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## KEY FACTORS TO IMPROVE PRODUCTION AND LONGEVITY OF PRIMIPAROUS SOWS

### *FATORES CHAVES PARA MELHORAR A PRODUÇÃO E A LONGEVIDADE DE FÊMEAS PRIMÍPARAS*

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### Summary

Energy and protein needs during lactation are substantial and since many sows have a limited feed intake capacity, protein and fat reserves are severely depleted during lactation. This results in post-weaning fertility problems like prolonged weaning to oestrus intervals, lower ovulation rates and higher embryonic mortality. Especially in first litter sows feed intake is often suboptimal, resulting in a second litter syndrome (lower litter size and/or lower farrowing rate) as found in average farm records and within farms. Sows suffering from a second litter syndrome may have lower life time productivity.

An adequate feed intake during lactation, preventing high losses of body stores, is therefore important. Feed intake can be stimulated through good management in which attention should be given to gilt development, feed intake during pregnancy, water intake, ambient temperatures in the farrowing room and the feed intake and feeding pattern during lactation. Reducing the number of piglets during (part of) the lactation can be successful in improving reproductive results after lactation, but a risk is the occurrence of lactational oestrus. Post weaning feeding strategies or management strategies can also be used to improve fertility. Extending the time of first service after weaning by using Altrenogest or skipping-a-heat improves pregnancy rate and litter size. In early pregnancy sufficient feeding levels should be given to sows to optimize litter size in the next parity.

### 1. Introduction

During lactation, most sows lose protein and fat reserves. Weight and protein losses exceeding approximately 12% during lactation result in reproductive problems like extended weaning to oestrus intervals, lower pregnancy rates after insemination and lower subsequent litter sizes (e.g. THAKER & BILKEI, 2005). Especially first litter sows are at risk since they still have significant nutrient needs for growth to maturity, a lower feed intake capacity and lower metabolizable fat and protein stores. Therefore the primiparous sows are usually the problem category in the sow herd and most data presented in this review concern first litter sows. In this paper, effects of limited feed intake on reproduction are reviewed.

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Subsequently, management tools are evaluated to improve reproduction of sows through stimulating feed intake during lactation, lactational management strategies and post lactational repair.

## 2. Effects of a limited feed intake on reproduction

In the seventies and early eighties, lactational feed restriction resulted in quite dramatic effects on weaning to oestrus interval (an increase of about 10 days) and hardly any effects on ovulation rate and embryo survival. In more recent data, effects of feed restriction on weaning to estrus interval are quite small (less than a day) while effects on ovulation rate and embryo survival are more pronounced (see Table 1). Feed restriction seems to decrease ovulation rate by about 2 to 4 and embryo survival by about 10 to even 20%. This change in responsiveness of sows to feed restriction during lactation is a result of strong genetic selection for short weaning to estrus intervals in the past 20 years. As a result, effects of low feed intake during lactation on weaning to estrus intervals are less pronounced in modern sows but effects on litter size and pregnancy rate are more pronounced. Especially the first litter sow is vulnerable, due to a restricted feed intake capacity. Based on analyses of 135 USA farms (MORROW et al., 1992) showed that about 40% of the farms had a second litter syndrome (which means that the second litter size was lower or equal compared to the first litter size). Within farms, it appears that the first litter sows that increase less in body weight between first insemination as a gilt and first weaning have an increased risk for the second litter syndrome (HOVING et al., 2010), which was both related to the body weight increase during pregnancy and the body weight losses during lactation. Moreover, sows suffering from a low litter size in the second litter also have lower litter sizes in subsequent parities and are culled 1 parity earlier (HOVING et al., 2010) which stresses the economic importance to prevent the second litter syndrome

Table 1: Effects of feed intake (high vs low<sup>1</sup>) during lactation on weaning to oestrus interval (WEI), ovulation rate and embryo survival

	Weaning age	WEI (days)		Ovulation rate		Embryo Survival (%)	
		High	Low	High	Low	High	Low
KING & WILLIAMS, 1984	d32	<b>7.6</b> <sup>2</sup>	<b>19.9</b>	14.4	13.5	70	72
KIRKWOOD et al., 1987	d35	<b>4.3</b>	<b>5.8</b>	18.1	18.6	<b>83</b>	<b>68</b>
KIRKWOOD et al., 1990	d28	<b>6.0</b>	<b>8.9</b>	17.6	17.7	<b>83</b>	<b>72</b>
BAIDOO et al., 1992	d28	5.9	7.5	16.2	16.7	<b>85</b>	<b>64</b>
ZAK et al., 1997 L: wk1-3	d28	3.7	5.6	<b>19.9</b>	<b>15.4</b>	<b>88</b>	87
L: wk4	d28	5.1			<b>15.4</b>		<b>64</b>
ZAK et al., 1998	d28	<b>4.2</b>	<b>6.3</b>	14.4	15.6	83	72
QUESNEL & PRUNIER, 1998	d24	5.7	5.9	19.2	20.7	-	-
VAN DEN BRAND et al., 2000	d22	5.1	5.7	<b>18.1</b>	<b>16.4</b>	68	68
TERLETSKI et al., unpublished <sup>3</sup>	d21	6.6	6.7	<b>18.6</b>	<b>16.7</b>	64	69
VINSKY et al., 2006 <sup>4</sup>	d21	5.3	5.4	18.3	18.2	<b>79</b>	<b>68</b>
FOXCROFT et al, unpublished	d21	5.7	5.5	18.5	17.5	<b>65</b>	<b>78</b>

<sup>1</sup> High ca. 80-90% of ad libitum; Low ca. 40-60% of ad libitum

<sup>2</sup> **Bold** means significant difference (P<0.05)

<sup>3</sup> High: Control fed >190kg farrow weight, Low: Restricted fed < 170 kg farrow weight

<sup>4</sup> number of female embryos lower in Restrict sows

### **3. Potential ways to optimize post weaning reproductive performance**

The most logical way to prevent post lactational reproductive problems is to prevent excessive weight loss during lactation. This can be achieved for example by optimizing feed or nutrient intake during lactation, optimising gilt development or weaning management strategies that reduce the suckling stimulus, which will be discussed below.

#### **3.1. Gilt development**

Gilt development has been related to post weaning reproductive problems but optimal gilt development is a subject that gives a lot of debate. Generally speaking, mating gilts at a young age or relatively low in body weight may not have negative consequences for first litter size. However, second litter size may still be compromised since young sows have the desire to grow and feed intake capacity is limited during first lactation. Experimental data from our research group indicate that sows with low weaning weights after first lactation (less than 150 kg) have a reduced second litter size. This has led to the advice to inseminate gilts at an older age, when they are more mature. First breeding ages of 240-260 days are nowadays common in Europe. It is debatable if this is economically attractive. Data from our own research group seem to indicate that gilts with similar breeding weights and ages can still vary substantially in lactational weight loss and subsequent reproductive performance. The challenge is to predict the problem animals.

#### **3.2. Feed intake during pregnancy**

Several studies have shown that excessive feed intake during pregnancy decreases the voluntary feed intake during lactation (e.g. MULLAN & WILLIAMS, 1989, YANG et al., 1989, DOURMAND, 1991). WELDON et al. (1994) showed that gilts fed high feeding levels during pregnancy developed glucose intolerance explaining the low feeding levels in early lactation.

YANG et al. (1989) showed that insufficient feed intake during pregnancy (resulting in thin sows) can not be compensated by increased voluntary feed intake during lactation in first litter sows and thus results in a prolonged weaning to oestrus interval. Therefore, gilts should be fed according to their requirements for maintenance, reproduction and growth but not be overfed. EVERTS et al. (1994) advise an energy intake of 24.8 and 36.1 MJ Metabolizable Energy (ME) per day at the beginning and end of pregnancy, respectively. With regard to reproductive performance Yang et al. (1989) advice a target back fat thickness (P2) at first parturition of 20 mm. CLOWES et al. (2003) advice a target back fat thickness of 17-20 mm at a weight of 175- 185 kg.

#### **3.3. Ambient temperature**

Thermal requirements for lactating sows are considerably lower than temperature requirements for piglets. New born piglets have a lower critical temperature of about 32-35<sup>o</sup>C which gradually lowers to a temperature of 24-27<sup>o</sup>C at 4 weeks of age. For sows, the upper critical temperature is not studied in detail but is probably lower than 22 to 25<sup>o</sup>C. Normally, barn temperatures during lactation are often well above 22<sup>o</sup>C and supplemental heating is provided to the piglets by means of floor heating or radiant heat (lamps). Above the upper critical temperature sows will lower their feed intake to prevent overheating. BLACK et al. (1993) calculated, based on 9 experiments, that for each degree Celsius above 16 <sup>o</sup>C, the daily voluntary feed intake decreased by 2.4 MJ Digestible Energy (a normal lactating sow diet provided about 13.8 MJ DE/kg). QUINIOU & NOBLET (1999) showed that at a temperature range of 25-27 <sup>o</sup>C voluntary feed intake decreased with 214 g per <sup>o</sup>C. In that similar temperature range, SILVA et al. (2009a) showed that when humidity was high (RH 94%), the decrease in feed intake was dramatic (492 g/ <sup>o</sup>C/day). Therefore, high ambient temperatures can significantly reduce feed intake during lactation. Skin wetting, drip cooling and

snout coolers may increase lactation feed intake of sows at high ambient temperatures (see MAKKINK & SCHRAMA, 1998, for review). VAN WAGENBERG (2006) and SILVA et al. (2009b) showed that floor cooling increased feed intake of sows by 12-18%, increased weaning weight of piglets and reduced weight loss of sows.

Effects of low ambient temperatures on piglets are most severe during the first days after birth, while negative effects of high ambient temperature on the sow are predominant during mid and late lactation when milk production and feed intake are high. Therefore, it might be beneficial to have high temperatures during the first week of lactation and, if possible, lower temperatures thereafter. According to MAKKINK & SCHRAMA (1998), room temperatures in late lactation may even be as low as 16<sup>o</sup> C when a good microclimate is available for piglets. However, good experimental data on this are missing. Low ambient temperatures will increase feed intake of sows during lactation and will therefore be helpful in preventing reproductive problems in first litter sows.

### **3.4. Feed intake pattern**

Some reports show that feeding lactating sows more than two times a day will improve feed intake and sometimes better feed intakes are found when using ad lib feeding systems. HOOFS & ELST-WAHLE. (1993), for example, found a 10% higher feed intake when using self feeders in stead of feeding twice a day. Generally, it is advisable to remove feed from the trough once daily when using ad lib feeding to prevent the feed from moulding and becoming sour.

KOKETSU et al. (1996a,b) characterized feed intake patterns during the course of lactation and studied the effect on reproductive output. Sows showing an increase in feed intake, regardless of whether the increase was rapid or gradual, with no drop during the course of lactation, showed the best reproductive performance. If sows are overfed at the onset of lactation sometimes a drop in feed take is seen later in lactation. In those sows, reproductive output is lower. Therefore it is advised to increase feed intake gradually in the first days of lactation. EVERTS et al. (1995), for example, advice 2 kg of diet at farrowing and a stepwise increase of feed intake of 0.5 kg per day until the recommended feed intake is reached.

### **3.5. High fat diets during lactation**

Another approach that has been followed to reduce mobilisation of body stores is increasing the dietary fat content. When feeding high fat diets a reduction of feed intake is often seen in sows. However in a review on high fat diets, DROCHNER (1989) showed that in older parity sows total ME intake was still increased by about 3-32% (as a mean 12 %). Fat as an energy source also seems to increase milk fat content and in some cases total milk output (PETTIGREW, 1981; DROCHER, 1989). VAN DEN BRAND et al. (2000c) measured energy and protein balances in primiparous, isocalorically fed sows with fat-rich (13.5 % fat) or carbohydrate-rich diets (3.4 % fat) at two different feeding levels (63 and 47 MJ ME/d). At high feeding levels the fat rich diet resulted in an increased milk fat content and a significantly higher body fat loss from the sows. Over a 21 day lactation period the fat rich diet resulted in 3.8 kg more loss of fat reserves as compared to the starch rich diet. At low feed intake levels, losses of body condition were similar for both diets.

Fat rich diets may be beneficial in a hot climate since heat production of sows is lower when fat is used for milk production instead of carbohydrates. However the milk fat driving effect of the fat rich diet makes it unlikely that fat rich diets will help the sow to prevent loss of body condition even when the energy intake is higher. It is therefore also questionable whether high fat diets are beneficial for prevention of reproductive problems.

The aim of the work of VAN DEN BRAND (2000a,b) was to study if carbohydrate rich diets during lactation would positively influence reproductive characteristics of sows during. Carbohydrate rich diets stimulate insulin production and insulin is believed to stimulate LH release from the pituitary gland and to stimulate growth of follicles (see KEMP, 1998, for review). In the catabolic first litter sow, however, insulin

stimulating diets fed during lactation failed to improve reproductive characteristics like LH release during and after lactation, peri-ovulatory reproductive hormone profiles, ovulation rate and embryonic survival (VAN DEN BRAND 2000a,b). In multiparous sows, fed insulin stimulating diets during lactation and after lactation, effects of insulin levels on LH surge size and progesterone levels in early pregnancy were reported with may favour embryo survival (KEMP et al. 1995).

### **3.6. Optimal water intake**

Due to high barn temperature and the production of about 10 kg of milk per day, water requirements of sows are high. FRASER & PHILIPS (1989) showed that in systems with a nipple drinker delivery system of 0.7 L/min water intake of sows around farrowing and in early lactation can be dramatically low. Associations were found between water intake of sows and growth and mortality in the piglets. Therefore, it is advised to supply water ad libitum during lactation and to regularly check the water output of nipple drinkers which should be 2 to 4 litres per min.

### **3.7. Reduction of the suckling stimulus**

Another approach to relieve the sow from the burden of lactation is through reduction of the suckling stimulus. Reducing the number of piglets during (part of) the lactation may help to reduce milk production from the sow and may also reduce the inhibition of the suckling induced suppression of LH release by endogenous opioids. However, lowering the number of piglets during lactation is often not successful, partly because piglets in smaller litters will consume more milk per piglet. Also, with the current genetics, litter sizes are so high that there is no possibility to have lower numbers of suckling piglets in gilts.

Management techniques like interrupted suckling (a daily temporary removal of the whole litter) or split weaning (a permanent removal of part of the litter a few days before completing weaning) can be successful but a drawback of the use of these techniques can be the occurrence of lactational oestrus. Lactational oestrus is often poorly expressed by the sow and occurs at unpredictable times. Therefore lactational oestrus should be prevented unless a management system is used that aims at inseminating sows at lactational oestrus (see LANGENDIJK et al. 2007, for review).

## **4. Potentials for post lactation repair**

A major cause for post lactational reproductive problems is found in the limited feed intake capacity during lactation resulting in excessive body weight losses. There are, however, possibilities for post-lactation repair.

### **4.1. Post weaning feeding**

In general, effects of post weaning feeding and management on weaning to oestrus interval are only found in sows with prolonged weaning to oestrus intervals after lactation. In sows with short weaning to oestrus intervals, follicles are recruited directly after weaning to grow out to preovulatory sizes. These sows can not have shorter weaning to oestrus intervals. FAHMY & DUFOR (1976) found that ad lib feeding after weaning as compared to restricted feeding increased the percentage of sows in oestrus within 7 days after weaning from 52 to 62%. VAN DEN BRAND et al. (2001) showed that feeding carbohydrate rich diets after weaning compared to fat rich diets resulted in a shorter weaning to oestrus interval. In their study, carbohydrate rich diets increased the average percentage of first litter sows in oestrus within 9 days after weaning from 52 to 67%.

More recent data (VAN DEN BRAND et al., 2006, 2009) indicate that dextrose supplementation between weaning and oestrus did not result in a shortening of the (already short) weaning-to-oestrus interval, but resulted in a numerically higher and more uniform birth weights of piglets and increased pre-weaning

survival of small piglets. Further, inclusion of fermentable NSP (e.g. sugar beet pulp) from weaning until mating increases the number of total and live-born piglets (SORENSEN, 1994, VAN DER PEET et al, 2004). Effects of both sugar beet pulp inclusion and dextrose are probably explained by the insulin and IGF-1 stimulating effect of these diets. There are indications that insulin and IGF-1 support follicle development and result in a more homogeneous follicle development between weaning and oestrus thereby reducing embryo and piglet variation in development.

#### **4.2. Boar stimulation**

Intensive boar contact after weaning improved the percentage of sows showing heat within 9 days post weaning from 30 to 51% (LANGENDIJK et al., 2000). In these studies no effects were found on ovulation rate or embryonic survival.

#### **4.3. Use of PG600**

The use of PG600 directly after weaning results in an improvement of the weaning to oestrus interval in many studies but sometimes, it results in lower pregnancy rate or lower litter sizes (KIRKWOOD, 1999). The latter may be related to differences in follicle development at time of PG600 injection, but no data are available to substantiate this.

#### **4.4. Use of progesterone analogues**

Epidemiological data showed that a short weaning to oestrus interval is a risk factor for the second litter syndrome. Sows with longer weaning to oestrus intervals have a lower chance of producing a small second litter (MORROW et al., 1992; LUCBERT & LAVOREL, 1984). Perhaps, therefore, ovulation rate or embryo survival can be improved by allowing the sow to recover for a longer period after lactation. One way to do that is to give the sows the progesterone analogue altrenogest 15-20 mg/day (Matrix or Regumate™) after weaning to artificially extend the weaning to oestrus interval. In most studies altrenogest is used from the day of weaning onwards for a period of 3 to 7 days. Use of altrenogest resulted in an increase in pregnancy rate of 5.6 to 15.7 % and an increase in subsequent litter size of about 0.2-0.8 piglets (BOLAND, 1983, JOHNSTON et al., 1992, MARTINAT-BOTTE et al., 1994). However, short term altrenogest treatment does not always give consistent better results. Some studies did not find any improvement due to altrenogest treatment. The application of altrenogest for short periods, like 7 days, is especially effective in sows with depressed follicle development at weaning, which are the sows that lose substantial body reserves during lactation (VAN LEEUWEN et al., in press and submitted).

Extending the use of altrenogest to 14 days of treatment seems to result in better and more consistent results (VAN LEEUWEN et al., in press). More detailed studies show that application of altrenogest after weaning results in increased ovulation rate, less variation in embryo development and/or a higher embryo survival, which may be explained by restoration of follicle development under altrenogest after lactation. (VAN LEEUWEN et al., 2010).

#### **4.5. Skip a heat**

Another approach allowing the first litter sow to recover from previous lactation is to inseminate the sow at the second heat after weaning instead of the first one (skip a heat). Skipping the first heat can improve pregnancy rates by 15 % and subsequent litter sizes by 1.3 to 2.5 piglets (CLOWES et al., 1994; VESSEUR, 1997). When using this approach, intense heat checking is important to make sure that the sow will show a second heat. Whether or not these techniques should be applied is a matter of economic calculations.

#### 4.6. Feeding levels during early pregnancy

After weaning, sows need to restore their body reserves that were lost during lactation. The period between weaning and estrus is too short to restore these reserves adequately. In practice, young sows are often kept on restricted feeding levels during early pregnancy. This strategy mainly originates from work on gilts, which shows that high feeding levels in early pregnancy increase embryonic mortality. There is, however, no evidence that this also holds for sows that have lost substantial body reserves during lactation. Recently, our lab studied effects of feeding level (2.5 or 3.25 kg/ day) from day 3 to 32 of pregnancy on litter size and farrowing rate. The high feeding level increased total born and live born piglets from sows pregnant from first insemination with 2.1 and 1.8 piglets, respectively. Piglet weights were similar at both feeding levels. However, farrowing rate seems (non-significant in this study) to be decreased (77 vs. 90%). So, high feeding levels increase litter size but may also give more sows returning to oestrus after first insemination.

### 5. References

- BAIDOO, S.K., AHERNE, F.X., KIRKWOOD, R.N. & FOXCROFT G.R. (1992) Effect of feed intake during lactation and after weaning on sow reproductive performance. *Canadian Journal of Animal Science*. 72, 911-17.
- BLACK, J.L., MULLAN, B.P., LORSCHY, M.L. & GILES, L.R. (1993) Lactation of sows during heat stress. *Livestock Production Science*. 35, 153-70.
- BOLAND, M.P. (1993) Control of oestrus in primiparous sows. *Theriogenology*. 19-3, 377-84.
- CLOWES, E.J., AHERNE, F.X. & FOXCROFT, G.R. (1994) Effect of delayed breeding on endocrinology and fecundity of sows. *Journal of Animal Science*. 72, 283-91.
- CLOWES, E.J., AHERNE, F.X., FOXCROFT, G.R. & BARACOS, V.E. (2003) Selective protein loss in lactating sows is associated with reduced litter growth and ovarian function. *Journal of Animal Science*. 81, 753-64
- DOURMAD, J.Y. (1991) Effect of feeding level in the gilt during pregnancy on voluntary feed intake during lactation and changes in body condition during gestation and lactation. *Livestock Production Science*. 27, 309-19.
- DROCHNER, W. (1989) Einflüsse von Fetzulagen an Sauen auf Aufzuchtleistung und Fruchtbarkeit. *Übersicht Tierernährung*. 17, 99-139.
- EVERTS, H., BLOK, M.C., KEMP, B., VAN DER PEET-SCHWERING, C.M.C. & SMITS, C.H.M. (1994) Requirements of pregnant sows. CVB documentation report 9. CVB Lelystad, The Netherlands. p 51.
- EVERTS, H., BLOK, M.C., KEMP, B., VAN DER PEET-SCHWERING, C.M.C. & SMITS, C.H.M. (1995) Requirements of lactating sows. CVB documentation report 13. CVB Lelystad, The Netherlands. p 45.
- FAMHY, M.H. & DUFOR, J.J. (1976) Effects of post-weaning stress and feeding management on return to oestrus and reproductive traits during early pregnancy in swine. *Animal Production*. 23, 103-10.
- FRASER, D. & PHILLIPS, P.A. (1989) Lethargy and low water intake by sows during early lactation: A cause of low piglet weight gain and survival. *Applied Animal Behaviour Science*. 24, 13-22.
- HOOFS, A. & ELST-WAHLE, L. TER (1993) Self feeding mangers for lactating sows. *Praktijkonderzoek Varkenshouderij*. 7, 16-8.
- HOVING, L.L., SOEDE, N.M., GRAAT, E.A.M., FEITSMA, H. & KEMP, B. (2010) Effect of live weight development and reproduction in first parity on reproductive performance of second parity sows. *Animal Reproduction Science*. 122, 82-9.
- JOHNSTON, N.E., EASTAUGH, M.W. & THORNTON, E.J. (1992) The short term use of regumate in first litter sows. Proceedings of International Pig Veterinary Society. The Hague, The Netherlands. p 457.

- KEMP, B., SOEDE, N.M., HELMOND, F.A. & BOSCH, M.W. (1995) Effects of energy source in the diet on reproductive hormones and insulin during lactation and subsequent estrus in multiparous sows. *Journal of Animal Science*. 73, 3022-29.
- KEMP, B. (1998) Lactational effects on the endocrinology of reproduction. In: The lactating sow. Eds Verstegen, Moughan and Schrama. Wageningen press. pp 241-57.
- KING, R.H. & WILLIAMS, I.H. (1984) The effect of nutrition on reproductive performance of the first litter sow: 2. Protein and energy intakes during lactation. *Animal Production*. 38, 249-56.
- KIRKWOOD, R.N., BAIDOO, S.K., AHERNE, F.X. & SATHEER, A.P. (1987) Influence of feeding level during lactation on occurrence and endocrinology of the post weaning estrus in sows. *Canadian Journal of Animal Science*. 67, 405-15.
- KIRKWOOD, R.N., BAIDOO, S.K., & AHERNE, F.X. (1990). The influence of feeding level during lactation and gestation on the endocrine status and reproductive function of second parity sows. *Canadian Journal of Animal Science*. 70: 1119-26.
- KIRKWOOD, R.N. (1999) Pharmacological intervention in swine reproduction. *Swine health and production*. 7, 29-35.
- KOKETSU, Y., DIAL, G.D., PETTIGREW, J.E., MARCH, W.E. & KING, V.L. (1996a) Characterisation of feed intake patterns during lactation in commercial herds. *Journal of Animal Science*. 74, 1202-10.
- KOKETSU, Y., DIAL, G.D., PETTIGREW, J.E., MARCH, W.E. & KING, V.L. (1996b) Feed intake patterns during lactation and subsequent reproductive performance. *Journal of Animal Science*. 74, 2875-84.
- LANGENDIJK, P., VAN DEN BRAND, H., SOEDE, N.M. & KEMP, B. (2000) Effect of boar contact on follicular development and estrus expression after weaning in primiparous sows. *Theriogenology*. 54, 1295-1303.
- LANGENDIJK, P., BERKEVELD, M., GERRITSEN, R., SOEDE, N.M. & KEMP, B. (2007) Intermittent suckling: Tackling lactational anoestrus and alleviating weaning risk for piglets. In: Paradigms in Pig Science. Eds. J. Wiseman., M.A. Varley., S. McOrist., B. Kemp. Nottingham University Press Nottingham, pp 359-84.
- LUCBERT, J. & LAVOREL, O. (1984) Baisse de prolificite de la truie en seconde portee: analyse des donnees de deux elevages experimentaux. 16emes. *Journées de la recherche porcine en France*. 115-24.
- MAKKINK, C.A. & SCHRAMA, J.W. (1998) Thermal requirements of the lactating sow. In: The lactating sow. Eds. M.W.A. Verstegen., P.J. Moughan. & J.W. Schrama. Wageningen Pers. pp 271-84.
- MARTINAT-BOTTE, F., BARITEAU, F., FORGERIT, Y., MACAR, C., POIRIER, P. & TERQUI, M. 1994. Control of reproduction with a progestogen- Altrenogest (Regumate) in gilts and weaning primiparous sows: Effect on Fertility and Litter size. *Reproduction Domestic Animals*. 29-5, 362-65.
- MORROW, W.E.M., LEMAN, A.D., WILLIAMSON, N.B., MORRISON, R.B. & ROBINSON, R.A. (1992) An epidemiological investigation of reduced second litter size in swine. *Preventive Veterinary Medicine*. 12, 15-26.
- MULLAN, B.P. & WILLIAMS, I.H. (1989) The effect of body reserves at farrowing on reproductive performance of the first-litter sow. *Animal Production*. 48, 449-57.
- QUESNEL, H. & PRUNIER, A. (1998) Effect of insulin administration before weaning on reproductive performance in feed restricted primiparous sows. *Animal Reproduction of Science*. 51, 119-29.
- QUINIOU, N. & NOBLET, J. (1999) Influence of high ambient temperatures on performance of multiparous sows. *Journal of Animal Science*. 77, 2124-34.
- SILVA, B.A.N., NOBLET, J., DONZELE, J.L., OLIVEIRA, R.F.M., PRIMOT, Y., GOURDINE, J.L. & RENAUDEAU, D. (2009a) Effects of dietary protein level and amino acid supplementation on performance of mixed-parity lactating sows in tropical humid climate. *Journal of Animal Science*. 87, 4003-12.
- SILVA, B.A.N., OLIVEIRA, R.F.M., DONZELE, J.L., FERNANDES, H.C., LIMA, A.L., RENAUDEAU, D. & NOBLET, J. (2009b) Effect of floor cooling and dietary amino acid content on performance and behaviour of lactating primiparous sows during summer. *Livestock Science*. 120, 25-34.
- SORENSEN, G. (1994) Pulpetter til soer. Meddelelse nr. 290. Landsudvalget for Svin/DANSKE SLAGTERIER.



THAKER, M. & BILKEI, G. (2005) Lactation weight loss influences subsequent reproductive performance of sows. *Animal Reproduction Science*. 88, 309-18.

VAN DEN BRAND, H., DIELEMAN, S.J., SOEDE, N.M. & KEMP, B. (2000a) Dietary energy source at two feeding levels during lactation in primiparous sows I Effects on glucose, insulin and LH and on follicle development, weaning-to-estrus interval and ovulation rate. *Journal of Animal Science*. 78, 396-404.

VAN DEN BRAND, H., SOEDE, N.M. & KEMP, B. (2000b) Dietary energy source at two feeding levels during lactation in primiparous sows II Effects on peri-estrus hormone profiles and embryo survival. *Journal of Animal Science*. 78, 405-11.

VAN DEN BRAND, H., HEETKAMP, M.J.W., SOEDE, N.M., SCHRAMA, J.W. & KEMP, B. (2000c) Energy balance of lactating sows as affected by feeding level and dietary energy source. *Journal of Animal Science*. 78, 1520-28.

VAN DEN BRAND, H., LANGENDIJK, P., SOEDE, N.M. & KEMP, B. (2001) Effects of post-weaning dietary energy source on reproductive performance in primiparous sows. *Journal of Animal Science*. 79, 420-26.

VAN DEN BRAND, H., SOEDE, N.M. & KEMP, B. (2006) Supplementation of dextrose to the diet during weaning to estrus interval affects subsequent variation in within-litter birth weight. *Animal Reproduction of Science*. 91, 353-85.

VAN DEN BRAND, H., ENCKEVOORT, I.C.M., VAN DER HOEVEN, E.M. & KEMP, B. (2009) Effects of dextrose plus lactose in sows diet on subsequent reproductive performance and within litter birth weight variation. *Reproduction of Domestic Animals*. 44, 884-88.

VAN DER PEET-SCHWERING, C.M.C., KEMP, B., BINNENDIJK, G.P., DEN HARTOG, L.A., SPOOLDER, H.A.M. & VERSTEGEN, M.W.A. (2004) Performance of sows fed high levels of non starch polysaccharides during gestation and lactation over three parities. *Journal of Animal Science*. 81, 2247-58

VAN LEEUWEN, J.J.J., WILLIAMS, S.I., KEMP, B. & SOEDE, N.M. (2010) Post weaning altrenogest treatment in primiparous sows: Effect of duration and dosage on follicular development and consequences for early pregnancy. *Animal Reproduction of Science*. 119, 258-64.

VAN LEEUWEN, J.J.J., WILLIAMS, S.I., MARTENS, M.R.T.M., JOURQUIN, J., DRIANCOURT, M.A., KEMP, B. & SOEDE, N.M.. The effect of different post-weaning altrenogest treatments of primiparous sows on follicular development, pregnancy rates and litter sizes. (*Journal of Animal Science* 2010-3246v1-20103246) *in press*.

VAN LEEUWEN, J.J.J., MARTENS, M.R.T.M., JOURQUIN, J., DRIANCOURT, M.A., KEMP, B. & SOEDE, N.M. Effects of pre- and post-weaning altrenogest treatments on follicular development farrowing rate and litter size in sows. *Submitted*.

VAN WAGENBERG, A.V., VAN DER PEET-SCHWERING, C.M.C., BINNENDIJK, G.P. & CLAESSEN, P.J.P.W. (2006) Effect of Floor cooling on farrowing sows and litter performance: Field experiment under Dutch conditions. *Transactions of the ASABE*. 49, 1521-27.

VESSEUR, P.C., KEMP, B., DEN HARTOG, L.A. & NOORDHUIZEN, J.P.T.M. (1997) Effect of split-weaning in first and second parity sows on sow and piglet performance. *Livestock Production Science*. 49, 277-85.

VINSKY, M.D., NOVAK, S., DIXON, W.T., KYCK, M.K. & FOXCROFT, G.R. (2006) Nutritional restriction in lactating sows selectively affects female embryo survival and overall litter development. *Reproduction Fertility Development*. 18, 347-55.

WELDON, W.C., LEWIS, A.J., LOUIS, G.F., KOVAR, L., GIESEMANN, M.A. & MILLER, P.S. (1994) Post partum hypophagia in primiparous sows: 2 Effects of gestation feeding level during gestation and exogenous insulin on lactation feed intake, glucose tolerance and epinephrine stimulated release of non esterified fatty acids and glucose. *Journal of Animal Science*. 72, 395-403.

YANG, H., EASTHAM, P.R., PHILLIPS, P. & WHITTEMORE, C.T. (1989) Reproduction, body weight and body condition of breeding sows with differing body fatness at parturition, differing nutrition during lactation, and differing litter size. *Animal Production*. 48, 181-201.

ZAK, L.J., COSGROVE, J.R., AHERNE, F.X. & FOXCROFT, G.R. (1997a) Pattern of feed intake and associated metabolic and endocrine changes differentially affect post weaning fertility in primiparous lactating sows. *Journal of Animal Science*. 75, 208-16.

ZAK, L.J., XU, X., HARDIN, R.T. & FOXCROFT, G.R. (1997b) Impact of different patterns of feed intake during lactation in the primiparous sow on follicular development and oocyte maturation. *Journal of Reproduction Fertility*. 110, 99-106.

ZAK, L.J., WILLIAMS, I.H., FOXCROFT, G.R., PLUSKE, J.R., GEGIESKI, A.C. CLOWES, E.J. & AHERNE, F.X. (1998) Feeding lactating primiparous sows to establish three different metabolic states. *Journal of Animal Science*. 76, 1145-53.