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Factors Affecting Physiology and Endocrinology of Farrowing

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1. Introduction

The highly prolific sow, defined as one giving birth to 16 or more liveborn piglets, presents a challenge to reproductive management of a sow herd (Boulot et al., 2008). From the point of view of reproductive management of the sow, feeding plays a key role. Therefore, recent findings related to feeding and how it affects farrowing, lactation and oestrus management are given the highest priority in the present paper. We report on recent findings related to feeding sows a high fiber diet during the period preceding parturition and its beneficial effect on gut function and duration of farrowing (Oliviero et al., 2009). In addition to feeding, arrangement of the farrowing pen (crate vs. pen; barren vs. enriched) appears as a critical factor determining the course of parturition. Our latest findings suggest that prohibiting the sow to exhibit nest building behaviour (Algers and Uvnäs - Moberg, 2007) prolongs parturition by an average of 90 minutes (Oliviero et al., 2008; 2010).

In addition, feeding sows with a high fiber diet during pregnancy, apart from being a beneficial feeding strategy from the welfare point of view, appears to increase the ad libitum feed intake during lactation. This effect seems to be carried over to the average daily gain of piglets, especially during the neonatal period (Quesnel et al., 2009, Peltoniemi et al., 2009). Amount of feed eaten by sows during lactation, on the other hand, appears as a key in enhancing gonadotrophin secretion and follicle development throughout lactation, however these effects of feeding become more evident towards the end of lactation (Kauffold et al., 2008). Follicles grow after weaning, as triggered by gonadotrophins FSH and LH, occurs the faster the better the stimulation by gonadotrophins has been prior to weaning (Prunier and Quesnel, 2000; Kauffold et al., 2008).

2. Successful farrowing

Successful farrowing can be defined as (1) sows given a chance to exhibit species specific nest building behaviour, (2) duration of farrowing not exceeding 5 hours, (3) all piglets in the litter born alive and (4) the first sucklings resulting in all newborn piglets receiving colostrum.

As fetuses grow fast at the end of pregnancy, there is a need to increase the energy intake by the sow. A common feeding strategy has been to put sows on lactation diet during the period before farrowing, in anticipation of the great energy requirement during lactation.

While being understandable as a strategy from the energy intake point of view during lactation, this strategy by large ignores the intestinal function and dietary metabolism during and shortly after farrowing.

In one of our studies (Oliviero et al., 2009) we investigated the energy balance related parameters of the sow around farrowing. The parameters indicating catabolism (NEFA and creatinine) increased significantly a few days before farrowing, showing a positive peak almost on the day of parturition (Figure 1a), concerning NEFA this is in agreement with the results of Le Cozler et al. (1999). On the other hand, the metabolic markers of dietary energy (urea, insulin and glucose), decreased significantly with the approach of farrowing, yielding a negative peak on the day of parturition (Figure 1b). This may be the result of an internal regulation of the metabolism as the sow approaches farrowing. At this time, metabolism of

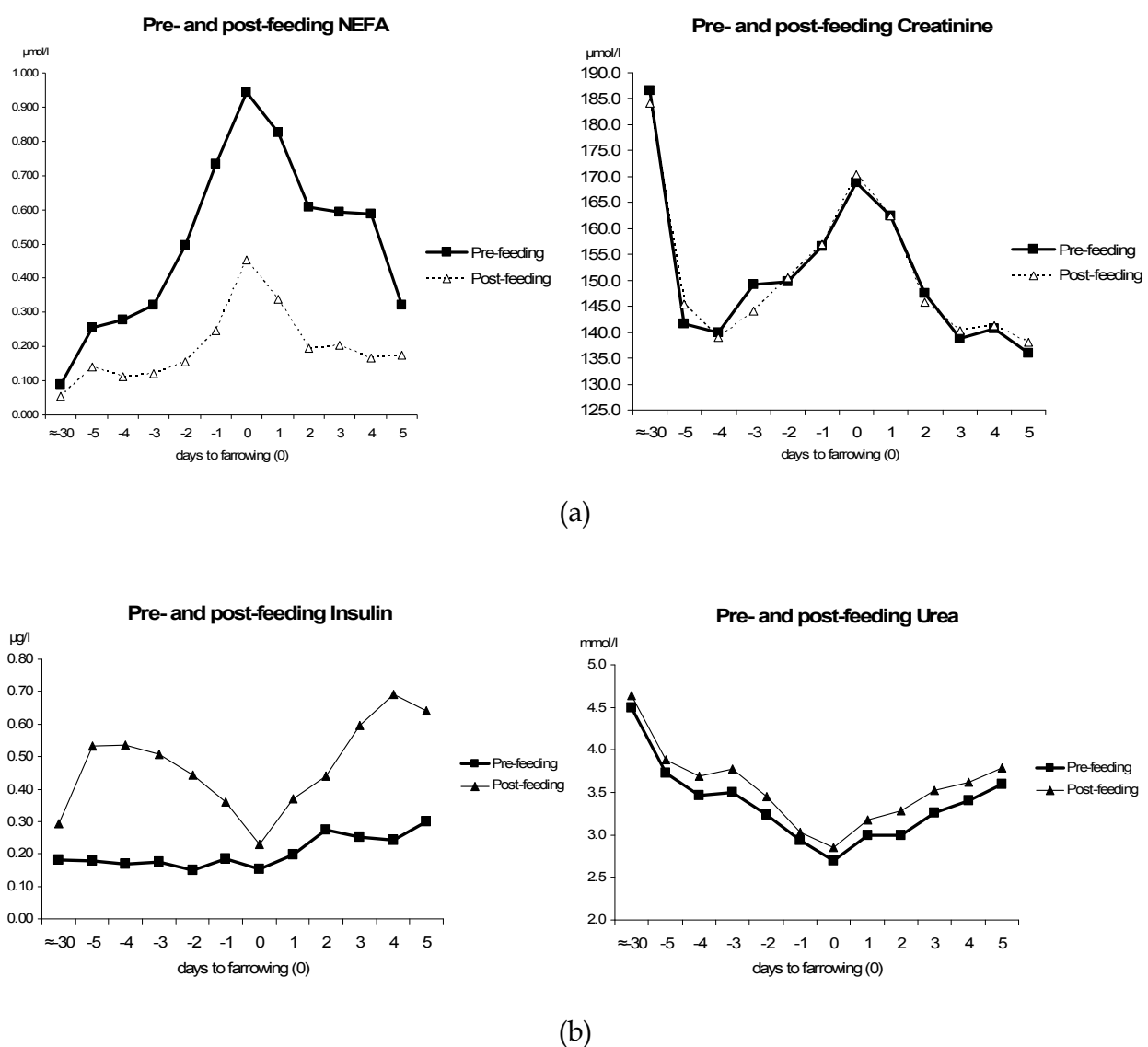


Fig. 1. Energy balance related parameters in sows (n = 41). At the top (a) there are the parameters indicating catabolism (NEFA and Creatinine) which have high levels at farrowing; at the bottom (b) there are the metabolic markers of dietary energy which on the contrary have low levels at farrowing.

the external source of energy decreases and the main source of energy becomes the internal body reserves (fat and muscles) as the peaks of NEFA and creatinine demonstrate. In this sensitive phase, diet and intestinal activity seems of secondary importance. The parturition process clearly takes priority over digestive and intestinal activity, but the demand for energy remains high or even higher, and it's supplied mobilising internal reserves. Therefore, around farrowing it appears important, to promote good intestinal activity with an adequate amount of fibre rather than just increase dietary energy intake.

We observed that after having been on a traditional lactation diet with 3,8 % of crude fiber prior to farrowing, sows showed an increased constipation incidence of up to 22 % for several days after farrowing (Figure 2; Oliviero et al., 2009). Gut function slows down during parturition anyway and overgrowth of bacteria in a gut filled with an energy-rich diet may lead into activation of the GALT (gut associated lymphoid tissue) system (Oliviero et al, 2009; Reiner et al., 2009). The activation of the GALT system would stimulate PGE₂ release, which may further suppress intestinal function until a leak of endotoxins through the gut wall occurs, bringing about a systemic response and clinical symptoms found in post partum dysgalactia syndrome, PDS (Reiner et al., 2009). Therefore, avoiding constipation by any means should be of interest to managers of any well functioning piglet producing unit.

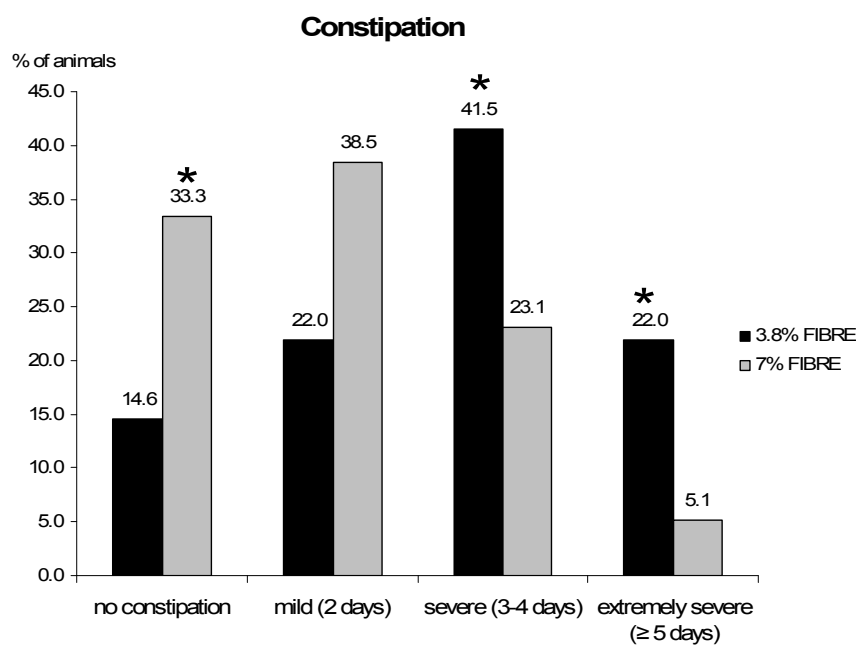


Fig. 2. Incidence of different grades of constipation in the 3.8% FIBRE group (n = 40) and in the 7% FIBRE group (n = 41), during the observational period (from 5 days before to 5 days after farrowing). Consecutive days of constipation are recorded, and for constipation is meant absence produced of feces. Asterisks represent significant differences between the two groups with $P < 0.05$.

While feeding sows laxatives like Glauber salt, cooked linseed mixture and commercial laxatives are among traditional measures to avoid constipation, our experiences support adding more fiber into sow diets before farrowing (Oliviero et al., 2009). A 7-11 % crude fiber content prior to farrowing appears as a reasonable measure to prevent constipation and an important part of management of successful farrowing (Oliviero et al., 2009; Quesnel

et al., 2009; Peltoniemi et al., 2009). The first beneficial function of a high fiber diet is the improved intestinal activity (Oliviero et al., 2009). However, other beneficial effects relating to the use of high fiber diets have also been reported. These include improved intestinal immunity due to an increased mucin production as well as improved energy utilization of the feed consumed.

Water intake of the sow before farrowing is an important parameter to monitor, since it is elementary to milk production. On average, sows drink 10-30 liters of water around farrowing (Oliviero et al., 2009). However, variation between individual sows was considerably large and sows on the high fiber diet drank significantly more than did sows on the traditional diet (Figure 3; Oliviero et al., 2009). This was attributed to either stimulating effect of fiber on water intake as such or the increased volume related to the higher fiber diet possibly explaining the difference compared to the traditional pre-farrowing diet (Oliviero et al., 2009). Whatever the cause, these findings encourage use of diets containing more fiber prior to farrowing. The usual flow recommendation of drinking water from nipples is 3-4 liters / minute and this is one of the easiest parameters to be measured on a health check call in a farrowing unit.

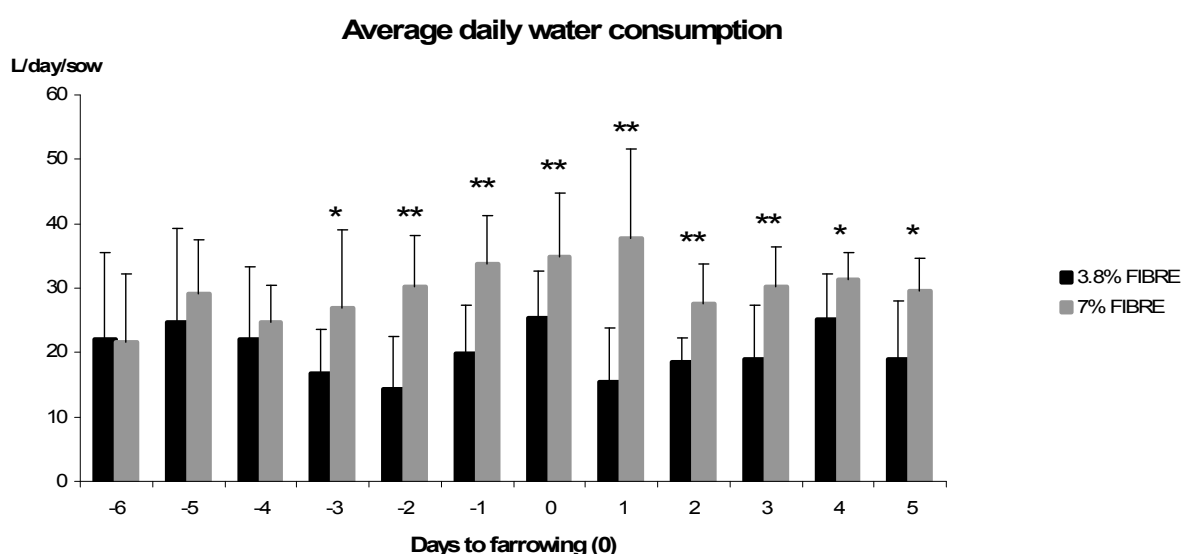


Fig. 3. Individual average daily water consumption and respective SD bars in the FIBRE group (n = 12) and in the LACT group (n = 12). The asterisk indicate the degree of significance (* = $P < 0.05$; ** = $P < 0.01$).

Data from our group show that sows not given a chance to express nest building behaviour have higher circulating cortisol concentrations before farrowing and lower oxytocin concentrations during the expulsion phase of farrowing (Figure 4; Oliviero et al., 2008a). From the practical viewpoint, however, maybe the most important observation was the one related to the duration of farrowing. If placed in a crate and not given a chance to build up a nest, it took an average of 1,5 hours longer from our experimental sows to deliver the litter than sows placed in a free pen with nesting material (Figure 4; Oliviero et a., 2008a; 2009). Furthermore, the average interval between piglets was considerably longer in crated sows with no nest building material (25 minutes CRATE vs. 16 minutes in PEN; Oliviero et al., 2008a).

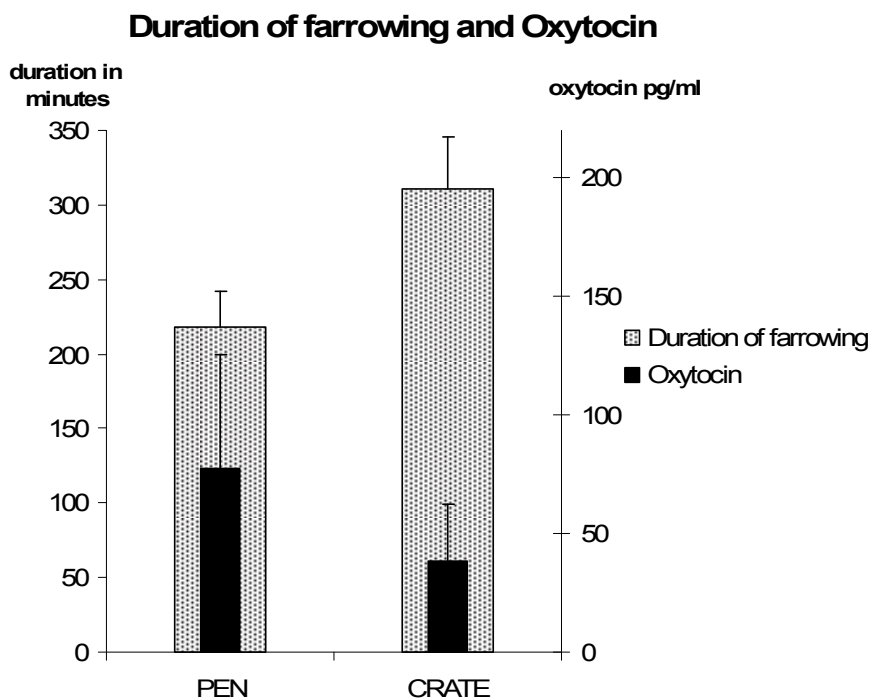


Fig. 4. Average duration of farrowing and average Oxytocin post-expulsion pulses in the PEN (n = 9) and CRATE (n = 9) groups of sows (mean \pm SD). Data from Oliviero et al., 2008.

Another explanation could be hormonal impairment due to the higher level of fat circulating in overfed sows. A higher level of fat can affect lipid-soluble steroids, and especially the progesterone:oestrogen ratio, which is known to affect oxytocin receptor activation (McCracken et al., 1999; Russell et al., 2003). Abnormalities due to oxytocin receptor activation may weaken the expulsive phase of parturition. A decline in progesterone and a concomitant increase in the oestrogen profile should occur 36 to 24 hours prior to parturition (Cowart, 2007). We observed a delayed decline in progesterone beyond day 1 after parturition in a number of our trial sows (Figure 5; Oliviero et al., 2008a), a delay that may be linked to obesity and the prolongation of parturition. If so, progesterone bound to fat may be too stable to promptly react to CL regression.

We have recorded duration of farrowing in several studies by now (Oliviero et al., 2008; 2010). From these studies it is apparent that a farrowing lasting longer than 5 hours is deemed unsuccessful and easily leads to complications for both the dam and the newborn. Therefore, we suggest that with the modern sow lines, a 5 hours threshold may be applied when making a difference between successful and unsuccessful farrowing. Several factors, as constipation, body condition of the sow, parity, breed and number of stillborn piglets affect duration of farrowing (Oliviero et al., 2010). Constipation, as discussed above, may be alleviated by increasing fiber content of the diet. Backfat thickness of higher than 17 mm, however, also appeared as a risk factor for prolonged farrowing in the genetically lean Finnish sow population (Oliviero et al., 2010).

Number of piglets stillborn prolonged duration of farrowing (Oliviero et al., 2010). It is known from previous studies that fetuses are usually alive shortly before farrowing. The great majority (>80%) of piglets that are deemed to born still, die during the course of parturition. It is therefore reasonable to assume that dystocia, whether due to the dam or the

fetus, is the major cause for piglets born still. According to Jackson (1972), in the sow, inertia uteri (37%) used to be considered as the most common cause for dystocia followed by the breech presentation (14,5%), obstruction of the birth canal (13%), simultaneous presentation (10%), downward torsion of the uterus (9%), downward deviation of the head (4%) and fetal oversize (3,5%). However, these robust classifications do not account for the more precise causes for intrapartum deaths of piglets, such as strangulation or early rupture of the umbilical cord or considerations relating to uterine contractions.

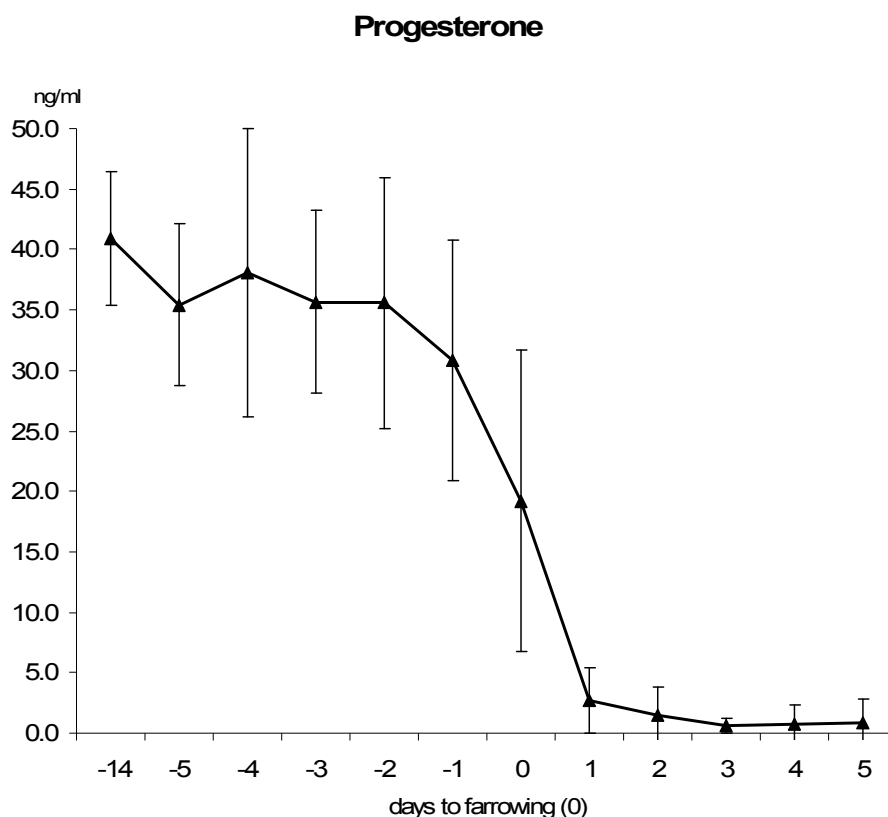


Fig. 5. Some sows showed a delayed decline in circulating progesterone before farrowing. The sows in this study (n = 38) showed still high levels of progesterone on the day of farrowing.

We found that also the level of back fat affected the duration of farrowing even though the sows used in this study were not particularly fat (Figure 6). Sows with a back fat average higher than 17 mm had an average duration of farrowing of 385 ± 197 min (n = 48), whereas those with a back fat average of less than 17 mm had an average duration of farrowing of 230 ± 103 min (n = 124; $p < 0.001$). One explanation could be a progesterone impairment due to the higher level of fat in those sows as described in the paragraph above. Another hypothesis could be that fat sows have more adipose layers around the birth canal (Cowart, 2007), thereby reducing the diameter of the birth canal, which can create a physical obstacle to birth during the expulsive phase with delayed farrowing.

It is very well known, that piglets need their passive immunity acquired through colostrum, otherwise they will not be able to cope with the environmental infective pressure. As every piglet is in need of colostrum and one that is missing out is clearly the one at risk of losing

life already in the early days. Colostrum transmission through the gut wall of the piglet can only occur during the first day of life and the amount of colostrum is not increasing according to the number of piglets born. Therefore, in a large litter, supervision is required, not only during the process of parturition, but also attending that even the last piglets born will receive adequate amount of colostrum. We found that, after stillborn, the most common primary cause of perinatal mortality is starvation (Table 1). Piglets which are unable to adequately feed themselves within the first days of life have less chance to survive and more chances to get crushed by the sow because of their state of lethargy which reduce their ability to move and react fast.

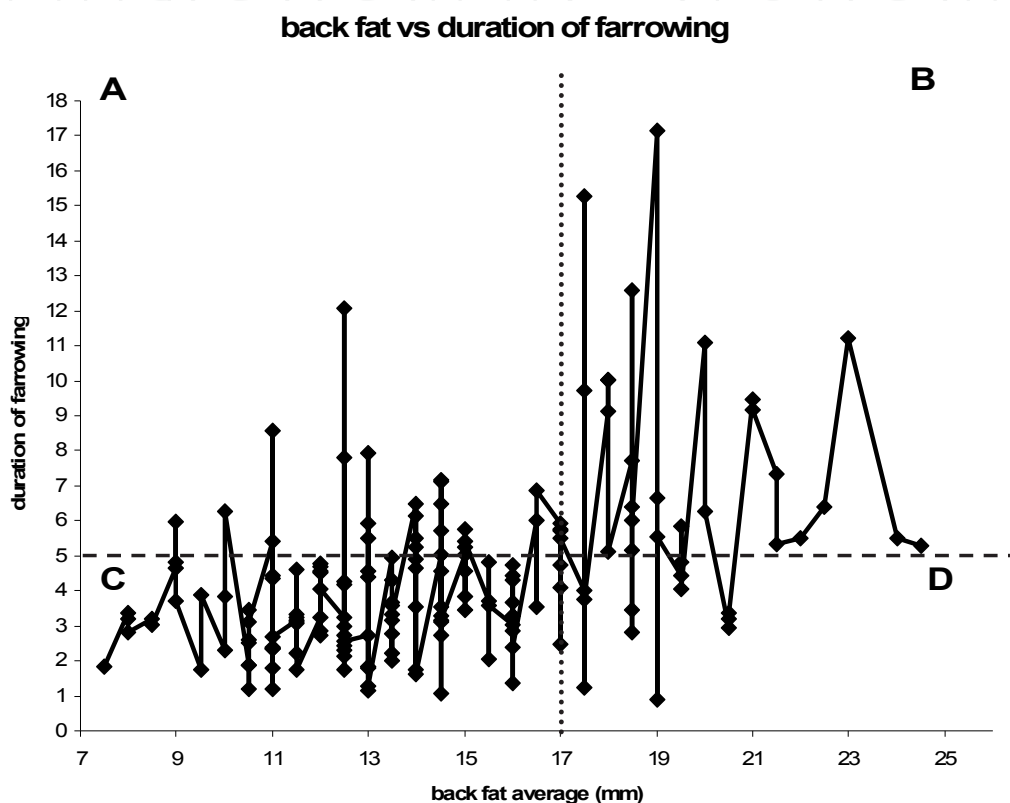


Fig. 6. Individual sows plotted by back fat average (mm) and the duration of farrowing (hours). The horizontal dashed line discriminates prolonged farrowing (> 5 h; A, B); the vertical dotted line discriminates the fatter sows (B, D). Most of the fatter sows had duration of farrowing longer than 5 hours (area B), while most of the thinner sows had farrowings duration shorter than 5 hours (area C).

3. Lactation performance of the sow and piglets

To care for a large litter, adequate feed intake of the sow is of great significance. A drop in feed intake around farrowing can be considered as physiological. Stepwise rise in feed intake by 0,5 kg of feed / day until day 10 or so will be enough to reach the target daily intake of about 8 kg, equal to about 100 MJ ME for a sow nursing 12 piglets (Peltoniemi and Kemp., 2009). A too steep rise in feed intake after farrowing will jeopardize the success of the whole lactation, since there will be a decline in intake, followed by fluctuation of it for most of the duration of lactation.

Cause of mortality	<i>n</i>	%
Stillborn	50	34.5
Starvation	30	20.7
Trauma	27	18.6
Infections	17	11.7
Other*	21	14.5
Total	145	100

*Anaemia, malformed, autolysis.

Table 1. Primary causes of piglet mortality (from birth to day 5 of life) determined after post-mortem examination (41 litters).

A balanced nutritional program designed to avoid excessive weight loss during lactation is of great importance for successful lactation. It has been shown that feeding the sow with higher amounts of fiber during pregnancy, intake of feed during lactation can be increased with a corresponding increase in performance of piglets (Quesnel et al., 2009). It has also been shown, that increasing fiber intake through the reproductive life of the sow appears as a feasible approach, contributing to improved welfare of the sow as well as good reproductive performance of the sow and improved growth performance of piglets (Peltoniemi et al., 2009).

Piglet mortality and mean birth weight appear to be closely associated with litter size. When litter size increased from 10 to 15, number of stillborn piglets went up from 0,3 to 1,0 and the proportion of piglets weighing less than 1 kg went up from 3 to 15 %, respectively (Boulot et al., 2008). In large litters, supervision of farrowing is therefore necessary. The first issue there is an accurate prediction of farrowing. We have developed techniques, whereby prediction of farrowing becomes possible and feasible. Movement sensors monitoring impending farrowing can be used to predict the expulsion phase of farrowing 24 hours prior to the first birth of the first piglet (Oliviero et al., 2008b). Other modern technology, such as use of thermocameras may be applied to detect hypothermic newborn piglets that require immediate attention by the caretakers.

We argue that the present development regarding piglets born in the pig industry is not on a sustainable basis. Instead of the number of piglets born alive, more research effort should be aimed at increasing the birth weight of piglets born and decreasing the still birth rate. Moreover, more attention should be paid to the quality of newborn piglets, the quality of piglets weaned and the quality of fattening pigs. The quality of piglets and fattening pigs in the pig production may be achieved by long term studies, starting during the fetal period, focusing on early development of the piglet and finally exploring the fattening phase of the pig.

4. Gonadotrophins and follicle development

Intake of feed by sows during lactation appears as a key in enhancing gonadotrophin secretion and follicle development throughout lactation, however these effects of feeding become more evident towards the end of lactation (Kauffold et al., 2008). Follicle growth after weaning, as triggered by gonadotrophins FSH and LH, then occurs the faster the better the stimulation by gonadotrophins has been prior to weaning (Kauffold et al., 2008).

Decreasing lactation length is a commonly taken strategy in Europe to hasten the reproductive cycle of the high producing sow and avoid excessive weight loss. However, the sustainability and ethical grounds for these strategies need thorough attention in the near future.

After weaning follicles grow approximately 1 mm / day. They reach the ovulatory size at about 7-10 mm within a week after weaning. The most recent findings in our group suggest that follicles ovulating at the size of 7 or 8 mm result in improved fertilization rates and larger litters than follicles ovulating at < 7 mm or > 8 mm (Vehmas et al., unpublished). Ultrasound technology (US) can nowadays be effectively applied in mating units to monitor insemination accuracy of insemination operators. In problem farms, inseminations occurring too early or too late in relation to ovulation can be picked up by US and relevant recommendations to change the AI strategy can be given. The optimal insemination time is estimated to be 0-16 hours prior to ovulation, which occurs at approximately when two thirds of the standing oestrus has passed.

Follicle development can also be monitored with regard to possible not-expected physiological or pathological findings at the ovary. After weaning, detection of corpora lutea may indicate lactational oestrus, while cystic follicles, for instance, are among classical examples of application of ultrasound technology in sow herds.

5. Conclusions

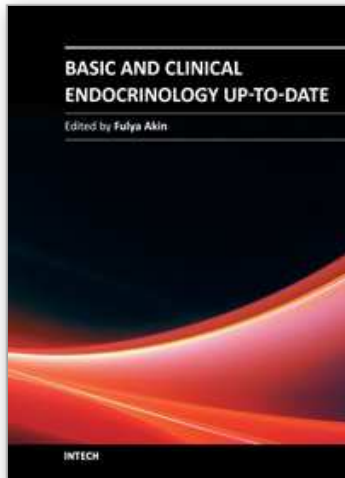
Successful farrowing includes components of maternal behavior, duration of farrowing, piglet mortality and colostrum intake. Feeding is considered as the major factor in the reproductive management of the hyperprolific sow. New insights such as adding more fiber to sow diets during pregnancy and especially in the period prior to farrowing prevent constipation, increase water intake of the sow around parturition and increase milk intake and performance of piglets. Use of modern technology in supervision of farrowing may improve losses related to large litters. Use of ultrasound technology after weaning to monitor follicular growth may further improve litter size. In breeding programs, new components of maternal characteristics such as maternal behavior, ease of parturition, colostrum production, and piglet quality parameters may be taken to further improve success rate of reproductive management.

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