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RESEARCH ARTICLE

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Relationship between birth order, birth weight, colostrum intake, acquisition of passive immunity and pre-weaning mortality of piglets

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Abstract

This study investigates the relation between birth order (BO), birth weight (BW_0), colostrum intake (CI), level of passive immunity and pre-weaning mortality of piglets. The animals used were 551 cross-bred piglets [Piétrain × (Large-White × Landrace)] born from 40 sows. Colostrum immunoglobulins G (IgG) determinations were made from 17 sows. Colostrum samples were obtained at birth of the first piglet then at 3, 6, 12, 24, and 36 h later, and on the first-two and the last-two piglets born. Serum IgG determinations from 68 piglets were made at 2d of age and at weaning. Individual CI was estimated from body weight gain. Relative birth order (RBO) and BW_0 within-litter were weakly (R^2<0.05) but positively correlated (p<0.01). Colostrum intake of piglets was independent from RBO (p>0.10) but increased by 26 ± 1.6 g per 100 g increase in BW0 (p<0.001). Serum IgG concentrations of the last two born piglets were 29.5% lower (p<0.01) than the first two born at 2 d of age, and 25% (p<0.05) at weaning. They were also lower at weaning than at 2 d of age (p<0.001). Serum IgG concentrations of piglets at weaning and at 2 d of age were positively correlated (R^2 =0.50, p<0.001). Within-litter, CI explained 11% (p<0.01) of the variation observed in piglets' IgG at 2d of age. Mortality of piglets was irrespective of RBO (p>0.10). It was concluded that despite last-born piglets obtained less passive immunity than first-born, they were not at higher risk of dying before weaning. Major causes of mortality were low birth weight and insufficient colostrum (energy) intake.

Additional keywords: neonatal pig; colostrum consumption; immunoglobulin G; survival

Abbreviations used: BA (born alive piglets); BO (birth order); BW_0 (birth weight); CI (colostrum intake); CP (crude protein); DE (digestible energy); Ig (immunoglobulins); IgG (immunoglobulin G); LG (light weight piglets category); NM (normal weight piglets category); RBO (relative birth order); SP (sucking piglets); TB (total born piglets); t_{fs} (time elapsed from birth to the first sucking, min).

Authors' contributions: Conception of the experiment, data acquisition, interpretation of data, drafting of the manuscript, supervising the work: JLD. Analysis and interpretation of data; statistical analysis; drafting of the manuscript: RC. Data acquisition, laboratory analysis; technical support: FT

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Introduction

Piglets are born with low energy reserves (Mellor & Cockburn, 1986; Theil *et al.,* 2014) and deprived of immunoglobulins (Bourne, 1969). Therefore, it is of vital importance that piglets ingest adequate amounts of colostrum to provide enough energy and passive immunity to ensure their survival and development (Le Dividich *et al*., 2005; Quesnel *et al*., 2012). However, piglets in the same litter do not have a similar chance to obtain sufficient energy and colostral immunoglobulins (Ig). Compared with the first-born littermates, those born later in the birth order are reported to be lighter at birth (Friend & Cunningham, 1966; Hartsock & Graves, 1976; Motsi *et al*., 2006). However, according to Beaulieu *et al*. (2010) and Charneca *et al*. (2013a), birth weight and birth order are positively correlated. Additionally, late-born piglets are more prone to hypoxia during delivery, which may weaken the piglets and render them less capable to compete for colostrum (Herpin *et al*., 1996). Furthermore, the acquisition of passive immunity from the sow might be compromised in late-born piglets (de Passillé *et al*., 1988; Klobasa *et al*., 2004; Devillers *et al*., 2011; Kielland *et al*., 2015), due to the rapid decline of colostral Ig concentrations (Klobasa *et al*., 1987; Markowska-Daniel *et al.*, 2010) over time. In addition, there is little information available on colostrum intake by piglets born late in the farrowing process (Devillers *et al*., 2007). Therefore, the objective of the current experiment was to study the relationship between birth order and piglet's birth weight, colostrum intake, acquisition of passive immunity, and pre-weaning mortality.

Material and methods

Animals and housing

The experiment was conducted according to the European Community regulations concerning the use of animals for scientific purposes Directive 2010/63 (EU, 2010). Data were obtained from 40 sows and their litters of crossbred piglets [Piétrain × (Large-White × Landrace)]. Animals were kept at the experimental farm of INRA (Saint Gilles, France). Sows were fed a commercial diet twice a day at the rate of 2.6 to 2.8 kg/d until farrowing. From farrowing onwards, the feed offered was gradually increased (during 6-8 d of lactation) until *ad libitum* was reached. The gestation diet contained 132 g of crude protein (CP), 6.9 g total lysine and 12.5 MJ digestible energy (DE)/kg diet. The corresponding values for the lactation diet were 171 g CP, 9.1 g lysine and 13.0 MJ DE/kg diet. On d 104 ± 2 of gestation sows were moved to the farrowing rooms and housed in individual farrowing crates (2.0 m × 2.5 m). Environmental temperature of the farrowing rooms ranged between 22 and 24 °C. Farrowing pens were equipped with a heating lamp suspended above the creep area. In addition, an extra heating lamp was provided to piglets above the rear of the sow on the farrowing day. All sows farrowed naturally and farrowings were attended. At birth, piglets had their umbilical cord cut at 10-12 cm from the navel after which, they were identified, roughly dried and weighed. During weighing piglets were wrapped in a cloth to avoid movements and hence to limit biased measurements. Time of birth was registered. Piglets born in their placental envelopes had them removed without providing additional assistance. Duration of these operations did not exceed 2-3 min after which piglets were placed at their birth place. The number of total born piglets (TB); born alive piglets (BA), stillborn and mummified piglets, was recorded for each litter. Piglets that died after birth were also weighed but not clinically examined. Creep feed was offered to piglets from d 14 of lactation. Piglets were weaned at 28 ± 1 d.

Estimation of colostrum intake by piglets

The colostrum intake (CI, in g) of piglets during the first 24h after birth was estimated using the equation of Devillers *et al*. (2004b): $CI = -217.4 + 0.217\ T + 1861019\ BW24 / T + BW_0\ (54.8 - 1{,}861{,}019 / T)\ (0.9985\text{-}3.7 \times 10^{-4}\ t_{fs} + 6.1 \cdot 10^{-7} \times t_{fs}^2)$, where: BW_{24} = pig body weight at 24 h (kg), BW_0 = pig body weight at birth (kg), T = time elapsed from birth to weighing at t_{24} (min) and t_{fs} = time elapsed from birth to the first sucking (min). The interval from birth to the first sucking (t_{fs}) is estimated to be 15 to 30 min without major error (Devillers *et al*., 2004b). In the present study an average of 20 min was used. The 24 h time was calculated by adding 24 h to the mid duration of farrowing. Due to marked BW loss from birth to 24 h of age (between 93 and 244 g), 23 piglets had negative values for CI. Therefore, we considered the CI of those piglets to be nil. Colostrum production of the sow was defined as the sum of the individual CI of all piglets in the litter.

Colostrum and blood sampling, and analysis

From 17 of the 40 sows in the present experiment, colostrum samples (30-35 g/sow) were collected manually from most of the functional teats. Colostrum samples were collected at birth of the first piglet and at 3, 6, 12, 24 and 36 h later. Samples were pooled for each sow and collection time and immediately filtered and stored at –20 °C. From 3 h onwards, sows were administered intramuscularly a single dose of oxytocin (1 mL, 20 USP, Ocytovem CEVA Santé Animale, Libourne, France) to assist colostrum collection. At 2 d of lactation and at weaning, blood samples (1.0-1.5 mL) were obtained by vena cava puncture on the first two- and the last two piglets born in each litter. If a piglet died before the initial blood sampling, the nearest piglet in the birth order was sampled. Blood samples were allowed to clot at room temperature, were centrifuged at 5200g for 4 min and the serum was removed and frozen at –70 °C until analysis.

IgG concentrations for colostrum and serum samples were determined by ELISA test (pig IgG ELISA Quantitation kit, Bethyl Laboratories, Montgomery, TX, USA) following the procedure described by Devillers *et al*. (2004a).

Statistical analysis

Data were submitted to ANOVA using the IBM SPSS Statistics software (v.21, 2012). To compare litters of different sizes and to determine whether position of the piglet in the birth order (BO) affected within-litter birth weight (BW_0) and CI, position of the piglets in BO was expressed as relative BO (RBO) calculated as RBO = (BO – 1) / (Total born piglets – 1).

Regression analyses were used to determine the relationship between BW_0 and TB (with the exception of mummies and 4 stillbirths which were not weighed), BW_0 and BA piglets, CI and RBO. Regressions analyses were also used to determine the relationship between CI and BW_0, serum IgG concentrations of piglets at 2 d of age (IgG2d), and between IgG2d and RBO. In order to consider the litter effect, the values used for each regression were the unstandardized residues previously obtained by ANOVA, using litters as fixed effect.

To compare the characteristics of piglets that either died or survived during the suckling period within each litter, piglets were classified as either "light" (LG) [$BW_0 \leq$ (x-one SD)] or "normal" (NM) [$BW_0 >$ (x -one SD)], where x is the average BW_0 of the litter, and SD its standard deviation. Although trait residues were normally distributed there was an unbalanced number of animals per group therefore the comparison of means was made using the Mann–Whitney *U* non–parametric test.

To examine the effects of RBO on pre-weaning mortality, piglets were classified into deciles on the basis of their RBO. Mortality across deciles was analysed using a Chi square test.

For colostrum IgG composition the repeated measures ANOVA procedure was used using time of collection as within–subjects factor. For serum IgG concentrations the repeated measures ANOVA procedure was used using time of collection as within–subjects factor and type of piglet (first two *vs* last two born piglets) as between–subject factor.

Results

General

Parity of the sows averaged 3.5 ± 0.3 (s.e.) (range 1-7). Duration of parturition averaged 233 ± 16 min and was independent of TB (r=0.012; *p*=0.808). On average, BA per litter was 13.4 ± 0.4. Relatively to TB, there were 2% of born dead piglets (0.25% mummified piglets and 1.75% of stillborn) with 43% of stillbirths being born in the last quarter of RBO. Birth weight of BA piglets averaged 1427 ± 30 g. From the 40 sows on experiment, 13 had a litter size (BA) greater than 15 (mean 16.4 ± 0.3). From these sows, 15 piglets with an average BW_0 of 1419 ± 75 g and a RBO of 0.44 ± 0.06 were removed soon after the completion of farrowing and withdrawn from the study. After fostering and withdrawal, litter size designated as sucking piglets (SP) averaged 13.2 ± 0.4 with piglets' BW_0 averaging 1425 ± 31 g. At weaning, litter size (SP) and weight of piglets averaged 11.4 ± 0.4 and 6840 ± 93 g, respectively.

Relationship between BW_0, CI and RBO of piglets

The within-litter slope of the regression relating BW_0 of TB piglets to RBO was: b_{TB} = 116 ± 38 g RBO (R^2=0.002, *p*=0.002) (Fig. 1). Corresponding values for BW_0 of BA

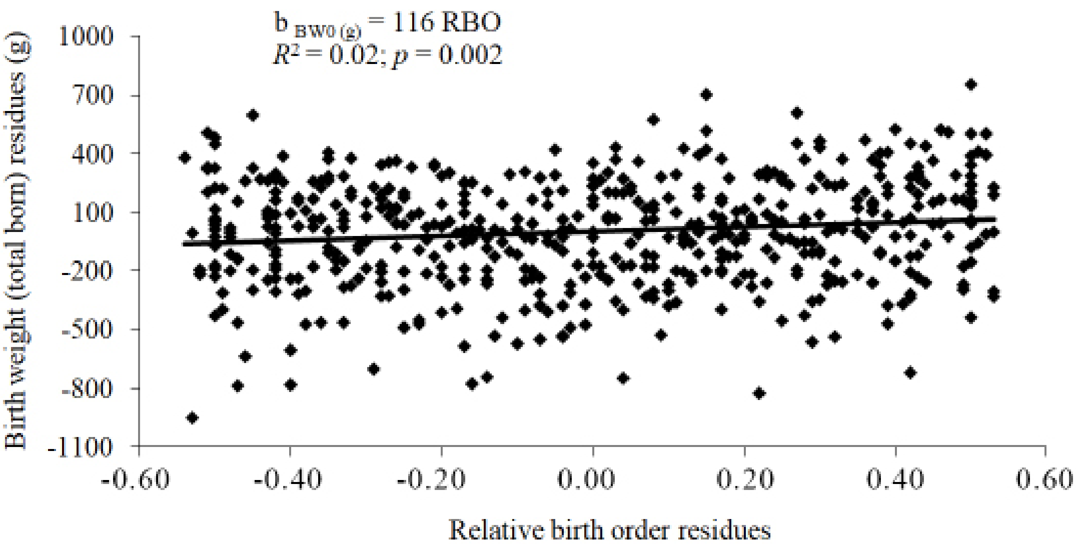

Figure 1. Within-litter relationship between birth weight (g) of total born piglets and relative birth order. Data presented are residues calculated after correction for litter effect

and SP piglets were: b_{BA} = 112 ± 37 g RBO (R^2=0.016, p=0.003), and b_{SP} = 115 ± 38 g RBO (R^2=0.017, p=0.002), respectively. The CI and the colostrum production of sows averaged 287 ± 13 g (range 0-882 g) and 3660 ± 160 g (range 1810-5770 g), respectively. The average within-litter CV for CI was 45% (ranging from 20 to 66%). The CI was independent from RBO (p=0.700), but positively related to BW_0 (b_{CI}) = 0.26 ± 0.016 BW_0 (g), R^2=0.29, p<0.001; Fig. 2). An increase of 100 g in BW_0 was associated with an increase of 26 g in CI. Colostrum production of sows was independent from SP litter size (p=0.132) and from litter weight (p=0.560). Consequently, colostrum per piglet decreased by 16 ± 5 g (p=0.006) per additional SP.

IgG concentration of colostrum

Colostrum IgG concentration at the different sampling moments are presented in Fig. 3. Immunoglobulin G concentration was highest at birth of the first piglet (75.4 ± 7.0 mg/mL) and showed a 10-fold decline (p<0.001) to 7.5 ± 1.3 mg/mL at 36 h after the birth of the first piglet (p<0.001). Furthermore, the CV of IgG concentration observed among sows for samples collected at the birth of the first piglet and at 12 h were 32% and 72%, respectively.

Serum IgG concentration of the first-two and the last-two piglets born sampled at 2 d of age and at weaning

The first two- and the last two-born piglets had similar BW_0 and CI, averaging 1466 ± 52 g and 314 ± 26 g, respectively. RBO of the first two- and the last two -piglets sampled averaged 0.05 ± 0.02 and 0.93 ± 0.02, respectively. Time elapsed between birth of the first two- and the last two- sampled piglets averaged 156 ± 13 min.

At 2 d of age, serum IgG concentrations (Fig. 4) were 29.5% lower (p=0.002) in the last two-born than in the first two-sampled piglets and it remained lower (p=0.030) at weaning. Irrespective of RBO, serum IgG concentrations were lower at weaning than at 2 d of age (p<0.001). There was a positive within-litter relationship between serum IgG concentrations at 2 d of age and CI (R^2=0.11, p=0.005). Within-litter, serum IgG concentrations at 2 d of age and at weaning were positively correlated (R^2=0.50, p<0.001)

Characteristics of pigs that died before weaning

Total pre-weaning mortality of SP piglets averaged 12.4%, with 51% of deaths occurring within 3 d of birth. The effect of birth weight on the characteristics of piglets that died after birth compared to those of survivors is presented in Table 1. Because of the imposed differences in BW_0 between the two groups, CI was expressed as CI/kg BW_0. Overall, piglets that died before weaning were lighter at birth (1141 ± 45 *vs* 1449 ± 14 g, p<0.001) and consumed less colostrum (85 ± 10 *vs* 211 ± 4 g/kg BW_0, p<0.001) than surviving piglets. Post-natal mortality was irrespective of deciles based on RBO (p=0.410). As expected, mortality was higher (38.4%) in the LG group, representing 51% of total

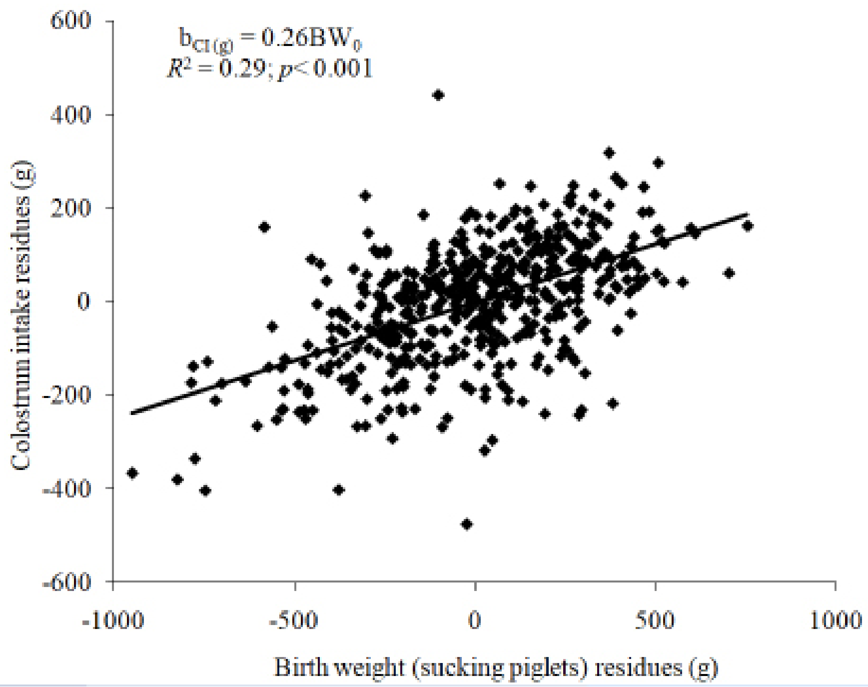

Figure 2. Within-litter relationship between colostrum intake (g) and birth weight of sucking piglets. Data presented are residues calculated after correction for litter effect.

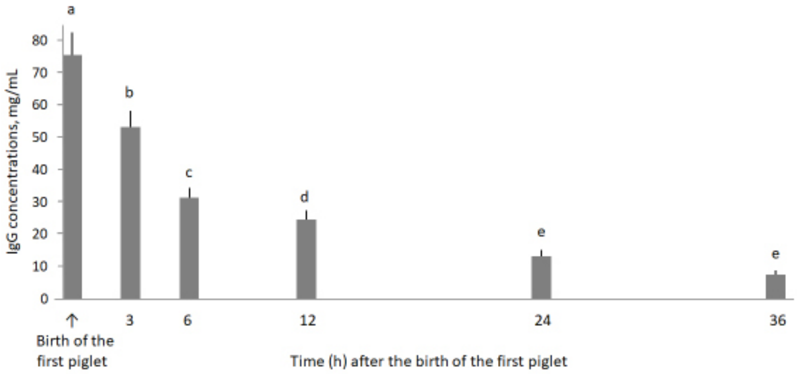

Figure 3. Pattern of colostrum IgG concentrations (±se) during 36h after the birth of the first piglet. Means with different superscript differ significantly (p<0.05).

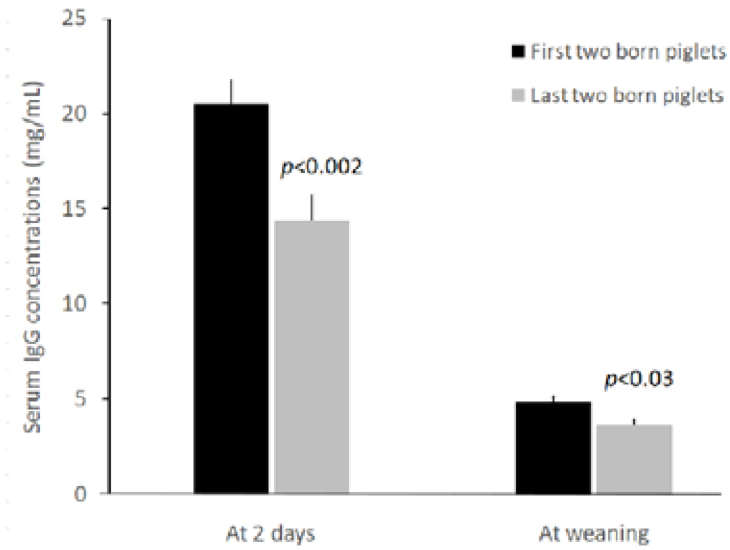

Figure 4. Serum IgG concentrations (±se) of piglets at 2d of age and at weaning at 28d of age. Serum IgG concentrations of the first – and the last – two born piglets were lower (p<0.0001) at weaning than at 2d of age.

mortality, and lower (7.3%) in NM group. Piglets from the LG group that survived until weaning consumed 15.4% more colostrum (p=0.013) than their counterparts from the NM group. Piglets that died in the LG group had lower BW0 than surviving piglets (p<0.001). No difference (p=0.065) in BW_0 was observed between dead and alive piglets in NM group. In both groups, dead piglets consumed less colostrum than their surviving littermates (p<0.001) and their body weight at death was not significantly different from their BW_0 (LG group, p=0.130; NM group, p=0.160).

Discussion

Reproductive performance of sows (litter size at birth and at weaning) and pre-weaning mortality observed in the present study were consistent with the national French results (IFIP, 2011). Stillbirths recorded in the present study (1.75%) were considerably less than those reported in the national French results (7%), which is probably due to the supervision of farrowings (Holyoake *et al.*, 1995). Duration of farrowing was independent of litter size (TB) and in the range of the 160 to 217 min reported by Le Cozler *et al*. (2002), Canario (2006), and Motsi *et al*. (2006). In this study, birth weight increased with RBO in agreement with Beaulieu *et al*. (2010) and Charneca *et al*. (2013a). However, RBO accounted only for approximately 1.6% of the variations observed in piglet birth weight. In contrast, several authors reported that piglets born earlier during farrowing were heavier than those born later (Friend& Cunningham, 1966; Hartsock & Graves, 1976; and Motsi *et al*., 2006). Average colostrum production of sows and CI of piglets

Table 1. Characteristics of piglets dying pre-weaning in comparison with survivors in relation to birth weight category.

	Birth weight (BW_0) category[1]		
	LG[2]	**NM**[2]	***p* value**
Piglets surviving to weaning			
N pigs	53	407	
BW_0, g	1046 ± 29[a]	1501 ± 14[a]	<0.001
CI, g/kg BW_0	240 ± 13[a]	208 ± 4[a]	0.005
Piglets dying pre-weaning			
N pigs	33	32	
Mortality, %	38.4	7.3	<0.001
BW_0, g	882 ± 38[b]	1407 ± 49[a]	<0.001
CI, g/kg BW_0	6 ± 11[b]	109 ± 14[b]	0.018
Weight at death, g	793 ± 45[b]	1628 ± 52[a]	<0.001
Age at death, d	1.8 ± 0.3	6.9 ± 0.3	0.002

[1] LG category, birth weight ≤ [x- one SD]; NM category, birth weight > [x- one SD], where x = average birth weight of the litter and SD is its standard deviation. Within birth weight category, different superscript lower case letters in the same traits indicates significant differences. [2] Intra LG category, compared with survivors, BW_0 and CI, g/kg BW_0 were lower in piglets dying (p=0.001). Intra NM category, compared with survivors, CI, g/kg BW_0 was lower in piglets dying (p<0.001) but not BW_0 (p=0.054). In both categories, body weights at death were not different from BW_0 (p>0.05).

were similar to that previously described in the literature: 3.4-4.9 kg/sow and 300-380 g/piglet (Devillers *et al.*, 2007; Quesnel, 2011; Loisel *et al.*, 2013; Charneca *et al.*, 2015). Moreover, colostrum production was independent from litter size (SP) and litter weight. Consequently, CI decreased by 16 g per additional SP born. This reduction in CI is in agreement with that reported by Devillers *et al.* (2007) (a decrease of 22 g per additional piglet born). Therefore, in larger litters, piglets are more likely to have a reduced/inadequate colostrum intake due to competition. According to Quesnel *et al.* (2012), an intake of about 180 g colostrum/kg BW_0 is required to provide the piglet with sufficient energy and IgG for survival. On this basis, 71% of the sows of this study could nurse 13 piglets averaging 1300 g birth weight. However, individual CI within-litter was very variable, with a CV ranging from 20 to 66%. An important factor accounting for this variability was the piglet birth weight. In this study, CI increased 26 g per 100 g increase in birth weight, which is similar to the increase of CIs (22-28 g) found by Devillers *et al.* (2007) and Charneca *et al.* (2015). In agreement with Fraser & Rushen (1992) and Devillers *et al.* (2007), birth order had no significant effect on CI despite later born piglets had shorter time and greater competition to suck. This is likely because the rate of CI is the highest during the first few hours after birth (Castrén *et al.*, 1991; Fraser & Rushen, 1992; Le Dividich *et al.*, 1997). We hypothesise that, when last- piglets were born, the first-born were sated and therefore less active, allowing last-born piglets to display more teat seeking activity.

The pattern of colostrum IgG concentrations over the first 36 hours after the onset of parturition was similar to that previously reported (Klobasa *et al.*, 1987; Rooke *et al.*, 2003; Markoswska-Daniel *et al.*, 2010; Charneca *et al.*, 2015). The fact that the serum IgG concentrations at 2 d of age were lower in late-born piglets than in their earlier born littermates is in agreement with the findings of de Passillé *et al.* (1988), Bland *et al.* (2003), Devillers *et al.* (2007) and Cabrera *et al.* (2012). Similar observations were also made on 1d old piglets (Kielland *et al.*, 2015). Piglets deprived of sucking for 4 h after birth had also lower serum IgG concentrations than their non-deprived of sucking littermates (Coalson & Lecce, 1973). In contrast, only marginal effect of birth order on serum IgG concentrations was observed by Cabrera *et al.* (2012) while no effect was found by Nguyen *et al.* (2013). The lower serum IgG concentrations in the last-born piglets are commonly attributed to the intake of colostrum with a lower concentration in IgG (Lay *et al.*, 2002). It could also be caused by a lower intake of colostrum. However, according to present results, this is not the case as CI was independent of RBO. Further, despite the fact that colostrum is the unique source of IgG for piglets, CI explained only 11% of the total variability found in piglet IgG concentrations. Similarly, Cabrera *et al.* (2012) reported that colostral IgG concentrations explained only 6% of the variation observed in piglet IgG concentrations, while no correlation was found by Markoswska-Daniel *et al.* (2010). Yet, Werhahn *et al.* (1981) reported a dose response relationship between the porcine IgG administrated to the newborn pig and the plasma IgG concentrations at 12 h post-feeding. However, in the present study, the amount of ingested colostral IgG could not be determined accurately due to the combination of the various decreasing patterns of IgG concentrations of colostrum and the various intake behaviours of piglets over time.

Late born piglets are reported to have a higher mortality rate after birth than earlier born littermates (Hartsock & Graves, 1976; Tuchscherer *et al*., 2000; Rootwelt *et al*., 2012; Panzardi *et al.*, 2013). In addition to obtaining less immune protection, late-born piglets are reported to be at greater risk of hypoxia and of death during or just after birth (Randall, 1972). In this study, this is illustrated by the fact that 43% of stillbirths were born in the last quarter of RBO, which is in accordance with the previous results of Herpin *et al.* (1996), Pedersen *et al.* (2011) and Rootwelt *et al.* (2012). However, post-natal mortality was similar across deciles suggesting that mortality of live born piglets was evenly distributed in the birth order which is in agreement with Cabrera *et al*. (2012) and Charneca *et al*. (2015). Present study indicates that birth weight and CI are the major determinants of post-natal mortality. However, while CI is independent on RBO (Devillers *et al*., 2011; Quesnel *et al.*, 2012), birth weight is positively, although marginally, related to RBO, accounting only for 1.6% of the birth weight variation.

Yet, high mortality has been correlated with low levels of serum IgG (Hendrix *et al*., 1978; Blecha & Kelley, 1981; Klobasa *et al*., 1981; Devillers *et al*., 2011). However, these mortalities may simply be associated with an insufficient nutrition rather than disease. This is illustrated by the study of Devillers *et al*. (2011) showing that piglets dying during the first three post-natal days had 44% less serum IgG concentrations at 2 d of age than survivors but had consumed 2.3 times less colostrum (147 *vs* 333 g) and hence energy. From this, the probability of dying is not increased in last-born piglets despite their lower intake of IgG than the earlier born piglets. Present findings agree with the observation of Tyler *et al*. (1990), and Rootwelt *et al*. (2012) which state that serum IgG concentrations at 24-60 h of age is a poor predictor of piglet survival. However, in the present study, piglets were sampled at 2 d of age when the largest part (51%) of mortality had occurred, and it is not known whether insufficient passive immunity was the real cause of these deaths. Further, present results and others (Rooke *et al*., 2003; Markoswska-Daniel *et al.*, 2010; Devillers *et al*., 2011) show a close positive within-litter relationship between serum IgG concentrations shortly after birth and at weaning indicating that level of systemic immunity at weaning is, at least partly, influenced by the level of passive immunity acquired through colostrum.

Piglets dying pre-weaning are characterized by low birth weight and low colostrum intake. The low-birth-weight piglets are recognized to be at a greater risk of pre-weaning mortality (English & Morrison, 1984; Gardner *et al*., 1989; Tuchscherer *et al*., 2000). Moreover, due to the low heat conserving capacity of the piglet (Berthon, 1994; Herpin *et al*., 2002) and its low body energy stores (Mellor & Cockburn, 1986; Theil *et al*., 2014), adequate intake of colostrum is vital not only to provide immunological protection but also to ensure sufficient supply of energy for metabolism. In this study, LG category piglets represented 16.4% of the pig population, but they contributed to 51% of the total pre-weaning mortality. In fact, most of these piglets could be classified as runt, and as such, are at physical disadvantage in competing with larger littermates for colostrum and milk. Indeed, from the 33 piglets dying from this category, 31 (94%) consumed less than 180 g colostrum/kg BW_0 (mean, 52 ± 10 g). Interestingly, piglets from this group which survived to weaning consumed 15.4% more colostrum/kg BW_0 than their counterparts of the NM category. Similarly, Ramackers *et al*. (2012) reported that survival of light piglets (≤ 1000 g) is more dependent on their body weight gain from birth to 24 h of age (and hence on their colostrum intake), than that of "normal piglets" (>1000 g). Other study by Ferrari *et al*. (2014) observed that the probability of death of low birth weight piglets (1.1-1.2 kg) compared to newborn heavy piglets (1.3-1.7 kg) was substantially reduced when CI of low birth weight piglets reached 250 g. In other words, to survive, light piglets must consume more colostrum per kg birth weight than heavier littermates which is consistent with the fact that the lower the birth weight, the greater the surface area per unit body weight and therefore the greater the energy required per unit body weight to maintain homeothermic balance (Curtis, 1970). This suggests that the determination of the amount of colostrum needed to survive and to thrive must take into account the birth weight of the piglets.

In conclusion, results reported here indicate that birth order has no significant effect on the within-litter birth weight, colostrum intake and post-natal mortality of piglets. Yet, compared to the first born, piglets born last in the birth sequence are underprivileged in the acquisition of passive immunity. However, they do not appear to be at higher risk of dying pre-weaning. In this study, low birth weight and insufficient colostrum intake were the major underlying causes of postnatal mortality. Results suggest that improving colostrum production of sows and selection of sows for litter uniformity (Damgaard *et al*., 2003; Bouquet *et al*., 2014), thus allowing a more uniform intake of colostrum by littermates (Charneca *et al*., 2013b) would reduce piglet mortality. Additionally, management strategies (De Vos *et al*., 2014) of low birth weight piglets should be considered in order to reduce mortality and improve performance at farm level.

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