Papers

Anaemia in the sow: a cohort study to assess factors with an impact on haemoglobin concentration, and the influence of haemoglobin concentration on the reproductive performance

V. Normand, H. Perrin, V. Auvigne, N. Robert, A. Laval

The aim of this study was to conduct a descriptive study of haemoglobin concentration found on high-prolificacy sows, to study the relationship between the concentration of haemoglobin and body reserves, and to determine whether anaemia is a risk factor for reproductive performance. A cohort of 308 sows from seven farms was followed from the last third of gestation to the confirmation of the following gestation. Haemoglobin concentration was assessed at four stages of the reproductive cycle: seven and four weeks before farrowing, a few days and three weeks after farrowing. Backfat thickness (BFT) was measured at parturition. The results were analysed using linear mixed-effect models. The mean haemoglobin concentration was 108.4 g/l. The mean modellised haemoglobin concentration of parity 1 sows with a BFT of 16 mm, sampled seven weeks before farrowing, was 118 g/l. Haemoglobin concentration of sows of parity 6 or higher was 8.0 g/l lower than those of parity 1 sows (95% confidence interval −11.0 to −5.1). Haemoglobin concentration is lower in sows with a lower BFT, whatever parity rank. There is no evidence of a relation between haemoglobin concentration and the number of total born, stillborn or number of piglets alive at three weeks and the next breeding performance.

Introduction

Iron is a trace element that is essential for its multiple roles in the metabolism of enzymes and the transport of oxygen. In the organism, it is mainly bound to proteins, including haemoglobin. Sixty-five per cent of the iron is contained in the red blood cells. Iron that is not used for the synthesis of haemoglobin is mainly stored as a protein complex, ferritin. The body draws on its ferritin reserves in case of increased demand. For most non-pregnant mammals not presenting with haemorrhagic conditions, the iron metabolism is a quasi-closed circle. Very small losses, via the digestive and urinary tract (0.5–1.5 mg/day), are compensated by oral intake. Iron is almost completely recycled upon degeneration of the red blood cells (Spears and Hansen 2008). During gestation and lactation, iron requirements are increased. This can be explained by the significant in utero transfer from mother to foetus, haemorrhage during parturition and, to a lesser extent, by excretion in the milk (1.3–1.8 mg/l). If the demand is higher than the intake, the organism stimulates erythropoiesis and mobilises the iron stored as ferritin. If these reserves are depleted, this leads to non-regenerative anaemia or ferriprive anaemia (Mahan 1990). The measurement of haemoglobin concentration remains the gold standard in veterinary medicine for the diagnosis of this anaemia.

Over the past 20 years, the prolificacy of pig farms has progressed steadily. On the one hand, the number of total born per litter has increased by 1.6 piglets in France since 1999, reaching 14.1 in 2009. At the same time, the number of weaned piglets only increased by 1.1, reaching 11.3. On the other hand, the farrowing interval was reduced by 3.2 days (IFIP 2010). Despite this significant increase in sow productivity, standards of recommended intakes for sows have not been reviewed since 1998 (National Research Council 1998). It is therefore possible that the nutritional intakes are no longer in line with the increased prolificacy of sows, and no longer allow sows to restore their iron reserves between pregnancies. It can therefore be hypothesised that there is an increased prevalence of anaemia among sows.

In pregnant women, anaemia increases foeto-maternal morbidity and mortality, even in cases of moderate anaemia. Other consequences include spontaneous abortions, premature births, low birth weight, impaired cellular immunity, a reduced antibody response, decreased bactericidal macrophage activity and a reduced production of lymphocytes (Dhur and others 1989, Carriaga and others 1991, Milman 2008). It can therefore be hypothesised that in sows, ferriprive anaemia is a risk factor for reproductive disorders, such as stillbirth, reduced fertility and early culling.

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V. Normand, DVM,
Porc.Spective – Chêne Vert Conseil, 32, rue du Gal Quinivet, Pontivy 56300, France
H. Perrin, DVM,
A. Laval, DVM, DipECPHM,
Oniris National Veterinary Faculty, BP 40706, Nantes Cedex 03 44307, France
V. Auvigne, DVM,
Ekipaj, 22 rue d'Assas, Angers 49000, France
N. Robert,
Ceva Santé Animale, BP 126, Libourne Cedex 33501, France

E-mail for correspondence: v.normand@chenevertconseil.com

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In this context, the aim of this study was to conduct a descriptive study of haemoglobin concentration currently found in high-prolificacy farms, to study the link between haemoglobin concentration and body reserves, and to determine if anaemia is a risk factor for reproductive performance.

Materials and methods

Study design, setting and participants

This was an observational study. A cohort of sows was followed from the last third of gestation to the confirmation of the subsequent gestation. The study was conducted between March and September 2009 in seven French farrow-to-finish farms (100–250 sows). The breed of the sows was either Large White × Landrace (four farms) or Sino-European (three farms). To be eligible, farms had to be prolific (>13.5 total born piglets/sow/litter, mummies included) and have more than 8 per cent stillbirths, or more than 15 per cent of manual assistance at farrowing. The piglets are weaned at 28 days on six farms and at 21 days on one farm.

Two to four successive batches were followed on each farm (total=25 batches). All sows of these batches (n=308) were included, with the exception of sows with a major disease at the start of the study (foot rot, lameness, large sores, abscesses). Inclusion took place seven weeks prior to farrowing, and the sows were followed until ultrasound confirmation of the subsequent gestation. Sows that were lost to follow-up before the last check were excluded (dead sows, abortions, lost from the study). Three subpopulations were defined according to the variables studied (Fig 1, Table 1). Median age at weaning was 27 days.

Variables

Anaemia status was assessed by haemoglobin concentration, measured on-farm with the Hemocue Hb 201+ device (Hemocue 2011). In sows, this test allows less invasive blood sampling and provides results with good accuracy compared with the standard spectroscopic analysis of haemoglobin concentration in the laboratory (Maes and others 2011). Kinetics was measured by determining the concentration at four time points during the reproductive cycle of each sow: seven and four weeks before farrowing, after farrowing (between two and five days, mean=4.7 days after farrowing) and three weeks after farrowing.

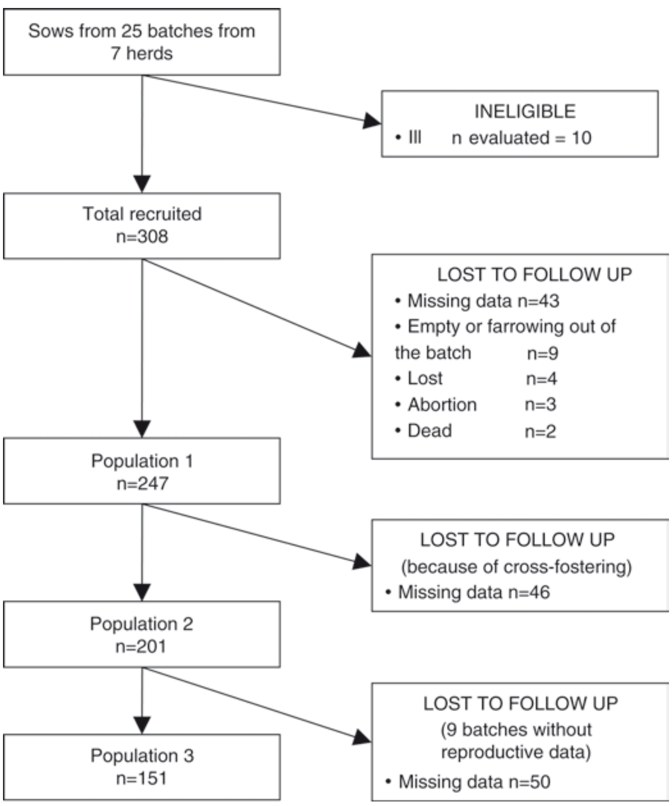

FIG 1: Flow diagram of the recruitment and follow-up of the sows

TABLE 1: Availability of variables according to subpopulations

	Population 1 (n=247)	Population 2 (n=201)	Population 3 (n=151)
Parity rank	Yes	Yes	Yes
Haemoglobin (four analyses)	Yes	Yes	Yes
Number of total born and stillborn piglets	Yes	Yes	Yes
Backfat thickness	Yes	Yes	Yes
Number of weaned piglets (biological and suckling)	No	Yes	Yes
Reproductive parameters (culling, insemination, pregnancy diagnosis)	No	No	Yes
Outcome	Total born and stillborn	Live piglets at 20 days	Successful/ unsuccessful breeding

A single drop of blood was needed to perform the test. The sample was taken at the tail (medial caudal vein) using a disposable needle. The blood was introduced into a disposable cuvette by capillarity, which was then placed in the reader. First, the reagents present in the cuvette lyse the red blood cells, which releases the haemoglobin. Next, the haemoglobin is converted to methaemoglobin. The test measures the light absorption at two different wavelengths, thus obtaining the concentration of haemoglobin of the blood sample. Results are obtained in less than a minute. The farmer was not informed of the result, so as to avoid influencing his decisions.

The level of body reserves was assessed by backfat thickness (BFT) using a Renco Lean Meter device. The measurement was taken at the level of the last floating rib, 7 cm on either side of the midline of the back.

At farrowing, the farmer recorded the number of liveborn and stillborn piglets for each sow. In case of cross-fostering, the piglets received an individual earmark to follow-up the adoptions. In this way, it was possible to obtain two sets of piglet data for each sow before weaning (on day 20 of lactation): the biological piglets, that is, born from the sow and suckled by her or by another sow; and the number of suckling piglets, whether her own or fostered.

To be considered 'breeding successfully', a sow should be inseminated the week after weaning and confirmed pregnant by ultrasound 25–40 days following insemination. A sow would therefore be considered as 'breeding unsuccessfully' because she was culled after weaning (farmer's decision), was not seen in oestrus, returned to oestrus after having been inseminated, or because she was found not pregnant at the ultrasound examination.

Statistical methods

First, statistical analysis was performed considering the haemoglobin concentration as a dependent variable (outcome). The explanatory variables (predictor) were parity, physiological stage, number of total born piglets and BFT.

Next, a series of tests was carried out by considering the haemoglobin concentration as predictor, with the explanatory variables being the number of total born, stillborn and alive piglets at weaning as well as success at breeding.

R software 2.9.0 (R Development Core Team 2009) was used. In all cases, univariate analyses were carried out, followed by multivariate analysis of the data using linear mixed-effect models. For all models, herd, batch and sow were set as nested random effects. Interactions, heterodasticity and linearity of relations were checked. For the quantitative dependent variables with a normal or near-normal distribution (haemoglobin, total born, piglets alive before weaning), linear models were used (lme procedure, method=ML). Poisson regression was used for the dependent variable 'stillbirths' (glmmPQL procedure, family=quasipoisson). Logistic regression was used for the dependent variable 'Successful Breeding' (glm procedure, family='binomial').

Results

Determinants of haemoglobin concentration

Analysis was performed for sows of population 1 (n=247). The characteristics of this population are given in Table 2 and Fig 2. Univariate analysis showed that the haemoglobin concentration decreases with

TABLE 2: Population 1 characteristics (n=247)

	N	Minimum	Median	Maximum	Mean	sd
Haemoglobin (g/l)	988	65	108	150	108.4	12.6
Backfat thickness at farrowing	247	8	16	29	16.3	3.8
Number of total born	247	3	15	23	15.0	3.6
Number of stillborn	247	0	1	12	1.4	1.8
Parity rank						
1	42 (17%)					
2 and 3	81 (33%)					
4 and 5	66 (27%)					
6 and +	58 (23%)					

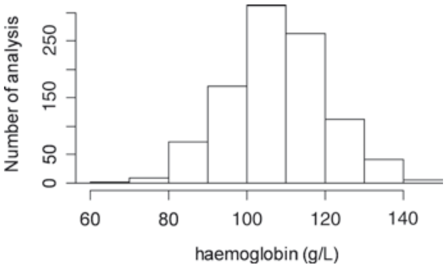

FIG 2: Distribution of haemoglobin concentration (n=988, all parities and physiological stages combined)

the parity rank (P<0.0001), and is lower after farrowing and weaning compared with seven and four weeks before farrowing (Fig 3). It is also lower if the BFT is low at farrowing (P<0.0001, Fig 4). However, there is no link with the number of total born piglets (P=0.40). These links are confirmed by the multivariate model. Interactions have been tested and are not significant; the effects of the three significant variables are therefore additive. The assumption of normality of residuals (sd=9.6, Shapiro test, P=0.08) and the hypothesis of heterodasticity are verified, meaning the model is valid. It explains 44 per cent of the observed variability of the haemoglobin concentration.

The mean haemoglobin concentration modellised for parity 1 sows with a BFT of 16 mm, sampled seven weeks before farrowing, is 118 g/l. Compared with parity 1 sows, haemoglobin concentration is 3.4 g/l lower in parity 2 and 3 sows (95% confidence interval (CI) −6.1 to −0.7), 6.7 g/l lower in parity 4 and 5 sows (95% CI −9.5 to −3.9) and 8.0 g/l lower in parity 6 and higher sows (95% CI −11.0 to −5.1). Compared with the first sample taken seven weeks before farrowing, the haemoglobin concentration at four weeks before farrowing is 2.7 g/l lower (95% CI −4.5 to −0.9), at farrowing 8.1 g/l lower (95% CI −10.0 to −6.3) and three weeks after farrowing 9.1 g/l lower (95% CI −10.9 to −7.3). Finally, a variation of 1 mm of BFT is related to a variation of 0.9 g/l of haemoglobin (95% CI 0.2 to 0.7) (Table 3).

Haemoglobin concentration as a risk factor

For the rest of the study, the mean haemoglobin concentration of the four checks is used as sole indicator of haemoglobin concentration of sows.

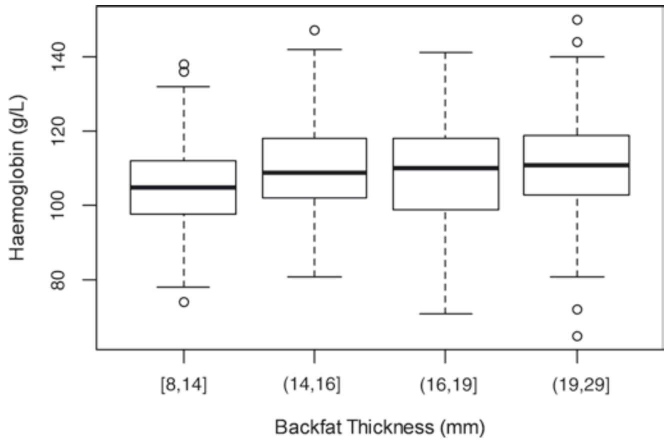

FIG 4: Haemoglobin concentration according to the backfat thickness at farrowing (raw data)

TABLE 3: Fixed effects for the linear mixed-effects model of haemoglobin

	Coefficient	se	DF	t-Value	p-Value
Intercept	110.4	2.5	738	43.7	0.0000
Gestation rank					
1	–	–	–	–	–
2 and 3	−3.4	1.4	220	−2.5	0.0149
4 and 5	−6.7	1.4	220	−4.7	0.0000
6 and +	−8.0	1.5	220	−5.3	0.0000
Physiological stage					
Seven weeks b.f.	–	–	–	–	
Four weeks b.f.	−2.7	0.9	738	−2.9	0.0041
Farrowing	−8.1	0.9	738	−8.8	0.0000
Three weeks a.f.	−9.1	0.9	738	−9.8	0.0000
Backfat thickness	0.5	0.1	220	3.7	0.0002

Total born and stillborn

Analysis is performed for sows of population 1 (n=247). For stillborns, the univariate analysis showed no relationship with the mean haemoglobin concentration (P=0.35). However, the number of stillborns increased with the parity rank (compared with parity 1 sows, P=0.07 for parity 4 and 5, and P<0.0001 for parity 6 and higher) and the number of total born. The number of stillborns had a non-significant tendency to decrease with an increasing BFT (P=0.06). However, multivariate analysis, after adjusting for the parity rank and the number of total born, did not confirm a link between the increase of BFT and a lower number of stillborn. At herd level, the mean (sd) haemoglobin concentration seven weeks before farrowing varied from 107.0 g/l (9.0) to 120.7 (12.8) g/l.

As for the total born, univariate analysis showed no relationship between the mean haemoglobin concentration and the number of total born (P=0.38), nor between the BFT and the number of total born (P=0.85). However, there was a non-significant tendency of a relationship between the number of total born and parity rank (P=0.09). The highest prolificacy was observed between parity 2 and 5. Multivariate analysis confirms these results.

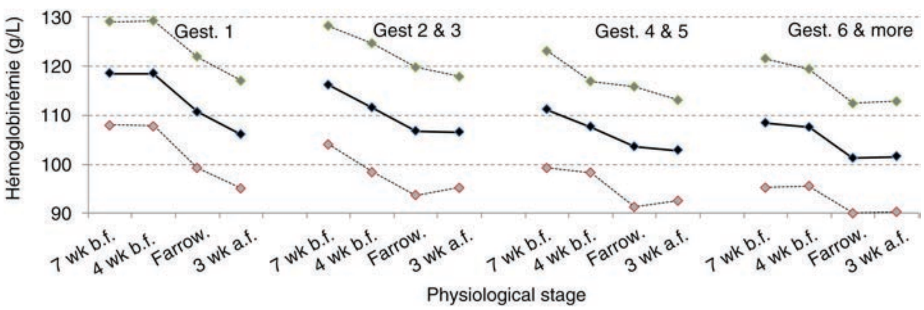

FIG 3: Haemoglobin concentration according to the physiological stage and parity rank (raw data, solid line=mean, dotted line=mean±sd, b.f.=before farrowing, a.f.=after farrowing)

Piglets alive at three weeks of age

Analysis was performed for sows for which the numbers of live piglets just before weaning were known (population 2, n=201). Population 2 was not significantly different from the excluded sows from population 1 as regards haemoglobin concentration seven weeks before farrowing (113.2 g/l v 114.3 g/l, P=0.57), BFT layer at farrowing (16.4 mm v 15.7 mm, P=0.29) and total born per sow (15.0 v 14.7, P=0.50).

For the number of biological piglets alive before weaning, univariate analysis did not reveal a link with the concentration of haemoglobin (P=0.85) or with BFT (P=0.46). However, the number of biological piglets alive before weaning depends on the parity rank (P=0.01) and is highest for ranks 3–5. Multivariate analysis confirms these results. The number of biological piglets alive before weaning was 10.7 for parity 1 sows, 11.6 for parity 2 and 3, 11.7 for parity 4 and 5, and 10.1 for parity 6 and higher sows.

Similarly, for the number of suckling piglets, univariate analysis did not reveal a link with the concentration of haemoglobin (P=0.18) or with BFT (P=0.85). The number of suckling piglets alive before weaning was 10.9 for parity 1 sows, 11.2 for parity 2 and 3, 11.4 for parity 4 and 5, and 10.2 for parity 6 and higher sows.

Successful breeding

Analysis was performed for sows that were followed-up to the ultrasound pregnancy diagnosis (population 3, n=151). Population 3 did not differ significantly from the excluded sows of population 1 regarding the haemoglobin concentration seven weeks before farrowing (113.9 g/l v 112.6 g/l, P=0.44) and total born per sow (15.1 v 14.8, P=0.47). Nevertheless, the backfat layer was slightly thicker in population 3 (16.9 mm v 15.4 mm, P=0.02). In short, the remaining population (151 sows) can be considered representative for the initial population (247 sows).

Seventy-eight per cent of the population 3 sows (n=118) were serviced in the week after weaning. Sows for which gestation was confirmed by ultrasound examination were considered 'successful breeders'. Causes of failure included culling after weaning (n=11), return to oestrus (n=14) and absence of gestation at the time of ultrasound examination (n=8).

Univariate analysis did not reveal a relationship between the success of breeding and the mean concentration of haemoglobin (P=0.69), BFT (P=0.46), or parity rank (P=0.14). However, the breeding success rate increased with increasing numbers of suckling piglets alive at three weeks of age (P=0.02). Multivariate analysis confirmed these results.

Discussion

The aim of this study was to describe haemoglobin concentration currently found in high-prolificacy sows, to study the relationship between haemoglobin concentration and body reserves, and to determine whether anaemia is a risk factor for reproductive performance. The study led to three main results.

The first result was the proven decrease of haemoglobin concentration over time during the sow's productive life. Gilts begin their reproductive life with a concentration of nearly 120 g/l. Subsequent gestations seem to contribute to a decrease in haemoglobin concentration, to fall below 110 g/l for sows of parity rank 6 and higher. In 1980, Meissonier had already studied this effect but was not able to prove it. The differences in reproductive performances between these two periods may explain the difference of results (Meissonier and others 1980).

The second result is the demonstration of a change in haemoglobin concentration according to the physiological stage: haemoglobin concentration at farrowing and at weaning are lower than those measured seven weeks before term. These results confirm those of Schalm and Calvo (Calvo and others 1989, Schalm 2000). It is not possible to determine the part of this decrease caused by the increased needs of the foetus towards the end of gestation, by haemorrhages or by haemodilution. However, the decrease of haemoglobin concentration measured at seven weeks before term over subsequent gestations seems to suggest that haemodilution is not the only factor explaining the drop in haemoglobin concentration at the end of gestation. Foetal iron requirements at the end of gestation, and haemorrhages during parturition contribute to the decrease in haemoglobin concentration.

Finally, it was shown that the thinner the sow, the lower its haemoglobin concentration, regardless of its parity rank. To our knowledge, this relationship has not been demonstrated before. The study does not allow the establishment of a causal link between these two parameters. However, the relationship between BFT and haemoglobin concentration underlines the importance of iron intake with feed to contribute to the body reserves and to the maintenance of haematological values. Current food intakes seem insufficient to compensate the loss of iron due to current reproductive performances (over 13.7 total born in the farms of this study) and by a very short unproductive period. The typical feed rations of the farms included in the study contain 400 mg of iron per day during pregnancy and 1125 mg during lactation. With an estimated bioavailability of 20 per cent, the true intake is therefore 80 mg and 225 mg per day, while the recommended daily intake (National Research Council 1998) is 137 mg and 382 mg per day, respectively.

However, our study did not demonstrate a link between haemoglobin concentration and reproductive performance, whether taking into account the number of total born, stillborn or weaned piglets, or the breeding success rate after weaning. These results are in contrast with those of an earlier study carried out on farms with a stillborn rate of up to 75 per cent, and where it was found that sows with very high stillborn rates had very low haemoglobin concentration, between 60 and 80 g/l. On those farms, corrective action by iron injection (500 mg) or oral administration (100 ppm) allowed a rapid and permanent return to more acceptable stillborn rates (Moore and others 1965). A more recent study (Lamana García-Fuente 1996) reached similar conclusions in a farm where the stillborn rate was higher than normal. Mean haemoglobin concentration was 80 g/l, and infectious causes were excluded. Following the supplementation of iron proteinate, the stillborn rate returned to an acceptable level. The absence of a link between haemoglobin concentration and performance in our study may be due to the fact that few sows had concentrations as low as those in the earlier studies (<80 g/l). Further studies on the relation between haemoglobin concentration and production performances should include herds with more obvious health and production problems. The lack of relationship may also be due to limitations of the study, particularly for the study of the breeding success, as the hazards of the study lead to a lower number of sows than initially planned in population 3. It should also be investigated if anaemia is a risk factor for culling, as it can be hypothesised that less prolific sows, which are preferentially culled, have a low haemoglobin concentration. Finally, it is possible that the farmer's assistance during farrowing masked the stillbirth rate.

In the absence of a link with reproductive performance, it is difficult to give a clear and precise standard below which a sow should be considered anaemic. Haemoglobin concentration in pigs is considered physiological between 100 and 160 g/l. However, the reference values depend on gender, age, stage of gestation or lactation and the season (Schalm 2000). Haemoglobin concentrations observed in our study were lower than those reported by Schalm, but in that study they were obtained from a smaller number of animals. The concentrations found in our study were also lower than those of Maes (Maes and others 2011) who observed a concentration of 128.4 g/l one week before farrowing in 88 sows of a 3.8 mean parity rank; we observed a concentration of 111.5 g/l in sows of parity 2–3 sampled four weeks before farrowing. Both studies used the same on-farm device. The main hypotheses to explain this difference include feeding (quantity, quality, iron source and concentration, trace elements and vitamins), the site of sampling (ear v tail), BFT and sow prolificacy. The latter was 1.9 piglets higher in our study (13.1 v 15.0 total born). In pregnant women, anaemia is defined as haemoglobin concentrations below 110 g/l during the first and third trimester of pregnancy, or below 105 g/l during the second trimester (Milman 2008).

Our study does not confirm the relationship between a low BFT at farrowing and the stillbirth rate (Vanderhaeghe and others 2010). But then, this was not the main objective, and the number of thin sows at farrowing (<14 mm) or at weaning (<12 mm) was probably insufficient to confirm this impact.

Another possible reason for the lack of relationship between haemoglobin concentration and reproductive performance is the fact that haemoglobin concentration may be a late criterion for iron deficiency. The study of other haematological parameters would need to be considered. In human medicine, the measurement of serum ferritin concentration is the gold standard. However, inflammatory reactions may distort the results. As sows are susceptible to cystitis in late gestation, the interpretation of this test would need to be adjusted according to the health status of the sow (Smith and others 1984, Breymann 2002). Another test is the determination of the percentage of hypochromic red blood cells. This test can detect a functional iron deficiency before the decrease of haemoglobin concentration. However, it is difficult to carry out on the farm, as red blood cells are fragile and lyse easily. Finally, the measurement of the serum transferrin receptor is a method used in human medicine. It is an early parameter that is not affected by inflammation (Carriaga and others 1991, Breymann 2002). However, it is an expensive test, which limits its use in farm animals.

These results were obtained from seven farms in France, with one to four consecutive batches for each farm. Pigs involved were of a conventional genetic origin. The study focused on prolific farms with a high rate of stillborns, based on our hypothesis that prolificacy might enhance the risk of anaemia and, therefore, of stillbirth. Farms with a 15 per cent or higher rate of assisted farrowing were considered to have a higher rate of stillbirths, as we presumed that manual assistance was given in an attempt to reduce the stillbirth rate without addressing the risk factors. The mean haemoglobin concentrations varied slightly between herds, but the study was not designed to analyse risk factors for anaemia at herd level. Levels of iron intake in feed and water were not investigated.

We found no marked difference between farms regarding breeds, management, type of food or drinking water, leading to the hypothesis of risk factor. The batches monitored in the seven farms were representative of normal herd demography. Only the proportion of gilts was slightly lower than generally recommended (17 v 20 per cent), with more sows of parity rank 6 and higher. The median BFT at farrowing was lower than the generally recommended standards (18 mm), and the proportion of sows outside the 14–20 mm range at farrowing was high (37 per cent). In other words, the farms in our study had sows that were relatively thin and heterogeneous. The farms had been selected for their high prolificacy and a relatively high stillborn rate (9.3 per cent of stillborns). This is a limitation for the generalisability of the study. It would be particularly interesting to determine whether the decrease of haemoglobin concentrations over the entire productive life of the sows is also observed in non-prolific farms.

It would also be interesting to further study the impact of haemoglobin concentration and BFT on reproduction by following the productive life of the sow, and at least by studying its impact on fertility and prolificacy of the subsequent cycle.

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