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1 The effect of post-farrowing ketoprofen on sow feed intake, nursing behaviour and

- 2 piglet performance
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14 Abstract

Farrowing is a critical time for sows and piglets. Poor post-farrowing sow recovery, 15 and piglet mortality represent a welfare concern, as well as an economic loss to the pig industry. 16 17 Providing a non-steroidal anti-inflammatory drug (NSAID) to the sow post-farrowing may improve sow welfare and productivity and thereby improve health status and welfare of the 18 piglets, which would be of economic benefit to pig producers. This study investigated the 19 production effects of providing the NSAID ketoprofen post-farrowing, to 24 primiparous (gilts) 20 21 and 32 multiparous (sows) breeding pigs, in a randomised, blinded, placebo-controlled trial. 22 Gilts and sows were allocated to receive ketoprofen (treated) or the equivalent volume of saline (control) by intramuscular injection 1.5 hours after the last piglet birth. Data collected included 23 24 sow feed intake, immune transfer (colostrum and piglet serum immunoglobulin-G (IgG)), 25 nursing behaviour and piglet weight, and mortality. An additional factor in this study was that 13 individuals required additional treatment in the days after farrowing for post-farrowing 26 27 illness. Therefore, data were analysed using mixed models, including treatment (treated or 28 control), parity group (gilt or sow), and additional treatment (yes or no) as fixed factors. Stepwise binomial logistic regression was used to analyse the association between the 29 experimental factors (treatment, additional treatment, gilt or sow), along with other gilt/sow, 30 litter, and piglet-based measures, with piglet death before weaning. Few treatment effects were 31 seen, with parameters being more affected by whether gilts and sows were treated for illness, 32 33 or between gilts and sows. The only variable to differ by treatment was suckle grunt duration, which was greater for control compared with treated dams (P = 0.05). Feed consumption was 34 greater for sows compared with gilts on days 6 and 7 post-farrowing, and serum IgG was 35 greater in piglets from sows than gilts (P < 0.05). Feed consumption was reduced in dams 36 needing additional treatment, from days 2-7 post-farrowing, and those developing illness 37 consumed less feed overall (P = 0.004). The best regression model for predicting the odds of a 38

piglet dying before weaning included number born alive (P = 0.03), requiring additional treatment (P = 0.006), being male (P = 0.0005), and pre-farrowing gilt/sow back-fat (P < 0.0001), which increased the log-odds of death, whereas, piglet body weight decreased the logodds of death (P < 0.0001). This study did not demonstrate clear benefits to ketoprofen, however, high individual variation in piglet mortality, indicates potential for targeted NSAID use.

45

46 Keywords: farrowing; ketoprofen; nursing behaviour; pain; performance; sow

47 Introduction

Farrowing is a critical time in pig production. A common feature of modern pig 48 production is increased litter size, and as the sow must produce enough milk to feed the litter, 49 50 feed volume and composition must adjust to cope with the increased demand (Theil, 2015). Further, each piglet must have access to a functioning teat as soon as possible after birth to 51 consume colostrum, followed by milk in order to survive (Baxter et al., 2013). Therefore, the 52 sow must recover quickly following farrowing, including feeding and drinking. However, at 53 that time the immunocompetence of the sow is impaired and as parturition is physically 54 55 demanding, the vulnerability to illness in early lactation is increased (Friendship and O'Sullivan, 2015). 56

Post-partum dysgalactia syndrome (PPDS) describes any condition that affects milk
production in the sow, including infections of the uterine tract (metritis) and udder (mastitis),
but milk production can also decline with no obvious signs of infection (Klopfenstein et al.,
2006). A number of non-infectious causes of PPDS have been discussed (Klopfenstein et al.,
2006) and pain experienced by the sow could contribute to a decreased interest in the piglets

and a reduction in milk let down (Peltoniemi and Oliviero, 2015). This has resulted in recent
research administering non-steroidal anti-inflammatory drugs (NSAIDs) post-farrowing and
measuring the benefits to health, welfare and productivity (Homedes et al., 2014; Mainau et
al., 2016, 2012; Sabaté et al., 2012; Tenbergen et al., 2014; Viitasaari et al., 2014, 2013).

A previous study, involving 15 commercial farms, investigated the production benefits 66 of providing the NSAID ketoprofen post-farrowing to all sows, and demonstrated a reduction 67 in piglet mortality and a greater number of piglets weaned (Homedes et al., 2014). Another 68 69 study found no piglet performance benefits of administering ketoprofen, but did identify other sow health and welfare benefits including a reduced loss in back-fat, body condition and 70 constipation, less severe shoulder sores, and a delay in feed refusal (Viitasaari et al., 2013). 71 Two studies in which meloxicam was administered after farrowing found no mortality 72 differences but did show an increased average daily weight gain of low birth weight piglets 73 74 (Mainau et al., 2012) and a tendency for increased piglet weight gain of litters of 11 to 13 75 piglets (Tenbergen et al., 2014). Another study using oral meloxicam, demonstrated 76 improvements in piglet weaning weight, average daily gain, and plasma IgG concentrations measured on day 1 and 2 post-farrowing (Mainau et al., 2016). The administration of NSAIDs 77 in addition to antibiotics has also been shown to aid in treatment of infectious causes of PPDS 78 (e.g. Hirsch et al., 2003; Tummaruk and Sang-Gassanee, 2013) and on a farm with a high 79 incidence of PPDS, piglet mortality was reduced and the number of piglets weaned increased 80 in sows given ketoprofen and antibiotics (Sabaté et al., 2012). 81

Ketoprofen is an NSAID with anti-inflammatory, analgesic, and antipyretic properties,
which was shown to reach maximum levels approximately one hour after intramuscular (IM)
injection in pigs (Raekallio et al., 2008), and reduced nociceptive thresholds in piglets with
kaolin-induced inflammation up to 24 hours after IM injection (Fosse et al., 2011). This study
investigated the use of ketoprofen after farrowing for primiparous (hereafter referred to as gilts)

and multiparous (referred to as sows) breeding pigs. The aim was to evaluate the benefits of
post-farrowing ketoprofen in terms of: i) gilt/sow feed intake; ii) immune transfer using IgG
from colostrum and piglet serum; iii) piglet performance including growth and mortality; and
iv) nursing behaviour. Based on previous studies, our hypothesis was that prompt postfarrowing treatment with ketoprofen improves sow recovery, including feed intake, and piglet
performance through immune transfer and nursing behaviour.

93 Materials and Methods

94 This experiment was carried out under UK Home Office Licence, in compliance with
95 EU Directive 2010/63/EU and following approval from the SRUC Animal Welfare and Ethical
96 Review Body (AWERB).

97 Animal housing and husbandry

Thirty-two Large White \times Landrace multiparous (mean parity 4.63 \pm 0.43) and 24 98 primiparous sows were used in this study. The study was carried out at the SRUC pig research 99 farm (Midlothian, UK), with gilts and sows farrowing in nine batches between February and 100 101 October 2014. No more than five days before the expected farrowing date, gilts and sows were moved into individual farrowing crates $(1.8 \times 0.5 \text{ m})$, with solid concrete flooring $(1.8 \times 1.5 \text{ m})$ 102 m), a small slatted area at the back $(0.5 \times 0.5 \text{ m})$ and a water and feed trough at the front. Piglets 103 104 had access to a heated creep area $(1.5 \times 0.65 \text{ m})$ in front of the water and feed trough. Gilts and sows were fed a standard pelleted lactation diet twice daily at 0745 and 1530 and had 105 continuous access to fresh water. Gilt and sow crates were cleaned daily at the morning feed, 106 107 and they were provided with fresh, long-stemmed straw. Additional straw was added and manure removed at the afternoon feed in the days preceding farrowing. Lights were switched 108 109 on immediately before the morning feed, turned off at 1630 and an additional night-light was provided in the centre of each room of crates. 110

During the experiment and only after the six hour post-injection data collection, cross-111 fostering was conducted where necessary to even up litter sizes to maximise piglet survival as 112 per normal farm practice. Cross fostering was conducted regardless of experimental treatments. 113 When litter sizes were uneven, the largest piglet(s) were removed and placed on a gilt or sow 114 with a smaller litter. Beyond the time of cross-fostering, data for individual foster piglets was 115 then recorded against the foster sow. Piglets received an intramuscular injection of iron on day 116 3 post-farrowing, and on the fourth week after farrowing (mean age 26.39 ± 0.20), weaning 117 took place. At weaning, piglets were ear tagged and vaccinated (CircoFLEX) as per farm 118 119 practice.

120 Blinding and treatments

This study was a randomised, blinded, placebo controlled trial, with gilts and sows 121 allocated to receive a single intra-muscular (IM) injection of ketoprofen (Ketofen; Merial 122 Animal Health Limited, Harlow, Essex, UK) or the equivalent volume of saline, 90 minutes 123 following the birth of the last piglet. Gilts and sows in each batch were randomly allocated to 124 receive either ketoprofen (treated; 3 mg per kg bodyweight or 1 ml per 33 kg pre-farrowing 125 bodyweight rounded down to the nearest 0.5 ml) or the equivalent volume of saline as a placebo 126 control (control). The 56 individuals were balanced as much as possible across batches and for 127 128 parity over the two treatment groups, however, an error in the treatment allocation, resulted in unbalanced groups for gilts (gilts: treated, n = 11, control, n = 13; sows: parity 2 to 4; treated, 129 n = 9, control, n = 8; parity 5 to 7; treated, n = 5, control, n = 6; parity 8+; treated, n = 2, control, 130 131 n = 2). One experimenter allocated individuals to the two treatment groups and a second added the ketoprofen or saline to individual brown medicine bottles, sealed with rubber stoppers 132 (Adelphi Healthcare Packaging, Haywards Heath, West Sussex, UK), which were labelled only 133 with the individual gilt or sow ear tag for identification. Ketofen contains the active ingredient 134

ketoprofen at 100 mg/ml contained in a solution of l arginine, benzyl alcohol (10 mg/ml), citric
acid monohydrate and water. It is a clear colourless solution, with low viscosity, making it
indistinguishable from the saline placebo to the third experimenter administering the injection,
who was unaware of the treatment.

Individuals were closely monitored for signs of farrowing, by observation at twice daily 139 feeding and through remote monitoring using a CCTV digital surveillance system around the 140 clock. Once the piglet expulsion phase began, the time of each piglet birth was recorded; and 141 142 90 minutes after the last piglet birth and the gilt or sow appeared to have finished farrowing, 143 ketoprofen or saline was administered by intra-muscular injection. Ketoprofen or saline were injected into the neck muscle, just behind the ear using an 18 gauge, 1.5 inch needle attached 144 to a PVC extension tube and using a 10 or 20 ml syringe (Henry Schein Animal Health, 145 Dumfries, Dumfries and Galloway, UK). Following treatment administration, individuals were 146 left undisturbed. 147

148 <u>Piglet measurements</u>

Six hours after the treatment administration, the litters were processed and three piglets 149 per litter were blood sampled. All piglets were collected and shut into the heated creep area 150 during processing. Each piglet was weighed, crown-rump length measured (from the tail base 151 to the top of the crown, in between the ears) and were labelled numerically on the back with a 152 permanent marker. Three piglets per litter were selected to be blood sampled for 153 154 immunoglobulin-G (IgG), based on weight: one less than 1.3 kg, one between 1.31 and 1.63 kg and one greater than 1.64 kg, balanced across litters for sex. If piglets at all weight ranges 155 were not available, alternatives were selected as close as possible, and very weak piglets were 156 avoided. 157

Selected piglets then had a topical local anaesthetic cream (EMLA) applied to their 158 right ear. Each piglet was then held, while cotton wool soaked in hot water was applied to the 159 right ear to promote vasodilation. A general purpose surgical steel lancet (HawksleyVet, 160 Lancing, Sussex, UK) was used to make a small incision in the most prominent ear vein. Blood 161 was allowed to pool briefly and collected into at least five 50 µl plain capillary tubes 162 (HawksleyVet, Lancing, Sussex, UK). Blood was left to coagulate in the tubes for one hour at 163 room temperature, before being sealed at one end using Cristaseal wax plates (HawksleyVet, 164 Lancing, Sussex, UK), and then placed into a micro haemocrit centrifuge (HawksleyVet, 165 166 Lancing, Sussex, UK) for 1.5 minutes at 13,000 g. The end of the tube containing the condensed cells was cut off and the serum was pushed out of the remaining section of tube 167 using a clean needle and syringe into a clean, pre-labelled 1.5 ml tube. Samples were then 168 169 stored at -70 °C to be assayed at a later date.

170 On day three post-farrowing, piglets were weighed when they were given a routine iron injection. At weaning, piglets were weighed and their crown-rump distance measured. All 171 172 piglet deaths from birth to weaning were recorded and the cause of death identified by visual examination, and from video recording, including: still birth, crushing by the sow, low 173 viability, starvation, savaged, 'greasy pig' (exudative epidermatis) and 'other' (unidentified 174 causes). During the experiment, several litters were affected by exudative epidermatis, a 175 bacterial skin infection, which was unrelated to the study, and was treated with long-acting 176 antibiotics (amoxicillin). 177

178 <u>Gilt and sow measurements</u>

On moving in before farrowing and out at weaning, all gilts and sows were weighed,
body condition scored (1 = very thin, 2 = thin, 3 = not too thin, not too fat, 4 = fat, 5 = very fat)

and had their back-fat depth measured at the P2 position (Piglog 105; Carometec Food
Technology, Smørum, Denmark).

At six hours after the treatment during piglet processing, a colostrum sample was collected from the dams. This was done by gently rubbing the udder, to ensure the dam was calm, then expressing colostrum from as many different teats as possible into a clean 30 ml plastic tube. Approximately 5 ml of colostrum was collected in the tube before pipetting into three 1.5 ml pre-labelled tubes, which were stored at -20°C to be assayed for IgG at a later date.

188 Gilt and sow feed intake was recorded on the day of farrowing, until seven days postfarrowing. Individuals were fed a standard pelleted lactation diet consisting of 16.4% crude 189 protein, 6.8 % crude oils and fats, 4.0% crude fibre, 5.8% crude ash, 13.8% moisture, 0.8% 190 191 calcium, 0.94% lysine, 0.25% methionine, 0.51% phosphorus and 0.22% sodium. Gilts and sows were fed, based on a feed chart, which was adjusted slightly according to the size, body 192 condition and appetite of the individual (e.g. gilts were fed slightly less than sows and a reduced 193 body condition score was given slightly more feed). Feed intake was restricted, and increased 194 gradually from day 0 to day 7. The amount fed was marked on the feed chart (in kg) and the 195 196 amount left over from the previous feed was removed, weighed and recorded at the next feeding time. 197

198 <u>Behaviour</u>

199 Closed-circuit television (CCTV) cameras (LL20, infra-red cameras, FR concepts, 200 Ireland) were mounted above each farrowing crate and were connected to a computer to record 201 behaviour using GeoVision Digital Surveillance System software (ezCCTV ltd, Herts, UK). 202 This surveillance system was also set up to enable remote monitoring of individuals. Digital 203 video footage was collected and stored to be observed later using The Observer XT 11.0 204 (Noldus Information Technology, Wageningen, The Netherlands). Three hour observations 205 were made for suckling behaviour between 15 and 18 hours after the last piglet was born, to coincide with a regular pattern of milk let down and udder massage by the piglets, (Castren et 206 al., 1989) which enabled obvious nursing bouts to be recognised on video. The frequencies and 207 208 duration of suckle grunting (rapid flank movements indicating suckle grunting), whether more than 50% of piglets were active at the udder (performing udder massage/rapid suckling 209 movements), as well as gilt and sow posture (stand, sit, kneel, lie lateral, lie ventral) and 210 drinking behaviour (snout in the drinking trough with head movements indicating drinking 211 behaviour) were recorded. 212

213 Analysis of Immunoglobulin G (IgG) concentrations

Sow colostrum and piglet serum samples were assayed for IgG using an enzyme linked immunosorbent assay (ELISA) kit (Bethyl Laboratories, Inc., Montgomery, Texas, USA). Colostrum and serum samples were removed from the freezer and allowed to thaw gradually at 4 °C overnight before the assay. On the day of the assay, samples were removed from the fridge, placed at room temperature for 30 minutes before further preparation.

Colostrum samples were centrifuged twice at 16,249 g for 2 minutes, removing the fat layer after each spin. Serum samples were centrifuged for one minute at 865 g. Assays were then conducted according to the manufacturer's instructions, with samples tested in duplicate. A test assay was run, indicating that a 1:500,000 dilution was best for both sample types. This dilution was created using serial dilution in, un-coated V-bottomed 96-well plates.

224 Quality control (QCs) samples were created using pooled colostrum samples to run 225 across and between plates to measure drift within and between plates. To avoid drift in the time 226 taken to add the samples to the coated plate, 130 μ l of standards, blanks, samples and QCs were 227 added to an uncoated 96-well plate according to the plate layout, before using a multi-channel 228 pipette to transfer into the coated plate. The plate was read using a MultiskanTM FC Microplate Photometer plate reader and results calculated using a 5 point logistic regression curve using Thermo Scientific SkanItTM for MultiskanTM FC software (version 2.5.1) (Thermo Fisher Scientific Inc, Waltham, Massachusetts, USA). Samples were spread across nine assay runs, balanced as much as possible for treatment, sample type (colostrum or serum), for gilts and sows and between farrowing batches. Duplicate samples with a coefficient of variation (CV) above 10% were repeated and those that failed to reach a CV% of less than 10% were left as missing values. The assay range was 1.37 - 1000 ng/ml.

The lower and upper detectable limits of the samples analysed were 4.76 and 77.37 ng/ml respectively. The average intra-assay CV was 6.66% (7.79, 6.91, 4.51, 6.69, 9.35, 6.17, 6.58, 9.07 and 2.82 for assay runs 1 to 9 respectively) and the inter-assay CV was 8.69%.

239 Data analysis

Unless stated at the start of each results section, data were available for all individuals. 240 241 Due to an error in the treatment allocation for gilts, there were 11 gilts and 16 sows in the ketoprofen treated group and 13 gilts and 16 sows in the saline control group. An additional 242 factor in this study was that 13 individuals; 5 gilts (4 treated and 1 control treatment) and 8 243 244 sows (4 treated and 4 control treatments) required additional treatment in the days after farrowing for PPDS. Therefore, data were analysed by treatment (treated vs. control), parity 245 group at the level of gilt vs. sow and whether additional treatment was needed (yes vs. no). All 246 247 data were analysed and descriptive statistics calculated using R version 3.3.1 (R core team, 2013). All figures were plotted using the ggplot2 function, and any correlations were conducted 248 using the spearman test function. Results were considered statistically significant at P < 0.05. 249

250 Feed intake

Feed consumed was analysed with linear mixed models, using the lmer function, with dam identity and batch in the random model. Initially, total feed consumed was analysed with treatment (treated or control), parity group (gilt or sow) and additional treatment (yes or no) and their interactions as fixed factors. Then each of the factor interactions with day was tested (0, 1, 2, 3, 4, 5, 6, and 7), including: day × treatment, day × gilt/sow and day × additional treatment. Post hoc analyses were conducted using the lsmeans function.

257 Immunoglobulin-G(IgG)

258 Colostrum IgG concentrations (mg/ml) were analysed using linear mixed models with the lmer function, with batch in the random model. Treatment (treated or control), parity group 259 (gilt or sow) and additional treatment (yes or no), and their interactions, and the number of 260 261 piglets born alive were added as fixed factors. Piglet serum IgG was also analysed using the lmer function, with dam identity and batch in the random model, also with treatment (treated 262 or control), parity group (gilt or sow) and additional treatment (yes or no) and their interactions, 263 and piglets born alive as fixed factors. A Spearman's rank correlation coefficient was 264 calculated between piglet weight (kg) and IgG concentration (mg/ml), resulting in no 265 significant correlation (rho = 0.039, P = 0.64), therefore piglet weight was not included in the 266 model. 267

268 *Production data*

The frequency of piglets born alive, still born, and number weaned, as well as live-born pre-weaning deaths were analysed at the litter level with a generalized linear mixed model, using the glmer function, using a Poisson distribution and log link function. Sow weights, batfat thickness, and piglet weights and crown rump distances were analysed using linear mixed 273 models with the lmer function. The number of piglets born alive was included as a random variable in the piglet mortality model. Gilt/sow identity and batch were included in the random 274 model for the piglet measures, and batch for the sow measures. Treatment, additional treatment, 275 276 gilt or sow and the interactions as fixed factors in all models. No piglets were fostered before the 6 hour post-injection sampling, therefore fostered piglets were analysed with their birth 277 dam for the 6 hour post-injection measures, and with their foster dam for the other piglet 278 measures. Sow weight and back-fat thickness was then analysed with moving in or post-279 weaning as a fixed factor, also with batch and ID in the random model. Body condition scores 280 281 were analysed with ordinal logistic regression models using the polr function, with treatment, additional treatment, gilt or sow and the interactions, and batch as fixed factors, and with 282 moving-in or post-weaning, and batch as fixed factors. 283

Piglets that were born alive were allocated as dead (yes) or alive (no) by weaning. A 284 stepwise binomial logistic regression was conducted using the glm and AIC.step functions, to 285 286 analyse associations between variables, and whether piglets died before weaning (yes or no). Variables included: treatment (treated or control), additional treatment (yes or no), gilt or sow, 287 batch, litter size at birth, piglet gender, piglet post 6 hour weight, and whether the piglet was 288 fostered (yes or no), as well as sow back-fat, body condition score, farrowing duration 289 (previously obtained from video footage), and lie lateral duration from behavioural 290 observations. Variables were chosen, based on available data, and including known risk factors 291 for piglet mortality (e.g. Baxter and Edwards, 2015). 292

293 Behaviour

Postures (stand, sit, kneel, lie lateral, lie ventral), suckle grunting and the duration when there were more than 50 % of piglets active at the udder, were converted to percentages of the three hour observation duration. The frequency of posture changes during the three hour observation period was also calculated. Individual bouts of suckle grunting were exported from
The Observer for each gilt or sow, to calculate the frequency of bouts, the mean duration of
each bout, and the mean inter-bout intervals. These behavioural variables were analysed using
linear mixed models with the lmer function, including treatment (treated or control), parity
group (gilt or sow) and additional treatment (yes or no) and their interactions as fixed factors,
with batch in the random model.

303 **Results**

304 Feed intake

305 Total feed consumed did not differ by treatment \times gilt/sow (t = -0.49, P = 0.62), treatment \times additional treatment (t = 1.39, P = 0.17), or gilt/sow \times additional treatment (t = 306 1.19, P = 0.23), by treatment (t = 0.33, P = 0.74), or between gilts and sows (t = 1.37, P = 0.17) 307 (Fig.1). However, total feed consumed differed by day \times additional treatment (t = -3.65, P = 308 0.0003), day \times gilt/sow (t = 3.20, P = 0.002), and overall by additional treatment (t = -2.92, P 309 = 0.004). Post hoc analysis revealed that sows consumed more feed compared with gilts on 310 days 6 and 7 post-farrowing (Fig.1 b) and that although individuals requiring additional 311 312 treatment consumed less feed throughout, the difference was not significant until day 2 post farrowing (Fig.1 c). 313

314 <u>Immunoglobulin-G (IgG)</u>

Colostrum IgG concentrations were available for 52 of the 56 gilts and sows. No significant interactions (treatment × gilt/sow: t = 0.40, P = 0.69; treatment × additional treatment: t = 0.85, P = 0.40; gilt/sow × additional treatment: t = -0.32, P = 0.75) were found, or differences for treatment (t = -0.81, P = 0.42), between gilts and sows (t = 0.73, P = 0.47), or with additional treatment (t = -0.14, P = 0.89) (Fig.2, A-C). Of the 168 piglets that were blood sampled, serum IgG concentrations were available for 147 piglets. There were no differences by treatment × gilt/sow (t = -0.75, P = 0.46), treatment × additional treatment (t = 1.03, P = 0.31), or gilt/sow × additional treatment (t = -0.78, P = 0.44). Piglets from sows had greater IgG concentrations than those from gilts (t = 2.10, P = 0.04), but piglet serum IgG, did not differ by treatment (t = -0.15, P = 0.88), or additional treatment (t = -0.22, P = 0.82) (Fig.2, D-F).

326 Production data

Table 1 presents production information, including litter, gilt/sow- and piglet-based 327 measures, by treatment, for gilts and sows, and by additional treatment. Table 2 presents the 328 329 total frequencies and causes of death, and frequencies of piglets fostered on and off treated and control gilts and sows, to illustrate the total numbers of piglet deaths by treatment for gilts and 330 sows, and the imbalance in piglet fostering between treatments. Figure 3 is a dot plot showing 331 the number of live-born deaths for individual treated and control gilts and sows, which shows 332 the individual variation in piglet pre-weaning deaths. There were no significant treatment \times 333 gilt/sow, treatment × additional treatment, or gilt/sow × additional treatment interactions for 334 any of the results presented in Table 1 (P > 0.05). As shown, none of the results presented 335 differed by treatment, or additional treatment (P > 0.05). However, pre-farrow and post-wean 336 337 weight differed between gilts and sows, as did the piglet weight and crown-rump measurements for piglets from gilts and sows (see Table 1). In addition, gilt or sow weight (t = -12.25, P <338 0.001), back-fat (t = -10.66, P < 0.001), and body-condition (t = -5.12, P < 0.001) were greater 339 overall pre-farrowing, compared with post-weaning. 340

Of the 705 piglets born alive, any row with missing values for any of the variables was excluded, leaving 659 rows of data for analysis. The best logistic regression model included the variables piglets born alive, additional treatment, piglet gender, sow back-fat, and piglet 6 hour post-injection weight, which were significant predictors of death before weaning. For every increase in piglet born alive in the litter, the log odds of dying before weaning increased (log-odds = 0.11, P = 0.03). Requiring additional treatment (log-odds = 0.87, P = 0.006), as well as being male (log-odds = 0.97, P = 0.0005) increased the log odds of dying before weaning. For every mm increase in gilt or sow back-fat, the log-odds of piglet death increased (log-odds = 0.16, P < 0.0001). Every kg increase in piglet 6 hour post-injection bodyweight, decreased the log-odds of dying before weaning, (log-odds = -4.18, P < 0.0001).

351 <u>Behaviour</u>

Behaviour was observed for 53 of the 56 individuals and results are shown in Table 2. 352 There were no significant interactions for treatment \times gilt/sow, treatment \times additional 353 treatment, or gilt/sow \times additional treatment, for any of the behaviours shown in Table 3 (P >354 0.05). For nursing behaviour, ketoprofen treated dams suckle grunted less (t = -2.02, P = 0.05) 355 than the controls, but there were no other differences between treatment groups, gilts and sows 356 357 and those requiring additional treatment or not (P > 0.05). For the postures observed, sitting and kneeling behaviour differed between gilts and sows (t = 2.08, P = 0.04 and t = 2.49, P =358 0.02 respectively), with greater values for sows compared with gilts. Lying lateral also differed 359 360 (t = -2.38, P = 0.02) with greater values for gilts than sows. There were no differences in drinking behaviour between treatment groups, gilts and sows or those requiring additional 361 treatment or not (P > 0.05). 362

363 Discussion

This study investigated effects of the provision of the NSAID ketoprofen to gilts and sows following farrowing. Few effects of the treatment were seen, with production parameters being more affected by whether individuals were treated for disease, or between gilts and sows.

367 <u>Feed intake</u>

In contrast to a previous study (Viitasaari et al., 2013), there was no difference in feed 368 369 consumption by gilts or sows given ketoprofen compared with controls. The previous study administered ketoprofen for three consecutive days following farrowing, which could have had 370 371 a greater effect on sows, and overall feed refusal rather than consumption was measured 372 (Viitasaari et al., 2013). In another study where the NSAID meloxicam was administered for three days post-farrowing, feed intake was not affected by drug treatment, but a difference 373 between primiparous and multiparous sows was found, as multiparous sows had consumed a 374 375 greater number of meals within an hour of feeding on days one, two and three post-farrowing (Mainau et al., 2012). In the current study, sows consumed more feed than gilts on days six and 376 seven post-farrowing, as sows increased their feed intake at a greater rate than gilts. The feed 377 that was not consumed was only measured at the next feeding time in this study, whereas the 378 previous study scored feed as being completely consumed or not, one hour after it was given 379 380 (Mainau et al., 2012). From day two after farrowing, and overall, there was a difference in the amount of feed consumed by individuals that required additional treatment compared to those 381 that did not. This is not surprising as reduced feed intake is a good indicator of illness. In future 382 383 studies, it would be interesting to measure the latency to feed and the time taken to fully consume the meal, as this could be an early indicator of subclinical PPDS and prompt treatment 384 could produce a better outcome for the sow and litter. 385

386 <u>Immune transfer</u>

Piglets obtain passive immunity through the ingestion of immunoglobulin from sow colostrum (Rooke and Bland, 2002), and those with low concentrations of immunoglobulin are less likely to survive (Cabrera et al., 2012). Therefore, this is an important measure in identifying the benefits of administering post-farrowing NSAIDs. No differences in colostrum or piglet serum IgG concentrations were detected in this study with drug treatment or whether additional treatment was required. A previous study found greater colostrum concentrations of piglets on day one and two post-farrowing from sows given oral meloxicam at farrowing (Mainau et al., 2016). As piglets were numerically heavier at six hours post-injection in this study, which could indicate greater colostrum intake, a difference may have been found if piglets were sampled at later time points.

Some studies have shown a link between colostrum intake and piglet birth weight 397 (Devillers et al., 2007; Fraser and Rushen, 1992; Nguyen et al., 2013; Quesnel, 2011), although 398 399 the link between colostrum consumed and piglet plasma IgG concentration plateau over a certain value, i.e. the link is stronger at lower concentrations (Devillers et al., 2011). No 400 association between piglet weight and IgG at the point of sampling was found in this study, 401 which was similar to a previous study (Cabrera et al., 2012), however, this could be explained 402 by excessively small and/or weak piglets not being selected for blood sampling in the current 403 404 and previous study (Cabrera et al., 2012). In addition, Fraser and Rushen, (1992) suggest that the failure to find a link between birth weight and IgG could be because of differences in blood 405 volume (affecting the concentration) between large and small piglets. 406

Sow colostrum had a numerically greater IgG concentration than gilt colostrum, and 407 piglet serum IgG was greater for piglets from sows compared with gilts. No link between piglet 408 plasma IgG concentration and parity was detected at birth in one study (Quesnel, 2011), and 409 another study showed a similar result, although it was not mentioned whether primiparous sows 410 were included (Nguyen et al., 2013). Other studies measuring sow colostrum have found 411 412 differences by parity, including lower concentrations measured 24 hours after birth in lower parity sows (Quesnel, 2011) and lower colostrum IgG concentrations in primiparous compared 413 with multiparous sows 48-72 hours after birth (Cabrera et al., 2012). 414

415 <u>Production data</u>

There were no overall significant differences in pre-weaning piglet deaths, weight or 416 417 size by treatment, or between those requiring additional treatment or not. However, it is worth discussing that numerically fewer piglets died in the ketoprofen compared with the saline-418 treated group, especially for gilts. High individual variation in piglet mortality was seen in this 419 420 study, which possibly resulted in this difference not reaching significance. As piglet weight six 421 hours after the injection was also numerically greater in ketoprofen-treated gilts and sows, it is 422 also possible that piglet birth weight was greater for treated gilts and sows, resulting in the 423 mortality difference. It is also possible that ketoprofen treatment increased piglet weight at six hours through increased colostrum intake, however, based on previous studies measuring early 424 piglet weight gain, this may not have accounted for all of this weight difference (e.g. de Passillé 425 and Rushen, 1989; Fraser and Rushen, 1992; Quesnel, 2011). This cannot be confirmed, since 426 piglets were not weighed before the injection was given, and in a previous study, where 16 427 428 sows were randomly allocated to be given butorphanol tartrate or a saline placebo postfarrowing, Haussmann et al., (1999) found a significant difference in birth weight of the piglets, 429 with those from control sows being significantly heavier. So this may be an accidental outcome 430 431 in this study and an important consideration for the piglet mortality difference between treatment groups. 432

A reduction in piglet mortality with the use of ketoprofen post-farrowing has been demonstrated previously in a study of 15 commercial farms (Homedes et al., 2014) and on a farm with a high incidence of PPDS (Sabaté et al., 2012), but another study reported no difference in mortality with the use of ketoprofen (Viitasaari et al., 2013). The individuals responsible for the care of the animals in the current study were blind to the treatments, and cross-fostering was performed to even litter size, resulting in more piglets being fostered off 439 the ketoprofen-treated gilts and more piglets being fostered onto the control gilts. This meant, despite a difference in mortality, no difference in the numbers of piglets weaned was detected 440 between treatment groups for gilts, which is a result found in previously, where fostering was 441 442 only conducted within treatment groups (Homedes et al., 2014; Sabaté et al., 2012). If ketoprofen does have an influence on piglet mortality, given the individual variation in the 443 number of deaths, early identification to enable targeted use of drugs to those that could benefit 444 445 the most would be the best use of drugs. No difference in mortality between treatment groups was detected the post-farrowing administration of the NSAID meloxicam (Mainau et al., 2012; 446 447 Tenbergen et al., 2014) or with the opioid butorphanol tartrate (Haussmann et al., 1999). However, average daily weight gain of low birth weight piglets (<1180g) was increased 448 (Mainau et al., 2012), growth rate of medium sized litters (11 to 13 piglets) tended to be greater 449 450 (Tenbergen et al., 2014), and average daily gain and weaning weight was greater (Mainau et al., 2016) for multiparous sows treated with meloxicam compared with a placebo. 451

452 Piglet mortality in this study was most influenced by previously demonstrated risk factors, including piglet weight, sow back-fat, piglet gender, sow post-farrowing illness and 453 454 the number of piglets born alive (for a review see Baxter and Edwards, 2015). It is widely 455 agreed that birth weight is the most important factor in neonatal piglet survival and lower average piglet weight at six hours post-injection in this study was most strongly associated with 456 pre-weaning death. Larger litter sizes come at the expense of reduced piglet viability, as well 457 as increased competition for colostrum and milk (Baxter and Edwards, 2015). Interestingly, 458 greater sow back-fat was associated with an increase in the odds of a piglet dying before 459 460 weaning. A previous study using a high number of sows found a quadratic effect of sow backfat at farrowing on the number of piglets weaned, with low and high back-fat being associated 461 with fewer piglets weaned (Kim et al., 2015). Male-biased pre-weaning mortality has been 462 found elsewhere, where piglets born were male-biased, and males were heavier at birth (Baxter 463

et al., 2012). This demonstrates a life-history strategy in domestic pig populations, with greater
pre-natal maternal investment and an over-supply of more vulnerable males, in expectation of
greater mortality (Baxter et al., 2012). Litter from sows developing PPDS suffer greater
mortality (Klopfenstein et al., 2006), and treatment with NSAIDs in addition to antibiotics, can
aid in the treatment of infectious causes of PPDS (Sabaté et al., 2012; Tummaruk and SangGassanee, 2013).

470 <u>Behaviour</u>

471 Posture was observed during nursing behaviour observations, with no differences by treatment. Previous studies investigating the administration of ketoprofen (Viitasaari et al., 472 473 2014) and meloxicam (Mainau et al., 2012) for three consecutive days post-farrowing showed 474 differences in the level of activity between individuals given the NSAID or a saline placebo only on the third day post farrowing. This included a decrease in the time spent lying by 475 meloxicam treated gilts and sows (Mainau et al., 2012) and an increased activity in younger 476 (parity 2 -3) sows treated with ketoprofen, compared with their placebo treated counterparts, 477 although older sows did not differ (Viitasaari et al., 2014). Greater activity suggests an 478 improvement in the speed of recovery following parturition with the use of NSAIDs. By 479 contrast, another study, using the opioid analgesic butorphanol tartrate post-farrowing showed 480 a reduced number of posture changes 48 hours post farrowing (Haussmann et al., 1999). 481

Sows showed more sitting and kneeling behaviour compared with gilts, which could be related to the difference in size, weight and fitness between these two groups and the ease of changing body position. The gilts in this study spent more time lying lateral, in contrast to a previous study that showed younger sows to be more active (Viitasaari et al., 2014). This could be due to genetic improvements, as the gilts in this study were acquired directly from a breeding company, whereas the sows were home bred from an older genetic line of the same breed. Modern breeding programs have focused on maternal traits to improve productivity, which could be reflected in greater lateral lying, allowing piglets access to the udder. Although there were no significant differences in posture between individuals that required additional treatment for PPDS, numerical differences for postures and the frequency of posture changes indicate PPDS individuals appear less active and, as with a reduction in feed intake, could be used as an early indication of PPDS to provide prompt treatment.

For the nursing behaviours observed, there was greater suckle grunting in control, compared with ketoprofen-treated dams. These data could indicate that ketoprofen dams had settled into a pattern of milk let-down sooner, providing support for the fact that the weight difference between ketoprofen and control-treatment dams could be due to greater colostrum intake. No previous studies have recorded nursing behaviour in relation to the use of postfarrowing NSAIDs.

500 Conclusion

This study did not demonstrate production benefits to the immediate post-farrowing 501 administration of ketoprofen. However, in this study, as with others, high individual sow 502 variation in piglet mortality was seen, with some performing well and the majority of piglet 503 mortality often coming from a low number of sows (Baxter et al., 2015; Hales et al., 2013). 504 505 Investigating whether pain is a component of decreased performance in these sows, could enable the targeted use of drugs. Additionally, identifying sows that could benefit from pain 506 relief using measures of farrowing ease (e.g. Mainau et al., 2010), feed intake, activity and 507 other behaviour measures, could assist with targeted drug treatment. 508

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516 **References**

Baxter, E., Rutherford, K., D'Eath, R., Arnott, G., Turner, S., Sandøe, P., Moustsen, V., 517 Thorup, F., Edwards, S., Lawrence, A., 2013. The welfare implications of large litter 518 size in the domestic pig II: management factors. Anim. Welf. 22, 219–238. 519 doi:10.7120/09627286.22.2.219 520 Baxter, E.M., Adeleye, O.O., Jack, M.C., Farish, M., Ison, S.H., Edwards, S.A., 2015. 521 Achieving optimum performance in a loose-housed farrowing system for sows: the 522 523 effects of space and temperature. Appl. Anim. Behav. Sci. Baxter, E.M., Edwards, S.A., 2015. Piglet mortality: causes and prevention, in: Farmer, C. 524 (Ed.), The Gestating and Lactating Sow. Wageningen Academic Publishers, pp. 253-525 278. 526 527 Baxter, E.M., Jarvis, S., Palarea-Albaladejo, J., Edwards, S.A., 2012. The weaker sex? the propensity for male-biased piglet mortality. PLoS One 7. 528 doi:10.1371/journal.pone.0030318 529 Cabrera, R.A., Lin, X., Campbell, J.M., Moeser, A.J., Odle, J., 2012. Influence of birth order, 530 birth weight, colostrum and serum immunoglobulin G on neonatal piglet survival. J. 531 Anim. Sci. Biotechnol. 3, 42. doi:10.1186/2049-1891-3-42 532 Castren, H., Algers, B., Jensen, P., Saloniemi, H., 1989. Suckling behaviour and milk 533 534 consumption in newborn piglets as a response to sow grunting. Appl. Anim. Behav. Sci. 535 24, 227-238. doi:10.1016/0168-1591(89)90069-5 de Passillé, A.M.B., Rushen, J., 1989. Using Early Suckling Behavior and Weight Gain To 536 537 Identify Piglets At Risk. Can. J. Anim. Sci. 69, 535–544. doi:10.4141/cjas89-066 Devillers, N., Farmer, C., Le Dividich, J., Prunier, A., 2007. Variability of colostrum yield 538 and colostrum intake in pigs. Animal 1, 1033. doi:10.1017/S175173110700016X 539 Devillers, N., Le Dividich, J., Prunier, A., 2011. Influence of colostrum intake on piglet 540 541 survival and immunity. Animal 5, 1605–1612. doi:10.1017/S175173111100067X Fosse, T.K., Toutain, P.L., Spadavecchia, C., Haga, H. a., Horsberg, T.E., Ranheim, B., 2011. 542 543 Ketoprofen in piglets: Enantioselective pharmacokinetics, pharmacodynamics and PK/PD modelling. J. Vet. Pharmacol. Ther. 34, 338-349. doi:10.1111/j.1365-544 2885.2010.01236.x 545 Fraser, D., Rushen, J., 1992. Colostrum intake by newborn piglets. Can. J. Anim. Sci. 72, 1– 546 547 13. doi:10.4141/cjas92-001 Friendship, R.M., O'Sullivan, T.L., 2015. Sow health, in: Farmer, C. (Ed.), The Gestating 548 and Lactating Sow. Wageningen Academic Publishers, pp. 409-422. 549 Hales, J., Moustsen, V. a, Nielsen, M.B.F., Hansen, C.F., 2013. Higher preweaning mortality 550 in free farrowing pens compared with farrowing crates in three commercial pig farms. 551 Animal 8, 113-120. doi:10.1017/S1751731113001869 552 Haussmann, M.F., Lay, D.C., Buchanan, H.S., Hopper, J.G., 1999. Butorphanol tartrate acts 553 to decrease sow activity, which could lead to reduced pig crushing. J. Anim. Sci. 2054-554 555 2059.

- Hirsch, A.C., Philipp, H., Kleemann, R., 2003. Investigation on the efficacy of meloxicam in
 sows with mastitis-metritis-agalactia syndrome. J. Vet. Pharmacol. Ther. 26, 355–60.
- Homedes, J., Salichs, M., Sabaté, D., Sust, M., Fabre, R., 2014. Effect of ketoprofen on preweaning piglet mortality on commercial farms. Vet. J. 201, 435–7.
 doi:10.1016/j.tvjl.2014.05.038
- Kim, J.S., Yang, X.J., Pangeni, D., Baidoo, S.K., 2015. Relationship between backfat
 thickness of sows during late gestation and reproductive efficiency at different parities.
 Acta Agric. Scand. Sect. A Anim. Sci. 65, 1–8. doi:10.1080/09064702.2015.1045932
- Klopfenstein, C., Farmer, C., Martineau, G.-P., 2006. Diseases of the mammary glands, in:
 Straw, B.E., Zimmermans, J.J., D'Allaire, S., Taylor, D.J. (Eds.), Diseases of Swine.
 Blackwell Publishing, pp. 57–85.
- Mainau, E., Dalmau, a, Ruiz-de-la-Torre, J.L., Manteca, X., 2010. A behavioural scale to
 measure ease of farrowing in sows. Theriogenology 74, 1279–87.
 doi:10.1016/j.theriogenology.2010.05.034
- Mainau, E., Ruiz-de-la-Torre, J.L., Dalmau, A., Salleras, J.M., Manteca, X., 2012. Effects of
 meloxicam (Metacam®) on post-farrowing sow behaviour and piglet performance.
 Animal 6, 494–501. doi:10.1017/S1751731111001790
- Mainau, E., Temple, D., Manteca, X., 2016. Experimental study on the effect of oral
 meloxicam administration in sows on pre-weaning mortality and growth and
 immunoglobulin G transfer to piglets. Prev. Vet. Med. 126, 48–53.
 doi:10.1016/j.prevetmed.2016.01.032
- Nguyen, K., Cassar, G., Friendship, R.M., Dewey, C., Farzan, a, Kirkwood, R.N., Hodgins,
 D., 2013. An investigation of the impacts of induced parturition, birth weight, birth
 order, litter size, and sow parity on piglet serum concentrations of immunoglobulin G. J.
 swine Heal. Prod. 21, 139–43.
- Peltoniemi, O.A.T., Oliviero, C., 2015. Housing, management and environment during
 farrowing and early lactation, in: Farmer, C. (Ed.), The Gestating and Lactating Sow.
 Wageningen Academic Publishers, pp. 231–252. doi:10.3920/978-90-8686-803-2
- Quesnel, H., 2011. Colostrum production by sows: variability of colostrum yield and
 immunoglobulin G concentrations. Animal 5, 1546–1553.
 doi:10.1017/S175173111100070X
- Raekallio, M.R., Mustonen, K.M., Heinonen, M.L., Peltoniemi, O.A.T., Säkkinen, M.S.,
 Peltoniemi, S.M., Honkavaara, J.M., Vainio, O.M., 2008. Evaluation of bioequivalence
 after oral, intramuscular, and intravenous administration of racemic ketoprofen in pigs.
 Am. J. Vet. Res. 69, 108–113.
- Rooke, J.A., Bland, I.M., 2002. The acquisition of passive immunity in the new-born piglet.
 Livest. Prod. Sci. 78, 13–23. doi:10.1016/S0301-6226(02)00182-3
- Sabaté, D., Salichs, M., Bosch, J., Ramó, P., Homedes, J., 2012. Efficacy of ketoprofen in the
 reduction of pre-weaning piglet mortality associated with sub-clinical forms of postpartum dysgalactia syndrome in sows. Pig J. 67, 19–23.
- 596 Tenbergen, R., Friendship, R., Cassar, G., Amezcua, M.R., Haley, D., 2014. Investigation of

- the use of meloxicam post farrowing for improving sow performance and reducing pain.J. Swine Heal. Prod. 22, 10–15.
- Theil, P.K., 2015. Transition feeding of sows, in: Farmer, C. (Ed.), The Gestating and
 Lactating Sow. Wageningen Academic Publishers, pp. 147–172.
- Tummaruk, P., Sang-Gassanee, K., 2013. Effect of farrowing duration, parity number and the
 type of anti-inflammatory drug on postparturient disorders in sows: A clinical study.
 Trop. Anim. Health Prod. 45, 1071–1077. doi:10.1007/s11250-012-0315-x
- Viitasaari, E., Hänninen, L., Heinonen, M., Raekallio, M., Orro, T., Peltoniemi, O., Valros,
 A., 2013. Effects of post-partum administration of ketoprofen on sow health and piglet
 growth. Vet. J. 198, 153–157. doi:10.1016/j.tvjl.2013.06.013
- Viitasaari, E., Raekallio, M., Heinonen, M., Valros, A., Peltoniemi, O., Hänninen, L., 2014.
 The effect of ketoprofen on post-partum behaviour in sows. Appl. Anim. Behav. Sci.
 158, 16–22. doi:10.1016/j.applanim.2014.06.005
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Fig.1. Mean ± SEM of the total feed consumed (kg) per day by a) treatment (treated or
control); b) gilts and sows and; c) additional treatment (yes or no). Bars with a * indicate a
significant difference (P < 0.05).

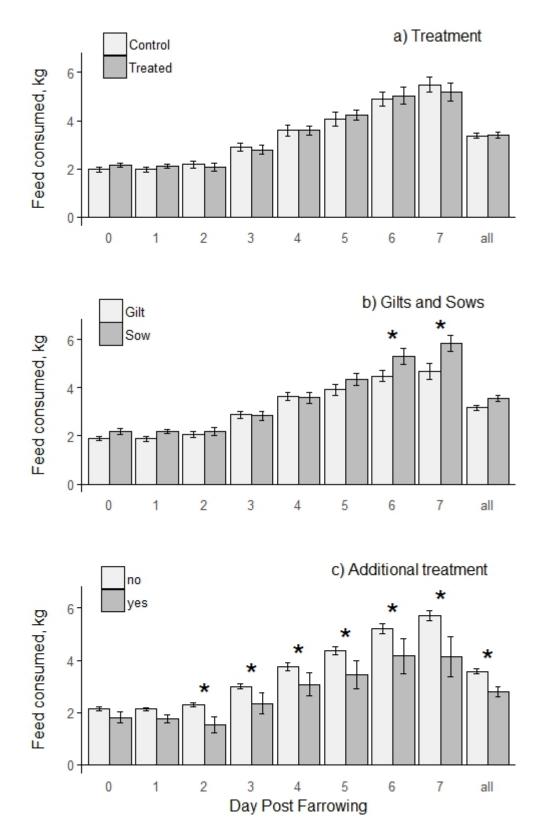
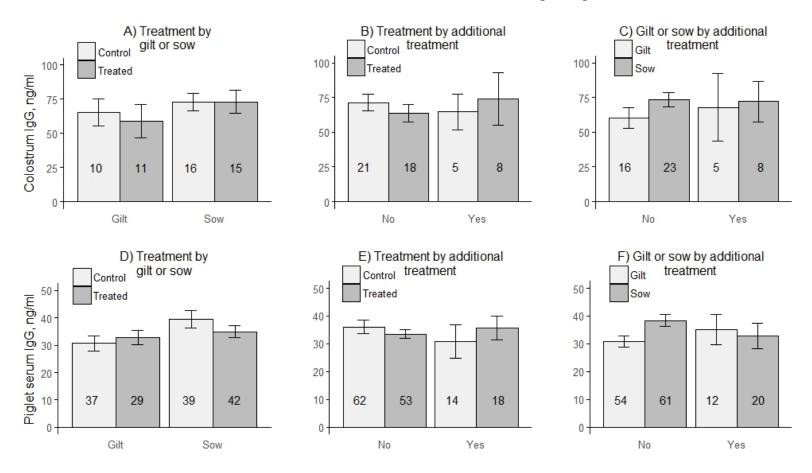
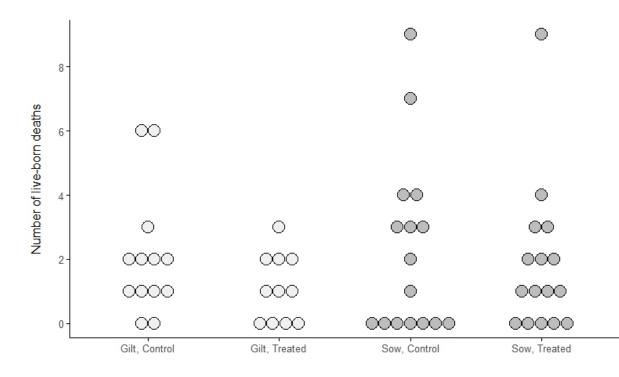


Fig.2. Mean \pm SEM for colostrum immunoglobulin-G concentrations (mg/ml) for A) gilts and sows \times treatment; B) additional treatment (yes or no) \times drug treatment and; C) additional treatment (yes or no) \times gilts and sows. Mean \pm SEM for piglet serum immunoglobulin-G concentrations (mg/ml) for D) gilts and sows \times treatment; E) additional treatment (yes or no) \times drug treatment and; F) additional treatment (yes or no) \times gilts and sows. Labels on the bars indicate the number of samples represente



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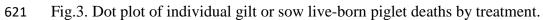


Table 1. Production information presented by treatment, gilts and sows, and additional treatment, including litter-based measures, gilts/sow based measures taken before moving in and at weaning, and piglet-based measures. Body condition was scored from 1 to 5 (1 = very thin, 5 = very fat) Gilt/sow data with different letters, represents an overall difference pre-farrowing, compared with post-weaning (P < 0.001). *One sow weaning

626 weight is missing.

	Treatment		Gilt or sow			Additional treatment			
Production data	Treated	Control	Р	Gilt	Sow	Р	Yes	No	Р
Litter data	_								
Born alive, frequency	12.6±0.7	13.0±0.7	0.92	12.3±0.8	13.2±0.6	0.65	13.5±0.9	12.6±0.5	0.65
Still born, frequency	0.4±0.2	0.5±0.2	0.66	0.2±0.1	0.7±0.2	0.16	0.3±0.2	0.5±0.1	0.99
Number weaned, frequency	10.7±0.4	10.9±0.3	0.91	10.8±0.4	10.9±0.3	0.62	10.5±0.4	10.9±0.3	0.72
Live-born deaths, frequency	2.4±0.3	3.0±0.4	0.37	2.5±0.3	2.9±0.4	0.83	3.4±0.6	2.5±0.3	0.23
Gilt/sow data	_								
^a Pre farrow weight, kg	260.2±7.7	261.5±7.7	0.87	223.4±5.8	289.0±3.5	0.00003	266.5±10.9	259.2±6.3	0.89
^b Post wean weight, kg	228.5±7.9	231.7±7.9	0.96	199.2±5.96	254.2±5.1*	0.01	228.2±12.5	230.8±5.9	0.52
^a Pre farrow back-fat, mm	19.0±0.8	18.8±0.9	0.44	17.4±0.9	20.0±0.8	0.33	19.1±1.4	18.8±0.7	0.48
^b Post wean back-fat, mm	14.0±0.8	14.2±0.7	0.93	13.3±0.9	14.7±0.6	0.85	13.5±0.9	14.3±0.6	0.79
^a Pre farrow body condition score	3.1±0.1	3.2±0.1	0.69	3.3±0.1	3.1±0.1	0.34	3.2±0.1	3.2±0.04	0.54
^b Post wean body condition score	2.6±0.1	2.7±0.1	0.18	2.7±0.1	2.7±0.1	0.35	2.7±0.1	2.7±0.1	0.87
Piglet data	_								
Piglet 6 hour weight, kg	1.5±0.02	1.4 ± 0.02	0.19	1.3±0.02	1.51±0.02	0.002	1.5±0.03	1.4±0.02	0.87
Piglet 6 hour crown-rump, cm	27.1±0.1	26.4±0.1	0.34	25.8±0.1	27.37±0.12	0.002	26.9±0.2	26.7±0.1	0.74
Piglet day 3 weight, kg	1.8±0.02	1.7±0.02	0.25	1.7±0.02	1.86±0.02	0.009	1.8±0.03	1.8±0.02	0.57
Piglet wean weight, kg	8.00±0.1	7.6±0.1	0.24	7.2±0.1	8.16±0.09	0.008	7.6±0.2	7.8±0.1	0.75
Piglet wean crown-rump, cm	50.3±0.3	49.5±0.2	0.62	48.7±0.3	50.72±0.25	0.06	49.2±0.4	50.1±0.2	0.74

Table 2. Frequencies of pre-weaning deaths, including totals and separated by suspected cause
of death, and the frequencies of piglets that were fostered on and off the litter for the 11 treated

	GI	LT	SC	T - 4 - 1 -	
	Treated $(n = 11)$	Control $(n = 13)$	Treated $(n = 16)$	Control $(n = 16)$	- Totals
Crushed	4	12	7	10	33
Low viability	2	8	8	8	26
Starve	1	1	6	7	15
Savage	0	1	4	1	6
Greasy pig	2	2	2	10	16
Other	0	3	1	2	6
Total deaths	9	27	28	38	102
Fostered on	4	13	5	7	29
Fostered off	14	5	11	12	42

and 13 control gilts and 16 treated and 16 control sows.

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Table 3. Behaviour results (mean \pm SEM) by treatment, gilts or sows and additional treatment, for three hour observations between 15 and 18 hours after the last piglet was born. Results are displayed as a percentage of time in the three hour observation (% of time), frequency of events in the observation, duration in seconds or minutes. Columns with a different letter indicate a difference (P < 0.05).

	Treat	tment	Gilts vs. Sow		Additional treatment	
Behaviour	Treated	Control	Gilt	Sow	Yes	No
Sow behaviour						
Stand, % of time	8.4±1.5	9.2±1.9	7.6±1.6	9.8±1.8	6.1±1.6	9.4±1.4
Sit, % of time	1.1±0.3	2.2±0.5	1.1±0.2 ^a	2.2 ± 0.5^{b}	$1.8{\pm}1.1$	1.6±0.3
Kneel, % of time	0.1 ± 0.04	0.1±0.03	0.1 ± 0.01^{a}	0.2 ± 0.04^{b}	0.1 ± 0.04	0.1±0.03
Lie lateral, % of time	79.7±3.3	77.2±3.6	83.3±2.9 ^a	74.4 ± 3.7^{b}	86.1±3.5	76.6±2.8
Lie ventral, % of time	10.7±2.9	11.3±2.9	8.0±1.9	13.5±3.3	5.9 ± 2.4	12.2±2.4
Posture changes, frequency	12.8±1.8	13.3±2.1	11.1±1.7	14.7 ± 2.1	9.6±2.7	13.9±1.6
Drinking, seconds	121.2±25.0	122.1±26.6	124.5±31.0	119.3±21.4	142.0±38.4	116.9±20.0
Nursing behaviour						
> 50 % of piglets active at udder, % of time	16.9±1.3	18.7±1.2	17.8±1.2	17.8±1.3	16.9±1.8	18.1±1.0
Suckle grunt duration, % of time	11.9±0.9 ^a	14.5 ± 1.0^{b}	13.8±1.1	12.8±0.9	11.2±0.9	13.7±0.8
Suckle grunt bouts, frequency	5.2±0.4	5.9±0.4	5.4±0.4	5.7 ± 0.5	5.0 ± 0.5	5.7±0.4
Mean suckle grunt bout duration, seconds	254.9±8.9	276.7±10.5	280.8±11.6	253.7±8.0	245.6±15.7	270.7±7.8
Inter bout interval, minutes	34.0±2.3	30.6±1.9	32.3±2.3	32.2±2.0	33.3±2.2	32.0±1.8

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