal behavioural characteristics and piglet survival and to develop behavioural scores that can be used directly in the breeding program.

The primary aim of our work was to find maternal behaviours important for piglet survival and to develop qualitative scores of those traits. Second, we studied the relationship between maternal behavioural scores, piglet mortality and the number of weaned piglets in three different sow breeds (Norsvin Landrace, Norsvin Duroc and crossbred Norsvin Landrace × Yorkshire).

2. Material and methods

The present research was conducted in accordance with the Norwegian laws and regulations controlling experiments and procedures on live animals (Nara, 1998).

2.1. Experimental design

The experiment took place at the Pig Research Unit at the Norwegian University of Life Sciences. Sows with their litters (n=38) from three different breed lines (purebred Norsvin Duroc (ND) sows (n=12), purebred Norsvin Landrace (NL) sows (n=12) and crossbreed Norsvin Landrace × Yorkshire (LY) sows (n=14)) were evaluated for their maternal behaviour. Selection criteria were that sows were healthy and 6 sows per breed were primiparous and 6 were multiparous. Sows in the respective breed groups (ND, NL, LY) were with their first (n=6, 6, 8), second (n=5, 0, 1), third (n=0, 4, 0), fourth (n=1, 0, 3), fifth (n=0, 1, 2), and sixth parity (n=0, 1, 0).

2.2. Housing and management

Housing and management routines are described in detail in Ocepek et al. (2016a) and the feeding strategy is presented in Ocepek et al. (2016b). Except of farrowing assistance (if sows were restless for more than 3-4 hours and had contractions for more than 1-2 hours without any newborn piglets) and cross-fostering (when litter size exceeded the number of functional teats) no routines were carried out. Human intervention was kept to a minimum, allowing feeding, provision of nest-building material (i.e., straw in a hayrack) two days before expected birth of the piglets, providing new sawdust as bedding material twice a day, cleaning the pen, giving iron orally to each piglet on day one, providing peat to piglets on a daily basis and surgical castration when piglets were between 10 and 14 days of age.

2.3. Litter size at birth and weaning

All the live-born piglets were individually counted and marked. Some piglets had to be cross fostered from the litter when the number of piglets exceeded the number of functional teats. Litter size at birth was defined as the number of each sow's live-born piglets plus the number of piglets fostered on, minus the number of piglets fostered off. The number of weaned piglets was defined as the number of piglets present in the litter at weaning (35 days of age).

2.4. Post mortem examination of dead piglets

All piglets that died before weaning were examined at the Norwegian Veterinary Institute, Pathology Section to identify causes such as stillborn (based on whether the lung tissue would float in water), postnatal mortality (piglets that died after the farrowing and before weaning), starvation (no colostrum/milk in the stomach), and maternal crushing (physical signs of crushing).

2.5. Sow assessment

2.5.1. Sow behaviour

The sows were continuously video-recorded from 3 days before until 3 days after farrowing. Above each pen, a camera for video and audio recordings (Foscam FI9821W, 1280×720P, ShenZhen Foscam Intelligent Technology Co., Ltd., Shenzhen, China) was mounted. Data of nest building activities (c_NBA) and sow communication while standing (c_SC) and lying (c_SCL) were obtained in order to verify the respective qualitative scores of nest building (q_NBA) and sow communication (q_SC). From the videos, c_NBA were analysed (manipulating, rooting, pawing, carrying nest building material) 12h before farrowing using instantaneous sampling with 5 min intervals. Communication with piglets initiated by the sow (sniffing, grunting, nudging) between nursings (communication during nursing was not documented) and while sows were either active (c_SC; standing, moving around or is about to lie down) or resting (c_SCL; lying) was recorded in the first 12h after parturition and 12h during the following day (0800 - 2000). Measures of c_NBA are presented as overall activities (total per 12h), while c_SC and c_SCL as the mean occurrence per hour during both days.

2.5.2. Sow behavioural scores

Qualitative score of q_NBA was assessed after sows begin to display farrowing preparation signs (restless behaviour, nesting behaviour, and teats ejected milk at hand milking) during morning and afternoon feeding within the last 24 hours before expected parturition. Q_NBA included rooting (nosing in the nest building material on the floor), pawing (leg in the nest building material on the floor), carrying nest building material, and chewing nest building material while the sow was active (standing or moving around). Q_NBA was scored using a scale from 1 to 3 as presented in table 1.

Sow maternal behavior score (q_SC and carefulness (q_SCR)) was assessed immediately after morning or afternoon feeding on day one postpartum while sow's change position, move around and at the moment the sow is about to lie down. Both maternal behavioral scores, Q_SC (sniffing, grunting and nudging) and q_SCR were assessed with a scale from 1 to 4 as presented in table 1. All behavioural scores were conducted by one trained observer (MO).

2.6. Statistical analysis

Statistical analyses were performed using SAS 9.4 statistical software program (SAS Institute. Inc., Cary, NC). The effects of breeds (ND, NL, NL×Y), parity (primiparous sows (Parity=1), multiparous sows (Parity>1)) and litter size were analyzed using a generalized linear model (GENMOD procedure) with a multinomial response distribution for the sows' qualitative behavioral scores (q_NBA, q_SC, and q_SCR) and a general linear model (GLM-procedure) for continuous measures of sow behaviours (c_NBA, c_SC and c_SCL).

Because residuals were not normally distributed, causes of piglet mortality (stillborn, starvation, maternal crushing) were analysed using a generalized linear model (GENMOD procedure) with Poisson response distribution. The model for the proportion of stillborn piglets included the fixed effect of c_NBA. The model for postnatal mortality and causes of postnatal mortality (starvation, maternal crushing) included fixed effects of c_NBA, c_SC and c_SCL. The differences in the number of weaned piglets were analysed using a GLM procedure including the effects of sow behaviours as continuous measures (c_NBA, c_SC, c_SCL).

In order to validate the relationships between sow behaviours as continuous measures and as qualitative scores (between c_NBA and q_NBA, between c_SC and q_SC and between c_SCL and q_SC), polyserial correlation coefficients were calculated. To analyse the differences between c_SC and c_SCL for each type of communication (sniffing, grunting, nudging) while sows were active or resting, a paired samples t-test was used. The relationship between sow behaviours (c_SC and c_SCL) was investigated using the Spearman rank correlation coefficient. Polychoric correlation coefficients were used when testing the relationships between sow behavioural scores (q_NBA, q_SC, and q_SCR).

Because q_SC and q_SCR were highly correlated ($r = 0.883$), two models were used for testing the effects of the qualitative scores on the number of weaned piglets as well as on piglet mortality variables (postnatal, starvation, maternal crushing). Model 1 included fixed effects of q_NBA and q_SC and model 2 included fixed effects of q_NBA and q_SCR.

The model for the proportion of stillborn piglets included the fixed effect of q_NBA. Variables of piglet mortality (starvation, maternal crushing) were analysed using a generalized linear model (GENMOD procedure) with Poisson response distribution including the fixed effects of sow behavioural scores from model 1 and model 2. The differences in the number of weaned piglets were analysed using a GLM procedure including the fixed effects of sow behavioural scores from model 1 (q_NBA, q_SC) and model 2 (q_NBA, q_SCR). The model with the best relative predictive accuracy for piglet mortality/survival was determined using the Akaike information criterion (AIC). The AIC values were also transformed to Akaike weights according to Wagenmakers and Farrell (2004), which provide the relative probability of each model having the best predictive accuracy. Akaike information criterion (AIC) for the number of weaned piglets from model 1 and model 2 were obtained using the GLM select routine.

3. Results

3.1. Nest building activities measured with instantaneous sampling (c_NBA) or by qualitative score (q_NBA)

Nest building activities (c_NBA), measured as their occurrence per 12 hours, were higher in the NL×Y sows than NL sows (Table 2; Fig. 1a). Sows with higher c_NBA had significantly lower proportions of stillborn and crushed piglets ($\chi^2_{1, 37} = 44.0$; $P < 0.001$; $\chi^2_{1, 37} = 7.3$; $P = 0.007$; respectively; Fig. 2a). There was no effect of c_NBA on overall postnatal mortality or proportion of starved piglets ($\chi^2_{1, 37} = 0.3$; $P = 0.610$; $\chi^2_{1, 37} = 0.6$; $P = 0.425$; respectively). The number of weaned piglets was not affected by c_NBA ($F_{1, 34} = 1.2$; $P = 0.242$).

There was a moderate positive correlation between c_NBA and q_NBA ($r = 0.469$; $P = 0.007$). During the last 12 hours before parturition, 43% of the sows showed no nest building activities (score 1; Fig. 3a), whereas 14 % of the sows spent a lot of time on nest building activities (score 3). There was no significant effect of breed, parity, or litter size on q_NBA (Table 2).

3.2. Communication as a continuous measure (c_SC and c_SCL) or a qualitative score (q_SC).

Sow communication with piglets was less frequent while standing (c_SC) than resting (c_SCL; 7.1±0.9 vs. 16.6±0.9; $t_{37} = 7.7$, $P < 0.001$), especially sniffing (3.2±0.4 vs. 7.3±0.5 $t_{37} = 7.0$, $P < 0.001$) and grunting (2.8±0.3 vs. 8.5±0.6; $t_{37} = 8.5$, $P < 0.001$), but there was no difference in nudging (0.8±0.2 vs. 1.0±0.2; $t_{37} = -1.4$, $P = 0.170$). C_SC was not affected by breed, parity, or litter size (Table 2). There was no correlation between c_SC and c_SCL ($r = -0.013$; $P = 0.941$). The ND sows had the highest c_SCL, with the NL×Y sows being intermediate (Table 2; Fig. 1b). Sows with larger litters had higher c_SCL (Table 2; Fig. 4).

Sows with higher c_SC had lower overall piglet mortality due to fewer piglets dying of starvation and maternal crushing ($\chi^2_{1, 37} = 16.9$; $P < 0.001$; $\chi^2_{1, 37} = 9.7$; $P = 0.002$; $\chi^2_{1, 37} = 9.1$; $P = 0.002$; respectively, Fig. 2b). Sows with higher c_SCL were the ones with higher overall postnatal mortality as well as a higher proportion of starved and crushed piglets ($\chi^2_{1, 37} = 19.5$; $P < 0.001$; $\chi^2_{1, 37} = 54.3$; $P < 0.001$; $\chi^2_{1, 37} = 9.9$; $P = 0.002$; respectively, Fig. 2c). While sows with higher c_SC had a higher number of weaned piglets ($F_{1, 34} = 17.4$; $P < 0.001$; Fig. 5a), there was no effect of c_SCL on the number of weaned piglets ($F_{1, 34} = 0.0$; $P = 0.994$).

There was a moderate positive correlation between q_SC and c_SC ($r = 0.439$; $P = 0.004$), whereas c_SCL was negatively correlated with q_SC ($r = -0.383$; $P = 0.012$). While 33% of the sows showed frequent communication and paid a lot of attention towards the piglets (score 4), 16 % of the sows did not communicate with the piglets in the observation period (score 1; Fig. 3b). The NL sows had higher q_SC than the ND sows (Table 2; Fig. 1c).

3.4. Sow carefulness score (q_SCR)

Eight percent of the sows were classified as moving in a careless way, stepping/lying on piglets and/or showing aggressive behavior towards them, while 21% of the sows were categorized as attentive, careful and protective towards the piglets (score 4; Fig. 3c). Q_SCR was unaffected by breed, parity, or litter size (Table 2).

3.5. Interrelationship between behavioural scores

There was a high positive correlation between q_SC and q_SCR ($r = 0.883$; $P < 0.001$). Q_NBA was not correlated with either q_SC ($r = 0.145$; $P = 0.190$) or q_SCR ($r = 0.132$; $P = 0.293$).

3.6. Relationship between behavioural scores and production parameters

The mean number of piglets at birth was 12.5±0.5, at weaning 10.8±0.5%, whereas the mean proportion of stillborn piglets was 7.3±1.5%. The overall mean postnatal mortality was 13.4±2.3%. The proportion of piglets that died due to starvation and maternal crushing was 3.1±1.3% and 5.0±1.4%, respectively. The effects of breed, parity and litter size on production parameters are reported in Ocepek et al. (2016b). Since q_SC and q_SCR were highly correlated, meaning that the scores represented similar information, we chose to test the effects of behavioural scores on production parameters (proportion of died piglets and number of weaned piglets) with each of them in separate models to find out which score has the best predictive accuracy for piglet mortality/survival using AIC.

3.6.1. Piglet mortality/survival in relation to sow behavioural scores (model 1, incl. q_NBA and q_SC)

The proportion of stillborn piglets was unaffected by q_NBA ($\chi^2_{1, 37} = 3.6$; $P = 0.072$). Sows with higher q_NBA had lower postnatal mortality due to fewer piglets being crushed (Table 3; Fig. 2d). The higher the q_SC, the lower the overall postnatal mortality, due to fewer piglets being crushed and starving (Table 3; Fig. 2e).

The number of weaned piglets was positively affected by q_NBA and q_SC ($F_{1, 35} = 2.1$; $P = 0.043$; Fig. 5b; $F_{1, 35} = 3.1$; $P = 0.004$; Fig. 5c; respectively).

3.6.2. Piglet mortality/survival in relation to sow behavioural scores (model 2, incl. q_NBA and q_SCR)

Sows with higher q_NBA had lower postnatal mortality due to lower maternal crushing (Table 3). The higher q_SCR, the lower overall postnatal mortality as well as and the proportion of crushed piglets (Table 3; Fig. 2f).

The number of weaned piglets was positively affected by q_NBA and q_SCR ($F_{1, 35} = 2.2$; $P = 0.035$; $F_{1, 35} = 2.3$; $P = 0.030$; Fig. 5d; respectively).

3.7. Predictive accuracy of behavioral scoring models (model 1 and model 2) for piglet mortality and survival

For each production parameter (postnatal mortality, starvation, maternal crushing, weaned piglets), model 1 (including q_SC as an independent variable) had clearly lower AIC values and higher AIC weights compared to model 2 (including q_SCR as an independent variable; Table 4). This implies that the q_SC measure will be more predictive of those production parameters than the q_SCR measure.

4. Discussion

Consistent with previous studies, approximately 20% of total born piglets were stillborn or died before weaning (Andersen et al., 2011; Pedersen et al., 2011), which is representative of the Norwegian average of 21% (Norsvin, 2015). In Norway, sows are kept loose during farrowing and lactation, allowing sows to move around and communicate freely with their offspring. Thus, finding maternal care behaviours important for piglet mortality/survival and developing qualitative scoring systems to promote those maternal care traits is crucial for ensuring the future sustainability of pig production and improving pig welfare. However, it is also important that maternal behavioural traits are as simple as possible to score for farmers if they are to have practical utility, while still being valid measures to include in breeding programs.

In this study, we identified maternal behaviour important for piglet survival. Current results provide first successfully developed qualitative scoring systems of those maternal care traits. We showed that both sow nest building activities (c_NBA) and sow communication (c_SC; while standing, moving or at the moment the sow is about to lie down), continuously measured behaviours analogous to the qualitative scores, have a large impact on improved piglet survival. We cannot confirm the same for sow communication while resting (c_SCL). However, this trait was greatly affected by breed and litter size. More detailed analyses of the importance of continuously measured behaviours (c_NBA, c_SC, c_SCL) for piglet survival will be a topic for further investigation and is currently under preparation. In the present study, the continuously measured behaviours were included only to verify the quality of our behavioural scores in two ways: to determine the correlation between continuous measures and qualitative behavioural scores, and to analyse the relationship between those measures and production parameters (piglet mortality and number of weaned piglets).

Our results showed that there was a moderate positive correlation between c_NBA and qualitative scores of nest building activities (q_NBA). Moreover, c_NBA and q_NBA were similarly related to production parameters up until weaning. Sows with higher c_NBA had lower proportions of stillborn piglets and there was also a tendency towards lower proportions of stillborn with increasing q_NBA. We confirm that our qualitative q_NBA is a good indicator of piglet survival as sows with higher scores weaned more piglets. In fact, sows that engaged more in nest building activities, whether obtained using c_NBA or q_NBA measures, had fewer piglet deaths due to maternal crushing.

Previously, it has been discussed that the level of pre-partum activities might predict sow behaviour during and after parturition (Jensen, 1993; Thodberg et al., 1999; Andersen et al., 2005; Yun et al., 2014; Illmann et al., 2015). Sows motivated in pre-partum nest building activates performed less postural changes during parturition (Thodberg et al, 1999; Johnson, 2007) and were more protective towards their offspring during and after parturition (Andersen et al., 2005; Yun et al., 2014). Indeed, our results showed direct links between higher pre-partum nest building and improved piglet survival. However, performance of nest building activities is also related to other factors such as environmental (pen vs. crates) and environmental enrichments (the provision of nest building material; Andersen et al. 2014; Yun et al., 2013). Even though sows were kept loose and had ad libitum access to nest building material prior to parturition in the present study, we demonstrated that there is still between-sow variation in q_NBA. As q_NBA was unaffected by parity and litter size, these traits could be selected for across sows' reproductive lifespans, irrespective of their litter size. Our findings suggest that this trait should be further investigated in larger-scale commercial farms and eventually implemented in the national breeding programme.

Another maternal care behaviour assessed in the present study was sow communication towards piglets. Our results showed that there was a moderate positive correlation between c_SC and sow communication towards piglets (q_SC), and both similarly influenced piglet mortality/survival. Sows with higher communication towards piglets, both c_SC and q_SC, had lower overall mortality due to fewer deaths of starvation and maternal crushing and those sows were capable of weaning more piglets. Consequently, we developed simple qualitative scorings of important maternal care traits.

Another very important finding of the present study is that qualitative scores of maternal care traits such as q_SC and sow carefulness score (q_SCR) were highly correlated. As we originally predicted, communication while standing, moving around, or before lying down orients the sow towards the piglets and, thus, she became careful, attentive and protective towards them. To test the impact of both scores on production parameters (piglet mortality and the number of weaned piglets), we compared two statistical models: model 1 included q_NBA and q_SC as independent variables, and model 2 included q_SCR replaced q_SC as independent variables. Although both q_SC and q_SCR significantly impacted piglet survival (i.e. lower overall mortality, lower maternal crushing and higher number of weaned piglets), model 1 including q_SC had higher predictive accuracy for productive parameters than model 2 inducing q_SCR (assessed by Akaike information criteria). However, as q_SC and q_SCR were unaffected by parity or litter size and because we found between-sow variation in both scores, it could be possible to select for both traits using those scores. Thus, we recommend that both scores should be further investigated in larger-scale commercial farms before making a decision on the best suited maternal care traits to implement in the national breeding programme.

Since in our study were three maternal care traits (q_NBA, q_SC, q_SCR) important for piglet survival, it could be possible to develop one maternal care index. Chiang et al. (2002) successfully developed a maternal care index in mice using different interaction types with pups, including nest building activities before birth. Their care index was found to improve pre-weaning survival of pups with a heritability of 0.24. If maternal care index can be developed from our scores (q_NBA, q_SC, q_SCR) and resulted in such high heritabilities, it could be possible to implement a care index in pig breeding programs. Since q_SC and q_SCR are highly correlated and of similar relevance for piglet survival, they could be merged into one redefined score before implementing it into a breeding goal. Previous work has attempted to define one modified score of maternal carefulness and communication. For instance, during each standing-to-lying event, the presence of sow behaviors such as sniffing piglets, rooting or pawing the floor, standing-to-lying carefully as well as the presence of piglets in the danger zone at standing-to-lying have been used (Špinka et al., 2000; Valros et al., 2002; Yun et al., 2013). However, under commercial conditions, maternal care traits should be scored as simply as possible and be validated to include it in the Norwegian national recording system "Ingris". The Ingris database already has information on production (growth and feed efficiency), carcass and meat quality (lean meat, intramuscular fat, drip loss, killing out), reproduction (weaning to services intervals), robustness (legs, toe, hernia, cryptorchism, arthritis, shoulder lesions, body condition, etc.), litter size (total born and stillborn) and indirect maternal ability (piglet survival, litter weight at 21 days, total number of teats, and reduction in inverted teats). Thereafter, the relationship between maternal care traits and other registered traits included in Ingris will be investigated. Genetic parameters have to be estimated for maternal care traits and their inherited properties calculated. Calculation of genetic variation, heritability and genetic correlation between maternal traits and other important traits implemented in the breeding goal of Norsvin Landrace will be estimated. Maternal care traits will be analyzed regarding their effect on piglet mortality, both as phenotypes and breeding values. Finally, the results from the genetic analysis will be the basis for determining the behavioral traits that the producers will continue to record and that we will select for, give an optimal weight and implement the traits in the operative breeding goal.

Currently, we have knowledge of which maternal care traits are directly related to piglet survival. Still, we need to know what farmers or caretakers are able to register practically under commercial conditions, and how effective these scores are compared to other factors on the farm (i.e. management, environment) that also influence production parameters. Afterwards, we can determine which traits can be feasibly measured and identify ways of implementing maternal care traits into the breeding goal. Although this scores were already tested with three experimental persons and all farmers were pre-trained, there is still a need to ensure that the farmers perceive the scores in the same way in future studies.

In conclusion, this study defined maternal care traits important for reducing piglet deaths and improving pre-weaning survival, as well as successfully developed simple qualitative scoring systems of these maternal care traits. Our scoring systems showed that sows that spent more time preparing their nest prior to parturition and communicated more with piglets (sniffing, grunting, nudging), were more careful (while standing, moving around or before lying down), and had lower overall piglet mortality due to less crushing. Thus, those sows weaned more piglets. In addition, higher communication with piglets was also associated with a lower proportion of starved piglets. Because of variance in our scores (nest building, sow communication and carefulness) and the fact they are not affected by parity or litter size, our findings indicate that it will be possible to select for this trait after testing in commercial herds.

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