CAUSES AND CONSEQUENCES OF VARIATION IN WEANING TO OESTRUS INTERVAL IN THE SOW

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CAUSES AND CONSEQUENCES OF VARIATION IN WEANING TO OESTRUS INTERVAL IN THE SOW

OORZAKEN EN GEVOLGEN VAN VERSCHILLEN IN INTERVAL SPENEN - BRONST VAN ZEUGEN

PROEFSCHRIFT

ter verkrijging van de graad van doctor
op gezag van rector magnificus,
dr C.M. Karssen,
in het openbaar te verdedigen
op dinsdag 17 juni 1997
des namiddags te vier uur in de Aula
van de Landbouwuniversiteit te Wageningen

door

P. C. VESSEUR

Stellingen

1. De lengte van het interval spenen-bronst is gerelateerd aan de worpgrootte en het partuspercentage in de volgende reproductiecyclus. Het interval spenen-bronst is dus niet alleen van (economisch) belang in verband met het aantal verliesdagen.
Dit proefschrift.

2. Reductie van de toom tot de zes lichtste biggen vanaf één week voor spenen heeft, tegen de verwachting in, geen significant effect op het interval spenen-bronst en de worpgrootte in de volgende reproductiecyclus.
Dit proefschrift.

3. Het overslaan van de eerste bronst na spenen bij eersteworpszeugen is zinvol.
Dit proefschrift.

4. In tegenstelling tot bij eerste- en tweedeworpszeugen is er bij meerdereworpszeugen geen relatie tussen gewichtsverlies tijdens de zoogperiode en lengte van het interval spenen-bronst gevonden.
Dit proefschrift.

5. Door het aanpassen van de inseminatiestrategie van zeugen aan het interval spenen-bronst zijn de resultaten van inseminaties te verbeteren.

6. Groepshuisvestingssystemen met grote dynamische groepen (de "eerste generatie groepshuisvestingssystemen") zijn nadelig voor de reproductie en het welzijn van de daar in gehuisveste eerste- en tweedeworpszeugen.

7. Het is geen toeval, dat in 1991, het jaar waarin de varkensziekte PRRS (Porcine Reproductive and Respiratory Syndrome) voor het eerst in Nederland werd vastgesteld, de Pestvogel (*Bombycilla garrulus*) weer in Nederland werd waargenomen.

8. De belasting van het milieu en de kans op voedselschaarste zijn vooral een gevolg van de bevolkingsgroei. Het afzien van nageslacht is dan ook het meest effectieve wapen tegen milieuvervuiling.
(*Vrij naar Midas Dekkers*).

9. Hoewel de gebarentaal die tijdens bepaalde verkeerssituaties tot expressie komt het tegendeel doet vermoeden, is het gevolg van dergelijke verkeerssituaties juist libidoverlagend.

10. Het schaatsen op kunstijs, ofwel het monotoon rondjes draaien in een prikkelarme omgeving, wordt steeds meer beoefend en is daarmee een belangrijk maatschappelijk signaal, daar een dergelijke stereotypie op een gestoord welzijn wijst.

Stellingen bij het proefschrift: "Causes and consequences of variation in weaning to oestrus interval in the sow", in het openbaar te verdedigen op dinsdag 17 juni 1997 des namiddags te vier uur in de aula van de Landbouwuniversiteit te Wageningen door P.C. Vesseur.

Voor Mieke, Esther en Karin

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ISBN 90 - 5485 - 678 - 5

Cover illustration: Peter Vesseur.

PREFACE

It seems likely that the over the years enhanced level of sow production has a biological limit. However, there is no proof that this limit has been reached yet. It is challenging to find out what factors are limiting further enhancement of sow production and to find ways to overcome these limiting effects.

Whether sow production can be improved further or not, does not seem the question to be answered. The question to be answered rather seems to be: how to improve sow production without risk of harming the well being of the sow and her piglets and without negative effects on the environment. For these items are the reason for some individuals or groups in our society to question research into further improvement of sow production. The disapproval of further enhancement of sow production seems to be fed by the impression that high production always conflicts with the well being of animals and the protection of the environment. In general, improvement of biological production does not seem to be ethical nowadays and has become obsolete, whereas it is accepted for many other kinds of (industrial) production.

Addressing the issue from a product point of view, it rather seems ethical to produce as efficient as possible as long as animal well being is not at pressure. Sustainable agriculture in general and pig husbandry in particular, seems availed with a high and efficient production. A high and efficient production reduces the input of raw materials, like feed components and energy, per unit of product. The waste production, like nitrogen, phosphorus, ammonia and carbon dioxide, per unit of product is smaller with a high and efficient production. From this point of view, further improvement of sow production will be helpful towards sustainable agriculture.

CONTENTS

CHAPTER 1

GENERAL INTRODUCTION

GENERAL INTRODUCTION

SOW PRODUCTION PERFORMANCE INDICATORS

Sow production, or the number of piglets produced per sow per year, is depending on the length of the reproduction cycle, the number of piglets born alive and the piglet mortality rate. The length of the average reproduction cycle of sows is depending on the length of the gestation period, the length of the lactation period, the weaning to first service interval, the first to last service interval and the number of non productive days of sows not culled directly after weaning, but before the production of a next litter.

The length of the gestation period is reasonably precise, approximately 112-116 days, depending on breed, litter size and season (First et el., 1982). There are no possibilities for substantial reduction of the gestation period. The length of the lactation period is depending on farm management and can be changed easily. The lactation period should be at least three weeks and not more than five weeks, to maximise the number of piglets per sow per year (Aumaître et al., 1976; Varley, 1982; Xue et al., 1991).

The weaning to oestrus interval (WOI), the interval from the day of weaning up to and including the first day the sow is showing standing heat, is part of the normal reproductive cycle of the sow. It is common practice to breed sows during their first detected oestrus and, therefore, the WOI is comparable with the, in sow records available, weaning to first service interval. A WOI of 4 or 5 days is common and strived for in current sow farming. The first to last service interval is depending on the percentage of sows not farrowing from the first service after weaning and served again in the second or a next cycle after weaning. These non productive days increase the average length of the reproduction cycle of sows on a farm. Non productive days are also caused by sows, not culled shortly after weaning, but before bringing a next litter. Anoestric sows and sows culled after an abortion or when found not pregnant, are examples of sows causing these non productive days.

WOI, farrowing rate from first service, number of piglets born alive and piglet mortality are the paramount important performance indicators for sow production.

WEANING TO OESTRUS INTERVAL (WOI)

Results from the period before 1980 show that the length of the WOI at farm level was between 11.5 and 20.5 days; looking only at lactation periods of less than 5 weeks the WOI was between 13.5 and 20.5 days (Van der Heyde et al., 1974; Aumaître et al., 1976; Bisperink, 1979; Fahmy et al., 1979).

In current sow farming, with lactation periods of three to four weeks, the WOI is much shorter than one would expect from the results in the late 1970s. The WOI as average of the annual results of minimal 600 Dutch sow farms between 1987 and 1994 are presented in Table 1. The farms used the management information system CBK® or TEA® (SIVA-produkten BA). The average WOI in 1987 was 8.6 days and it decreased to 7.0 days in 1994. The WOI was slightly increased during 1991, which can be attributed to the Porcine Respiratory and Reproduction Syndrome (PRRS) epidemic that year. After this epidemic, PRRS became endemic and the effects of the disease became less pronounced.

Table 1. **The weaning to oestrus interval (WOI) in days of farms that used the management information system: CBK® or TEA® (SIVA-produkten BA) and released their results to produce surveys.**

Year	1987	1988	1989	1990	1991[a]	1992	1993	1994
WOI	8.6	8.0	7.5	7.3	7.9	7.4	7.0	7.0

Results from MIS: TEA® and CBK® (Siva-produkten b.a., Wageningen, the Netherlands).
[a] In 1991 Porcine Respiratory and Reproduction Syndrome became endemic in the Netherlands.

In 1990, in the Netherlands, the average WOI on 660 sow farms using the CBK® programme (Siva-produkten b.a., Wageningen, the Netherlands), was 7.3 days (sd: 1,74; min.: 4,9 en max.: 18,6). In the same year, 1990, in the United States and Canada, the WOI on 463 of the 1351 farms using the Pig CHAMP® programme, was 7.7 days (sd: 4,79; min.: 4,1 en max.: 66,2) (Marsh et al., 1992).

The WOI during the last decade is much shorter than it was during the 1970s. This reduction in WOI has led to a shift in the distribution of sows after WOI (or after first day of standing heat after weaning; Figure 1). In Figure 1, the results of the research farm of the Research Institute for Pig Husbandry, Rosmalen, the Netherlands, over the year 1995, are presented together with results found in the 1970s (Fahmy et al., 1979). The average WOI in the 1995 data from the Rosmalen research farm was 5.8 days (8.1 days for primiparous and 5.1 days for multiparous sows). In the data of Fahmy et al. (1979) the average WOI was 18.7 days.

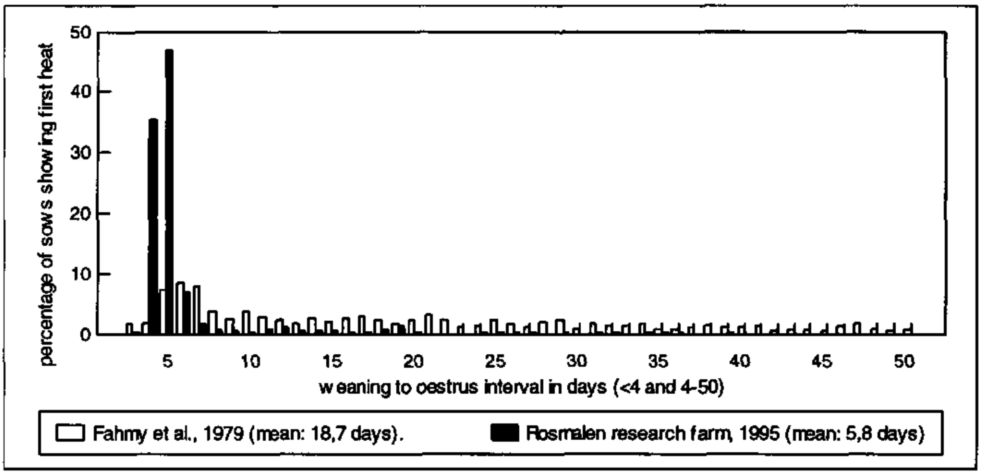

Figure 1. **Frequency distribution of weaning to oestrus intervals in sows.**

In the 1995 data, the percentage of sows with a WOI of 4 and 5 days was much higher than in the data from the 1970s. The percentage sows with a WOI longer than 5 days was higher in the data from the 1970s. The distributions are both truncated. Fahmy et al. (1979) reported that 12.9% of the primiparous sows did not show oestrus before day 50 after weaning and were culled. Culling for this reason at the research farm Rosmalen during 1995 was much lower: 1.4% (4.75% of the primiparous sows and 0.4% of the multiparous sows). In the 1995 data these sows were culled at day 40 after weaning; ten days earlier.

Factors that contributed to the reduction in weaning to oestrus interval

Factors that have contributed to the reduction of the WOI to the current level are: changes in the genetics through selection, increase in heterosis through the increased use of cross bred sows, changes in management with regard to feeding, housing and animal care and the use of oestrus inducing hormones.

There are differences in WOI between breeds and crossbreds (Burger, 1952; MacLean, 1969; Dyck, 1971, 1972, 1974; Legault, 1975; Fahmy and Dufour, 1976; Bisperink, 1979). It is possible to reduce the length of the WOI by selection (Napel et al., 1995). Crossing of pure lines results in a reduction of the WOI due to heterosis; Legault (1975) calculated an heterosis for this trait of -17,8%.

Fahmy (1981) reviewed the most important factors influencing the WOI, but it is not possible to get a clear view to which extent the different factors contributed to the reduction of the WOI over the years. Management factors like: improved housing during the lactation period and in the mating area, changes in feeding management during the lactation period and after weaning, improvements in feed composition and improved boar contact, are some of the important factors.

In the 1970s possibilities to reduce the length of the lactation period to improve sow production, or the number of piglets produced per sow per year, were studied (Varley, 1982). Van der Heyde et al. (1974) showed that reduction of the lactation period resulted in an increase in WOI; a lactation period of five weeks and more resulted in a WOI of 11.4 days, whereas a lactation period of less than five weeks resulted in a WOI of 13.6 days (results of first parity sows not included). Similar results were found in the Netherlands (Anonymous, 1980), but in this case the results of first parity sows were included; a suckling period of 25 ± 3 days resulted in a WOI of 13.4 days and a suckling period of 39 ± 3 days in a WOI of 11.7 days. The length of the lactation period in conventional production systems was, at that time, about six to eight weeks. The increase in WOI due to reduction in length of the lactation period, was an undesired side-effect.

The use of oestrus inducing hormones may have contributed to the reduction of the WOI. From Figure 1, we can see that over 90% of the sows in the 1995 data returned to oestrus before day 8 after weaning. Treatment with oestrus inducing hormones was performed at day 8 after weaning in the remaining 10% of sows (23% of the primiparous sows and 4% of the multiparous sows). In the data of the 1970s, 33.4% of the sows showed oestrus during the first week after weaning. Using the same strategy for oestrus induction as used in 1995, in the 1970s 66.6% of the sows would have been treated with oestrus inducing hormones. The effect on the length of the WOI oestrus inducing hormones will have had in the 1995 data, is limited compared with the effect that would have been possible in the data of the 1970s. The possible effect, oestrus inducing hormones may have on the WOI, is decreasing over the years

New aspects concerning the weaning to oestrus interval

In current sow farming the WOI is short: six to seven days (Table 1; Figure 1). It is possible to achieve a negative WOI, when sows are showing their first oestrus already during lactation. With a lactation period of three to four weeks, sows seldom show oestrus before weaning and management strategies to get sows in oestrus during lactation are not promising (Vesseur et al., 1995).

Indications that even a slightly prolonged WOI has consequences for sow production in terms of farrowing rate (FR) and litter size (Leman, 1990), is, besides the high culling rates as found in primiparous sows and the high use of oestrus inducing hormones, the major reason for renewed attention for variation in WOI. Leman (1990) analysed data of 66 farms and found that the length of the WOI seemed to have consequences for the technical results (FR and litter size) of the, in most cases, natural matings (see Figure 2). Consequences attributed to differences in WOI in field surveys, however, could be influenced by differences in mating frequency, semen quality of the boars used for natural matings and management.

The increase in litter size, like Leman (1990) showed for sows with a WOI of more than 15 days, has also been reported before by Love (1979); in primiparous sows, and by Fahmy et al. (1979). Fahmy et al. (1979) could not attribute the enhanced litter size to an increased number of ovulations. Van der Heyde et al. (1974) showed the FR to be the highest for sows with a WOI of four days and that it was lower in sows with a slightly prolonged WOI. The smaller litter size in sows with a slightly increased WOI of six to ten days, as published by Leman (1990), has not been reported before.

Many sows are, from an economic point of view, culled too early; 14% of the sows is already disposed of after the first litter (Dagorn and Vaudelet, 1993). Primiparous

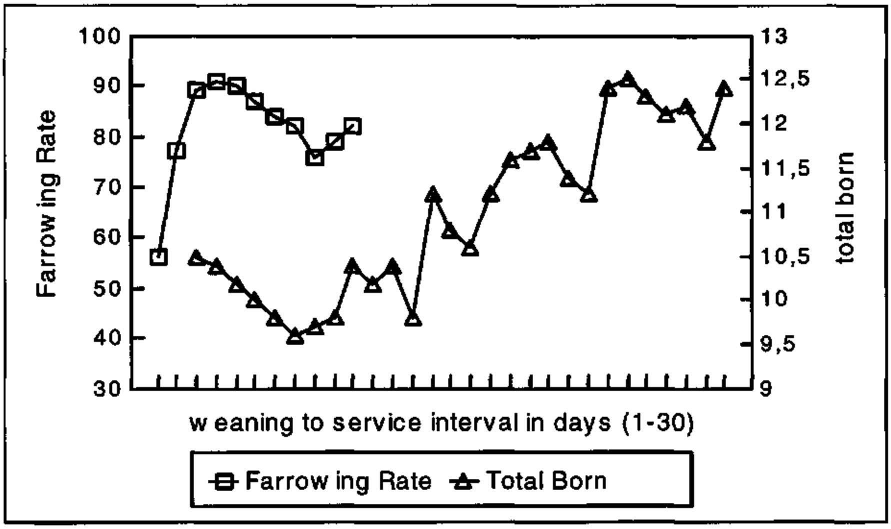

Figure 2. **Litter size and farrowing rate after weaning to service interval (Leman (1990). Farrowing rate was only published for sows with a weaning to service interval up to 11 days.**

sows are in 50% of the cases culled for reproduction reasons like anoestrus or repeat breeding (Dijkhuizen et al., 1989; Dagorn and Vaudelet, 1993; MLC, 1993; MLC, 1995). Particularly primiparous sows are likely to have a prolonged WOI or even become anestrous. The use of oestrus inducing hormones is higher in primiparous sows compared with higher parity sows.

OBJECTIVES FOR THE THESIS RESEARCH

The objectives of the research in this thesis were:

1. Assessment of the consequences of variation in WOI for farrowing rate and litter size, under controlled circumstances.
2. Assessment of the factors causing variation in WOI and of the mechanisms explaining the subsequent effects on farrowing rate and litter size.
3. Research into intervention strategies that may influence the length of the WOI, subsequent litter size and farrowing rate, or both.

RESEARCH PERFORMED FOR THIS THESIS

The relations between WOI and sow production, farrowing rate and litter size, are investigated using the database of a 390 sow research farm (Chapter 2 of this thesis). On this research farm production took place under controlled circumstances. For service only AI was used. Semen doses were checked on morphology, motility and concentration of spermatozoa by the commercial AI station that was providing the semen doses.

Differences in farrowing rate and litter size between sows with a WOI of four, five or six days were reported in Chapter 2. To find out whether these differences were influenced by insemination strategy, an experiment was conducted. In this experiment two inseminations were performed with a 24 h interval, at a fixed time during the day. Semen of two different, on their offspring recognisable, boar breeds was used for first and second insemination respectively and in reverse order. This way the offspring produced within this experiment could be traced back to the insemination (first or second). The number of piglets from each of the inseminations, first or second, and the distribution of litters after litter type (all piglets from first insemination, mixed or all piglets from second insemination) were analysed. Other factors that may influence the number of piglets born from each of the inseminations were taken into account (Chapter 3 of this thesis).

An observational study into the factors associated with a prolonged WOI, was performed. The purpose was to find the most promising ways to influence the WOI and/or the consequences of variation in WOI for litter size and farrowing rate (Chapter 4 of this thesis). Effects on the WOI of parity, sow body weight at different moments and body weight loss during lactation, loss in backfat thickness, housing system, breed, season and litter size at weaning, were studied.

Split-weaning was expected to affect both body weight loss and number of piglets at weaning and, therefore, seems a perspective way to influence the WOI, certainly in first and second parity sows. An experiment with split-weaning was conducted (Chapter 5 of this thesis).

Because in the observational study of Chapter 2 an increased production in sows with a WOI of 19 days or more could be expected, therefore, an experimental study was designed to deliberately prolong the WOI (Chapter 6 of this thesis). The objective of this study was to find out whether skipping one oestrus, to inseminate during the second oestrus after weaning, results in a comparable, or even higher, litter size.

In Chapter 7, the results of the research for this thesis are discussed in relation to the relevant physiological and hormonal mechanisms that play a role in the regulation of sow reproduction. The practical implications are given (Chapter 7).

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CHAPTER 2

THE EFFECT OF THE WEANING TO OESTRUS INTERVAL ON LITTER SIZE, LIVE BORN PIGLETS AND FARROWING RATE IN SOWS.

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Published in:
Journal of Animal Physiology and Animal Nutrition 71 (1994): 30-38.

THE EFFECT OF THE WEANING TO OESTRUS INTERVAL ON LITTER SIZE, LIVE BORN PIGLETS AND FARROWING RATE IN SOWS.

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INTRODUCTION

The weaning to oestrus interval (WOI) is an important trait (Burgers, 1952; Van der Heyde et al., 1974; Aumaitre et al. 1976; Fahmy et al., 1979; Fahmy, 1981). Currently the average number of non productive days, caused by a prolonged WOI, is low, but ranges are wide. In 1990, 463 users of the PigCHAMP program had a mean WOI of 7.7 days (se: 2.19; minimum: 4.1 and maximum: 66.2), (Marsh et al., 1992) and 660 users of the Dutch CBK program (SIVA-produkten BA) had a mean WOI of 7.3 days (se: 1.74; minimum: 4.9 and maximum: 18.6).

Fahmy et al. (1979) concluded that litter size increased with an increasing weaning to conception interval. Love (1979) and King et al. (1982) found an enhanced parity 2 litter size when the WOI was greater than 12 days. Van der Heyde et al. (1974) found a decreased farrowing rate when the WOI was 8 days or more as compared to a WOI of 5 days, sows weaned after 35 days of lactation and bred at day 10 or 11 after weaning showed very low farrowing rates. Leman (1990) pointed at the possibility of poor results when the WOI was prolonged up to 8 (litter size) or 9 days (farrowing rate) compared to shorter intervals and better results again when the interval became longer. In a retrospective study, the effect of the WOI on subsequent reproductive performance of first and higher parity sows was investigated. In the analyses, models with relevant factors and two-way interactions between these factors were used.

MATERIAL AND METHODS

Data of the research farm of the Research Institute for Pig Husbandry at Rosmalen were used for the analyses. On this closed 390 sow farm two types of crossings were used: a three-way crossing, with Dutch landrace (N) and Duroc (D) sow lines, and a rotation-crossing (R), with Dutch landrace (N), Great Yorkshire (Y) and Finnish landrace (F) sow lines. A Great Yorkshire boar line (Y_s) was used in both crossings for slaughter pig production.

Three housing systems were used on the farm: girth tethered sows, sows housed in crates and sows housed in a big (60-70 sows) continuous changing group with electronic identification and fed with two automatic feeder stations. The housing differed only during gestation, from about one month after insemination until one week before farrowing. Sows always returned to the system they came from. The number of sows in each system was about 130. Treatment in the farrowing house was the same for all sows, weaning took place at about 28 days after farrowing.

On the farm only artificial insemination was used, sows were inseminated when showing standing heat for the man. If still standing for the man the next day, a second insemination was performed.

Selection of data

Data of 3520 farrowings, from June 1987 until May 1992, followed by a WOI, were used. From February until July 1991 the results on the farm were influenced by an outbreak of PRRS (Porcine Respiratory and Reproduction Syndrome) and therefore the inseminations performed in this period and those that would result in a farrowing in this period, were excluded from analysis. Records (n=369) of sows treated with hormones to induce heat, were also excluded. The analysis of the effect of the WOI on litter size (total born and live born) was started with 2618 records. The period for farrowing rate was chosen shorter to be sure sows were able to complete a reproduction cycle, leaving 2317 records for this purpose.

Statistical methods

Litter size (born alive, stillborn and mummies) and number of live born piglets were subjected to analysis on factors and interactions, using the following model:

$y = \mu + x_1 + x_2 + x_3 + x_4 + e.$

y = dependent variable

μ = overall mean

x_1 = WOI (0-3, 4, 5, 6, 7, 8, 9-12, 13-18 and ≥19 days)

x_2 = parity (2, 3, 4, 5, 6, 7, 8 and ≥9) [1]

x_3 = housing system (girth tethered, crate housed and group housed)

x_4 = breed (N, DN, FYN, NFYN, YNFYN and FYNFYN)

e = error

Using SAS-GLM (SAS, 1989), factors and interactions were tested for significance and omitted from the model in a stepwise fashion, leaving only factors and interactions with a less than 10 percent level of confidence.

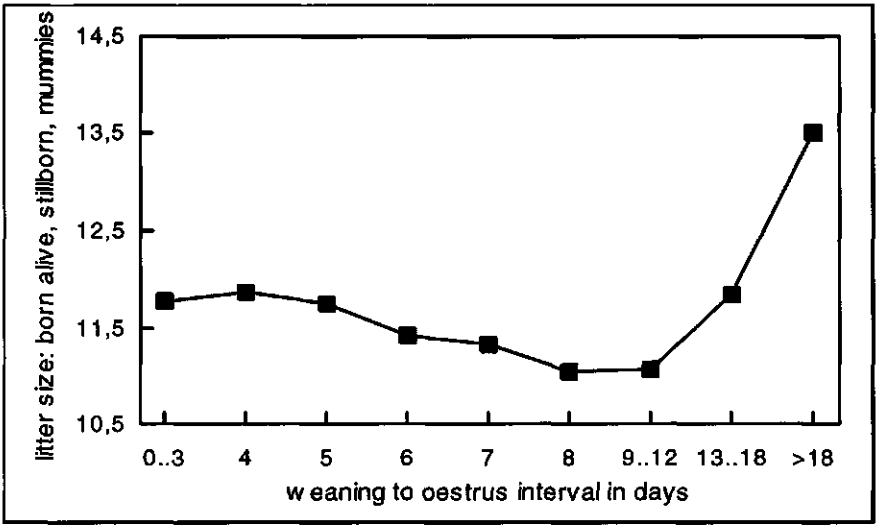
The farrowing rate, being a binary trait, was analysed using the multivariate logistic regression method: SAS-LOGISTIC (SAS, 1989). The strategy described by Hosmer and Lemeshow (1989) was followed. In summary, an univariate one way analysis was performed and variables showing a P-value of less than 0.25 were put in a multivariate model. Stepwise deletion of least significant variables was performed until all variables showed a P-value of less than 0.20. Checks for confounding consisted of comparison of regression coefficients from two runs: if ß's changed more than 25% or at least 0.1, confounding was assumed to be present. Subsequently, interactions between the remaining variables were evaluated by adding them, one by one, to the model and check on improvement of the model fit (2 log likelihood test; $P<0.25$). The estimated coefficients can be used to calculate odds ratio's (OR). The OR is defined as the ratio of the odds for $x=1$ (farrowing) to the odds for $x=0$ (not farrowing) and calculated as e^{β_i}. A 95% confidence interval is calculated as $e^{\beta_i \pm 1.96 * se}$ (se = standard error). Parity was classified as 1 (first parity sows) and 0 (second and higher parity sows).

[1] Because the effect of the WOI on the results of the following production cycle was of interest, the parity count of sows was enhanced after weaning.

RESULTS

The effect of the weaning to oestrus interval on litter size

Stepwise reduction of the model for litter size with not significant factors and interactions, resulted in a model composed of parity (P<0.001), breed (P<0.001) and WOI (P<0.05). Interactions were not significant. The R^2 of the model was 10.2%, the P value is <0.0001, the Root Mean Square Error was 2.848 and the mean litter size was 11.48.



litter size (total)	11.77	11.88	11.74	11.42	11.32	11.05	11.07	11.85	13.51
significancy P<0.05	ab	a	a	a	a	a	a	a	b
n	9	175	1263	328	107	63	52	43	21
standard error	0.96	0.23	0.12	0.19	0.30	0.39	0.42	0.46	0.66

Figure 1. **The influence of weaning to oestrus interval on litter size** (LSMeans).

Figure 1 shows the effect of the WOI on litter size. Litter size was decreasing from 11.9 piglets at a WOI of 4 days, to 11.1 piglets at a WOI of 8 days (P<0.06). When the WOI became longer than 9-12 days, the litter size increased. It was enhanced to 13.5 piglets after a WOI of 19 or more days, which was more than after a WOI of 5, 6, 7, 8 or 9-12 days respectively (P<0.01) and more than after a WOI of 4 or 13-18 days respectively (P<0.05).

The influence of parity on litter size is shown in Table 1. The second litter is smaller than the third or next litter (P<0.001) and the third litter is smaller than the fourth (P<0.05) or fifth, sixth or seventh litter (P<0.001).

The influence of breed or crossing on litter size is shown in Table 2. The purebred Dutch landrace (N), used to produce new purebred sows and crossbred sows with Duroc (DN), produces smaller litters than all other breeds (10.4, se: 0.28, P<0.001). The litter size of the FYNFYN rotation crossing sow is comparable with that of the DN crossbred sow and bigger than other breeds (12.9, se: 0.41, P<0.01).

Table 1. **The influence of parity on litter size (LSMeans).**

parity	2	3	4	5	6	7	8	≥9
litter size	10.2^{a}	11.4^{b}	11.9^{c}	12.2^{c}	12.3^{c}	12.4^{c}	11.9^{bc}	11.6^{bc}
n	447	447	369	288	202	152	96	60
Standard Error	0.18	0.21	0.23	0.25	0.27	0.30	0.34	0.42

Means within a row lacking common superscript letter differ (P<0.05)

Table 2. **The influence of breed on litter size (LSMeans).**

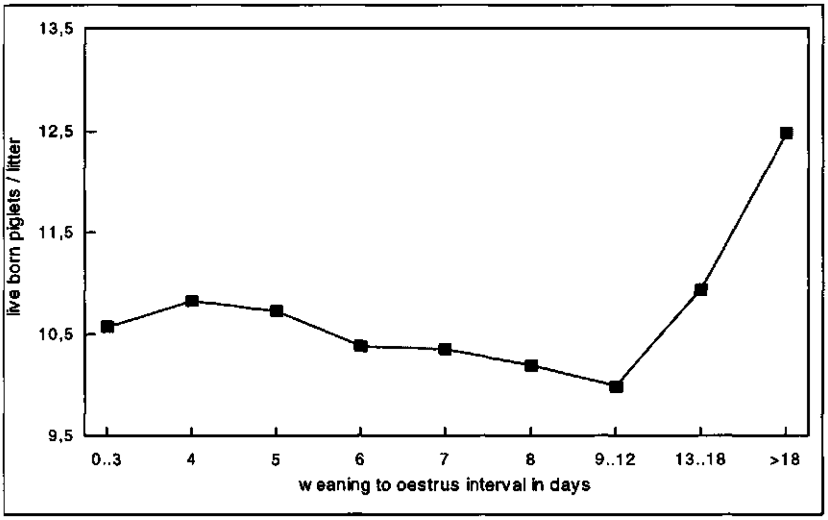
breed	N	NFYN	YNFYN	FYN	FYNFYN	DN
litter size	10.4^{a}	11.4^{b}	11.8^{bc}	11.7^{b}	12.9^{d}	12.2^{cd}
n	149	475	136	570	67	664
Standard Error	0.28	0.22	0.31	0.20	0.41	0.19

Means within a row lacking common superscript letter differ (P<0.01).

The effect of weaning to oestrus interval on number of live born piglets

Stepwise reduction of the model for the number of live born piglets with not significant factors and interactions, resulted in a model composed of parity (P<0.001), breed (P<0.001) and WOI (P<0.05). The R^2 of the model is 6.3%, the P value is <0.0001, the Root Mean Square error is 2.797 and the mean number of live born piglets is 10.65.

Figure 2 shows the effect of the WOI on the number of live born piglets. The number of live born piglets after a WOI of 6 days (10.4) was 0.3 piglets lower than after a WOI of 5 days (10.7) (P<0.05). The number of live born piglets after a WOI of 19 days or more (12.5), was higher than after a WOI of 5, 6, 7, 8 or 9-12 days respectively (1.8, 2.1, 2.1, 2.3 and 2.5 piglets respectively) (P<0.01) and also higher than after a WOI of 4 or 13-18 days respectively (1.7 and 1.6 piglet respectively) (P<0.05).



live born piglets	10.57	10.82	10.73	10.39	10.35	10.19	9.99	10.93	12.49
significancy P<0.05	abc	ab	a	b	ab	ab	ab	ab	c
n	9	175	1263	328	107	63	52	43	21
standard error	0.94	0.22	0.12	0.19	0.30	0.38	0.42	0.46	0.64

Figure 2. **The influence of the weaning to oestrus interval on number of live born piglets** (LSMeans).

The influence of parity on the number of live born piglets is shown in Table 3. The number of live born piglets in the second litter (9.8) was more than one piglet lower than the number in the third up to the seventh litter (P<0.01). The number of live born piglets in the eighth litter (10.1) was also lower than in the third up to the seventh litter (P<0.05), but comparable with that of the second litter.

Table 3. **The influence of parity on the number of live born piglets (LSMeans).**

parity	2	3	4	5	6	7	8	≥9
live born piglets	9.8[a]	10.9[b]	11.1[b]	11.2[b]	11.2[b]	11.0[b]	10.1[a]	10.4[ab]
n	447	447	369	288	202	152	96	60
Standard Error	0.18	0.21	0.22	0.24	0.26	0.30	0.34	0.41

Means within a row lacking common superscript letter differ (P<0.05)

Table 4. **The influence of breed on the number of live born piglets (LSMeans).**

breed	N	NFYN	YNFYN	FYN	FYNFYN	DN
live born piglets	9.5[a]	10.5[b]	10.7[bc]	10.7[bc]	11.9[d]	11.0[c]
n	149	475	136	570	67	664
Standard Error	0.27	0.21	0.30	0.20	0.41	0.19

Means within a row lacking common superscript letter differ (P<0.05)

The influence of breed or crossing on the number of live born piglets is shown in Table 4. The number of live born piglets is lower in the pure bred Dutch Landrace (N) sows (9.5, se: 0.27), compared with the crossbred sows (10.5-11.9, P<0.001). The number of live born piglets in the FYNFYN rotation crossing sow is the highest and differs significantly from other crossings (11.9, se: 0.41, P<0.05).

The difference between the litter size and the number of live born piglets is shown in Table 5. There is not much variation in the number of stillborn piglets, the number of mummies tends to decrease with an increasing WOI.

Table 5. **The number of live born piglets, mummies and stillborn piglets per weaning to oestrus interval class (LSMeans).**

WOI	0-3	4	5	6	7	8	9-12	13-18	≥19
n	9	175	1263	328	107	63	52	43	21
born alive	10.57	10.82	10.73	10.39	10.35	10.19	9.99	10.93	12.49
stillborn	0.86	0.87	0.85	0.90	0.82	0.74	0.89	0.82	0.93
mummies	0.36	0.19	0.15	0.14	0.15	0.11	0.18	0.09	0.09

The effect of weaning to oestrus interval on farrowing rate

In the univariate analysis, only parity and WOI showed P-values less than 0.25. The subsequent multiple logistic regression showed that the interaction between parity and WOI improved the fit of the bivariate model significantly (L = 45.083, 9 df, P<0.001). Because the interaction between parity and WOI was significant, the results should be interpreted at the specified parity levels separately. Results are shown in Figure 3 and Table 6.

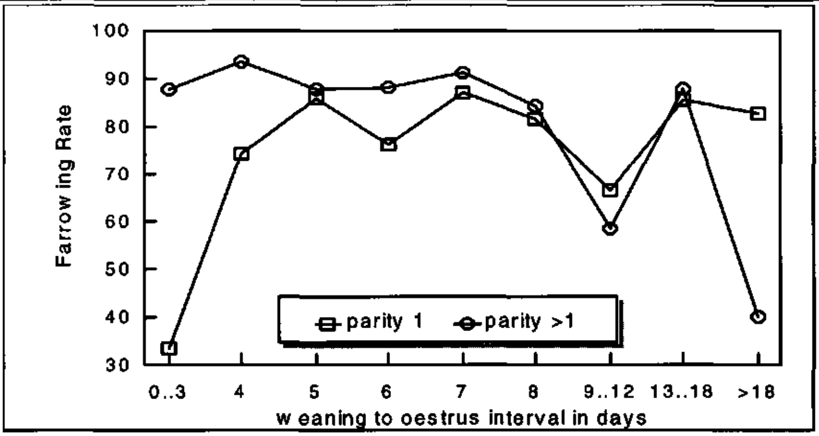
First parity sows inseminated at a WOI of 0-3 or 6 days show a significantly reduced risk to farrow (higher risk to have a low farrowing rate) when compared with first parity sows inseminated at WOI day 5. The same is true for WOI day 9-12. The number of sows inseminated at WOI day 0-3 is very low, which is reflected in a high standard error.

Higher parity sows inseminated at WOI day 4 showed a significantly increased risk to farrow when compared to higher parity sows inseminated at WOI day 5. Insemination at WOI day 9-12 showed, as in first parity sows, a significantly reduced risk of farrowing. The same was true for WOI day ≥19, however it should be stated that the number of sows in the latter category was very low, reflected in a high standard error.

DISCUSSION

The results of this analysis show the influence of the WOI on sow production in terms of litter size, piglets born alive and farrowing rate. The decrease in live born (and total born) piglets per litter on WOI day 6 to WOI day 9-12, compared to WOI day 5, is an important conclusion from this analysis. Probably due to the number of sows per interval class, it is not significant for all classes.

A WOI of 13-18 or ≥19 days results in bigger litters and the litters born from inseminations performed after 18 days post weaning are even significantly bigger than litters from inseminations performed on day 4 or 5 post weaning. Love (1979) and King et al. (1982) found an enhanced litter size in second parity sows with a WOI greater than 12 days.



parity 1	33.3	74.1	85.5	76.1	86.8	81.6	66.7	85.4	82.6
n	6	27	204	92	38	38	51	41	23
parity > 1	87.5	93.5	87.7	88.2	91.3	84.2	58.6	87.5	40.0
n	8	139	1203	287	80	38	29	8	5

Figure 3. **The effect of weaning to oestrus interval on farrowing rate.**

Table 6. **The effect of the weaning to oestrus interval (WOI) on farrowing rate (FR) according to multiple logistic regression and corrected for parity class.**

variable	n	FR	ß	SE	P	OR	95% CI
First parity sows							
WOI 0-3	6	33.3	-2.4906	0.8889	0.005	0.08	0.02-0.47
WOI 4	27	74.1	-0.7477	0.4828	0.121	0.47	
WOI 5	204	85.8	0			1	reference
WOI 6	92	76.1	-0.6400	0.3161	0.043	0.53	0.28-0.98
WOI 7	38	86.8	0.0896	0.5201	0.863	1.09	
WOI 8	38	81.6	-0.3094	0.4640	0.505	0.73	
WOI 9-12	51	66.7	-1.1043	0.3584	0.002	0.33	0.16-0.67
WOI 13-18	41	85.4	-0.0339	0.4852	0.944	0.97	
WOI ≥19	23	82.6	-0.2393	0.5855	0.683	0.79	
Second and higher parity sows							
WOI 0-3	8	87.5	-0.0182	1.0726	0.987	0.98	
WOI 4	139	93.5	0.7062	0.3557	0.047	2.03	1.01-4.07
WOI 5	1203	87.7	0			1	reference
WOI 6	287	88.2	0.0429	0.2027	0.832	1.04	
WOI 7	80	91.3	0.3805	0.4053	0.348	1.46	
WOI 8	38	84.2	-0.2901	0.4535	0.522	0.75	
WOI 9-12	29	58.6	-1.6158	0.3871	0.0001	0.20	0.09-0.42
WOI 13-18	8	87.5	-0.0182	1.0726	0.986	0.98	
WOI ≥19	5	40.0	-2.3695	0.9171	0.010	0.09	0.02-0.56

The influence of parity on litter size and number of live born piglets makes clear that the second litter is smaller than the following litters. The maximum litter size is reached at the fourth litter and after the seventh litter, litter size as number of live born piglets becomes smaller (the first litter is not looked into in this analysis). An important conclusion of this analysis is, that there is no interaction between parity and WOI and that the poor results of a prolonged interval cannot be explained by parity. The effect of parity on WOI is well described in the literature (Hurtgen et al., 1980; Karlberg, 1980; Fahmy, 1981; Clark et al., 1986a; Xue et al., 1991); first parity and, in a less degree, second parity sows have a longer WOI. The effect of parity on litter size is also well described (Clark & Leman, 1986b); second litters are smaller than the third up to the eighth litter. The genotype of the sow is also of influence on litter size and on WOI, but genotype does not explain the differences found and there is also no interaction with the WOI. The pure line Dutch landrace sows produce smaller litters than the F1-crossing with Duroc or the different genotypes in the rotation crossing. Heterosis effects are likely to be responsible for the differences in litter size and live born piglets between genotypes (Fahmy et al., 1979; Hurtgen, 1981). The differences in piglet production, found at different WOI's, should be explained in an other way. Condition related differences in follicular development and LH and progesterone production affecting ovulation and embryo survival might be important factors, in which insulin and IGF-1 are suggested to play an important role (Dyck, 1974; Veldhuis et al., 1986; Cox et al., 1987; Matamoros et al., 1990; Pettigrew & Tokach, 1992). Oestrus expression or oestrus length and time of insemination in relation to the time of ovulation is another possibility affecting results of inseminations performed at different intervals (Rojkittikhun et al. 1992). Reduced follicular development , poor oestrus expression and reduced oestrus length may well be linked. Van der Lende & Schoenmakers (1990) found a linear increase in number of embryo's with the number of corpora lutea before day 35 of pregnancy and concluded that an increase in ovulation rate can result in an increase in average litter size.

The small number of mummies found at WOI day 13-18 and ≥19, might be a key to the explanation of the litter size after a long WOI, it might be in line with lower embryo mortality.

Sows inseminated between day 9 and 12 post weaning are at higher risk to have a low farrowing rate. This is found in both primiparous and multiparous sows (OR: 0.33 and 0.20 respectively). Together with the small litters, this makes breeding sows in heat between 9 and 12 days post weaning, very unsuccessful and should, therefor, be avoided. Once a sow comes in heat at this time the only possibilities are: culling or breeding at the next oestrus, which is not necessarily a very bad alternative. The best strategy however seems trying to avoid prolonged intervals. Multiparous sows coming in heat on day 4 post weaning show a high farrowing rate (93.5%), the OR being 2.03 and thus they are more likely to farrow than multiparous sows inseminated on day 5 post weaning ($P<0.05$).

The optimal WOI for multiparous sows is four days and the optimal WOI for primiparous sows is five days. First parity sows showing heat for the first time on day 6 post weaning, are at risk to have a low farrowing rate. Because of the low number of sows in the WOI-classes 0-3 and ≥19, no sound conclusions can be drawn from those results.

The importance of a short WOI to minimise extra days in order to maximise sow production by enhancement of the farrowing index is not in discussion. The reduction of the WOI in practice is often achieved by the use of hormones to induce oestrus in animals with a prolonged WOI. Records of sows treated with hormones were excluded from this analysis (about 10%, especially first litter sows).

The extreme good results of sows with a WOI ≥19 days, in terms of litter size and number of piglets born alive, make it worthwhile to look into this in further research. Data of Leman (1990) also showed larger litters at WOI's of 15 days and longer.

Summarising one can state that the weaning to oestrus interval has a clear effect on litter size, number of live born piglets and farrowing rate.

SUMMARY

During a five year period, data were collected on a 390 sow pig unit. This unit consisted of three 130 sow subunits which only differed in housing system during gestation. The data were used to analyse the effects of the weaning to oestrus interval (WOI) on litter size, number of life bom piglets and farrowing rate.

Litter size (total born) was gradually decreasing from 11.9, at a WOI of four days, to 11.1, at a WOI of eight days ($P<0.06$). When the WOI was longer than twelve days the litter size increased. When the WOI was longer than eighteen days, an insemination resulted in a total of 13.5 piglets, which is significantly more ($P<0.01$) than at a WOI of five days. The number of piglets born alive after insemination of sows with a WOI of six days was lower than that of sows with a WOI of five days (10.39 versus 10.73; $P<0.05$). Sows with a WOI of more than eighteen days, produced 1.8 live born piglets per litter more than sows with a WOI of five days ($P<0.01$).

Conceming the farrowing rate it is concluded that first parity sows have low farrowing rates when bred during the first week after weaning compared with higher parity sows; at a WOI of four and six days the results were worst, 74.1 and 76.1% ($P<0.05$), and a WOI of five days gave the optimal situation (85.8%). Higher parity sows showed the best farrowing rate at a WOI of four days (93.5%). Farrowing rates of first and higher parity sows with a WOI of nine to twelve days were very low (66.7 and 58.6%, $P<0.01$ and $P<0.001$ respectively).
(Key words: sow production, farrowing rate, weaning to oestrus interval, housing system, parity, breed).

ZUSAMMENFASSUNG

Auf einem Betrieb mit 390 Sauen wurden während einer Periode von fünf Jahren Daten gesammelt. Der Betrieb besteht aus 3 Einheiten von je 130 Sauen. Die Einheiten unterschieden sich nur im Haltungssystem der tragenden Sauen. Die Daten wurden erhoben um nachzuforschen ob die Unterschiede in Würf- größe,

Anzahl der lebend geborenen Ferkel und Abferkelrate erklärt werden können durch die Variation im Rauscheintervall (WOI).

Die Wurfgröße verringerte sich von 11,9 bei einem WOI von 4 Tagen nach 11,1 bei einem WOI von 8 Tagen (p<0,06). Ein WOI größer als 12 Tagen äußerte sich in einem großere Wurf. Bei einem WOI über 18 Tagen war die wurfgröße mit 13,5 Ferkel signifikant höher als bei einem WOI von 5 Tagen mit einer Wurfgröße von 11,7 Ferkel (p<0,01).

Die Anzahl lebend geborener Ferkel lag niedriger bei Sauen mit einem WOI von 6 Tagen (10,4) als bei Sauen mit einem WOI von 5 Tagen (10,7) (p<0,05). Sauen mit einem WOI über 18 Tagen haben 1,8 lebend geborenen Ferkel mehr gewurfen als Sauen mit einem WOI von 5 Tagen (p<0,01).

Erstlingssauen hatten nach einem WOI von 4 oder 6 Tagen eine niedrigere Abferkelrate (bzw. 74,1 und 76,1%) als ältere Sauen (bzw. 93,4 und 88,2%), (p<0,05). Bei einem WOI von 9 bis 12 Tagen lag die abferkelrate, sowohl bei den Erstlingssauen als bei den älteren Sauen, niedriger als bei einem WOI von 5 Tagen (bzw. 66,7 und 58,6% bei einem WOI von 9 bis 12 Tagen und bzw. 85,8 und 87,7% bei einem WOI von 5 Tagen), (p<0,01).

(Schlüsselworte: Leistung von Sauen, Abferkelrate, Rauscheinterval, Haltungs-system, Zyklusnummer, Rasse).

ACKNOWLEDGEMENTS

The authors wish to thank dr.ir.K. Frankena, ing.R.H.J. Scholten and ing.G.P. Binnendijk for their kind assistance.

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CHAPTER 3

FACTORS INFLUENCING THE PROPORTION OF OFFSPRING FROM A SECOND INSEMINATION IN SOWS.

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Published in:

Animal Reproduction Science, 1996, 41: 255-265.

FACTORS INFLUENCING THE PROPORTION OF OFFSPRING FROM A SECOND INSEMINATION IN SOWS.

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Accepted 6 November 1995

ABSTRACT

Sows (n=367) showing standing heat between day 4 and 6 after weaning were inseminated twice with a 24 h interval. To distinguish offspring, Great Yorkshire (GY) semen was used for first insemination (ins1) and Meishan (MEI) semen for second (ins2), or in reverse order. Factors influencing the number of piglets born from ins2 were: weaning to oestrus interval (WOI, $P<0.001$), genotype of the sow ($P<0.05$), parity ($P<0.10$) and the interaction between treatment and MEI boar (MEI for ins1 or for ins2, $P<0.001$). The distribution of litters after litter type (1, completely from ins1; 2, mixed litters; 3, completely from ins2) was depending on: WOI ($P<0.001$), genotype ($P<0.05$) and the interaction between treatment and MEI boar ($P<0.001$). The interaction between treatment and MEI boar was due to one of the MEI boars that produced lower numbers of offspring compared with the other boars. The number of offspring from ins2, 24 h later, was higher in case the ins1 was performed with semen of this MEI boar ($P<0.05$). The number of offspring from ins1, 24 h earlier, was higher when ins2 was with semen of this boar ($P<0.05$).

It is concluded that the second insemination, 24 h after the first, did contribute to the offspring and that the level of this contribution was depending on the factors WOI, genotype of the sow, parity and boar.

Keywords: Pig-fertility; Weaning to oestrus interval; Artificial insemination; Boar fertility

INTRODUCTION

Insemination strategies are often topic for discussion in pig husbandry. Several authors reported an increased farrowing rate and litter size after a second insemination (Reed, 1982; Clark and Leman, 1986) or repeated natural mating (Tilton and Cole, 1982; O'Grady et al., 1983) during the same oestrus. O'Grady et al. (1983) found no effect on farrowing rate or litter size of double mating, with a 6 h or a 24 h interval, compared with single mating. They also found no effect of triple mating compared with double mating, with a 24 h interval between first and last mating. Gooneratne et al. (1989) did not find an effect of single or double insemination, with a 16-20 h interval, on farrowing rate or litter size in their experiment.

Slijkhuis and Schneijdenberg (1987) showed an effect of duration of standing heat on farrowing rate and litter size but no effect of frequency of insemination. They found a higher farrowing rate and increased litter size in sows showing standing heat during 2 subsequent days when compared with sows showing standing heat during only 1 day. They also showed that farrowing rate and litter size of sows showing standing heat during 2 subsequent days and inseminated only once on the first day, did not differ from sows inseminated twice on the 2 subsequent days.

Flowers and Esbenshade (1993) concluded that insemination frequency is of importance in sow production. Their results show an effect of mating frequency in gilts showing oestrus for 2 days, not in gilts showing oestrus for 1 day. However, no differences were found between gilts inseminated two or three times and an interval between first and last insemination of approximately 24 h. Gilts inseminated four times, with an interval between first and last insemination of approximately 32 h and an interval between subsequent inseminations of 8 and 16 h, showed an increased number of piglets born alive compared with gilts inseminated twice, with an interval between inseminations of 24 h. Gilts inseminated three times with intervals between inseminations of 8 and 16 h and an interval between first and last insemination of 24 h, produced an intermediate number of piglets born alive.

Dziuk (1970) inseminated twice with an approximate 6 h interval and this resulted in offspring from both inseminations; the boar used closest to ovulation being sire of most of the piglets when the interval between first boar and ovulation was 14 h or more. In case the first boar was used between 14 and 6 h before ovulation, more offspring was from this first boar than from the second boar, used 6 h later. Heterospermic insemination or competitive double mating with a 10 min interval resulted in a greater proportion of offspring per litter from some sires than others and this was used to assess male fertility (Martin and Dzíuk, 1977).

The present experiment was undertaken to investigate the contribution of the second insemination, 24 h after the first, to the litter in sows. Moreover it was examined which factors were of influence on the contribution of each of the two inseminations performed.

MATERIALS AND METHODS

Experimental animals, diets and housing

In this experiment 389 sows, weaned between October 1991 and November 1992, were used. The sows were from a rotation crossing with the following sow lines: Dutch Landrace (N), Great Yorkshire sow line (Y) and Finnish Landrace (F).

Sows received a commercial sow diet (12.5 MJ metabolisable energy (ME) kg^{-1} and 138 g crude protein (CP) kg^{-1}) during gestation increasing in two increments from 2.4 to 3.5 kg day^{-1}. Between weaning and insemination 3.5 kg of the same diet was fed. From 1 week before farrowing and during lactation sows were fed semi ad libitum (6-7 kg) of a second commercial sow diet (12.9 MJ ME kg^{-1} and 156 g CP kg^{-1}).

From 1 week before farrowing, during lactation and after weaning until 1 month after insemination, all sows were housed individually in (farrowing) crates. During the rest of the gestation period three housing systems were used: girth tethering, housing in crates and group housing with automatic feeder stations. Sows always returned to the same housing system for gestating sows.

Experimental design

Twice daily, around 08:00 h and 14:00 h, sows were checked for standing heat for the man by the farm staff. Sows with a weaning to oestrus interval (WOI) of 4, 5 or 6 days (first day of standing heat for the man) were used in this experiment. Inseminations were performed daily around 14:00 h. Sows were inseminated twice with a 24 h interval. The first insemination was performed on the first day of standing heat for the man. Boars of the Great Yorkshire breed (GY) and of the Meishan breed (MEI) were used to provide semen for artificial insemination (AI). Semen was collected and standardised at 3 x 10^9 motile spermatozoa of good quality per dose of 80 ml at a commercial AI-centre. The diluent used to standardize concentration and volume for AI was Modified (IVO) Beltsvile Thawing Solution. GY doses were commercial available "mixed doses", MEI-doses were "single boar doses". Three MEI boars were used in the experiment; MEI65, MEI83 and MEI84. Daily fresh semen was delivered at the farm and AI was performed by farm staff.

Two insemination schemes were used: first insemination (ins1) GY and second insemination (ins2) MEI (treatment A); ins1 MEI and ins2 GY (treatment B).

The breed of the sire of each piglet born alive or stillborn, but fresh, was determined immediately after birth. MEI crossing piglets had skin folds, nasal folds, thick, long ears and a declining croup.

Statistical methods

Sows were classified according to parity at weaning (1, 2, 3-5 and 6 or more) and genotype used in the analysis is referred to as: NFYN, YNFYN and FYNFYN.

Linear logistic regression models were fitted to the binary farrowing rate data. The regression models included: treatment, MEI boar, WOI, parity, genotype of the sow and housing system, as well as all two-factor interactions. Linear regression models were fitted to the data for number of live born piglets, number of live plus stillborn piglets, number of piglets born from ins1 and number of piglets born from ins2. The relationship between the same explaining factors and the division into litter type categories (category 1: all piglets from ins1; category 2: piglets from both inseminations; category 3: all piglets from ins2) was modelled using the proportional odds model after McCullagh (McCullagh, 1980; McCullagh and Nelder, 1989). The model quantifies the effect of both inseminations by the construction of an underlying continuous scale on which the distribution of all treatment groups is logistic with standard deviation $\pi/\sqrt{3}$. Two unknown cut-points provide a quantification of the difference between successive categories on the logistic scale. The model is based on the probability γ_{ij} for the response of a randomly chosen sow with treatment i is in category j or lower. The model has the form

$$\log(\gamma_{ij}/(1-\gamma_{ij}))=\theta_j - \text{treatment}_i,$$

where θ_j (j=1,2) is the cut-point between category j and j+1 and treatment denotes the mean for treatment i on the logistic scale. Means were modelled using the six explanatory factors and their 2-factor interactions. As the treatment mean increases the probability of the response lying in the higher categories also increases. Both estimates of cut-point values between the three different categories and treatment effects were obtained using the method of maximum likelihood for multinomial data (Keen and Engel, 1994). In the results means and significance on the underlying logistic scale are given. Also the distribution after litter type on a, with the results of the model composed, original scale as one would have expected if the data had been orthogonal, are given.

Likelihood ratio tests were used to test the effects of specific factors in the logistic models leading to the approximate χ^2 test for the reduction in residual deviance. For linear models effects of specific factors were tested using the F-test for the additional sum of squares. For the proportional odds model, Wald-tests were used to test effects of model terms, resulting in approximate χ^2 tests.

Model selection has been carried out by fitting the models with all main effects and two-factor interactions to the data and excluding interactions which were not significant (Brown, 1976). Results of the regression analysis are presented for the selected models. Statistical analyses were conducted using GENSTAT 5 (Genstat 5 Committee, 1993).

RESULTS

Animals excluded from analysis

Of 389 sows, 8 sows did not show standing heat for the man 24 h after the first insemination and were therefore excluded from analysis. The other sows (n=381; 97,9%) still showed standing heat for the man 24 h after the first insemination. Data of sows with a WOI of 6 days (n=15; 3.7%) were discarded in the analysis because of their low number. In total, 22 records were discarded (one of the sows fits in both groups). For the factor WOI two levels (4, 5) remained for analysis.

Animals included

The number of sows used in the analysis was 367. In Table 1 the results of the regression analysis (selected models) are presented for the main factors and the significant interactions for each trait. In the following paragraphs the results for each of the significant factors and interaction are presented. Housing system had no effect on any of the dependent variables.

Table 1: **Results of the regression analysis for farrowing rate (*FR*), live and stillborn piglets (*L/S*), live born piglets (*L*), live and stillborn piglets from ins1 (*L/S1*), life and stillborn piglets from ins2 (*L/S2*), live born piglets from ins1 (*L1*), life born piglets from ins2 (*L2*) and distribution after litter type (*LT*) (completely from ins1, mixed litter, completely from ins2)**

Effect	*FR*	*L/S*	*L*	*L/S1*	*L/S2*	*L1*	*L2*	*LT*[a]
WOI	*[b]	ns	ns	***	***	***	***	***
Genotype	*	ns	ns	**	*	**	*	*
Parity	ns	★	★	*	ns	*	★	ns
Treatment (T)	★	ns	ns	*	*	*	*	***
MEI-boar	ns	*	*	ns	ns	ns	ns	ns
T X MEI[c]				***	***	***	***	***
Housing syst.	ns	ns	ns	ns	ns	ns	ns	ns

[a] Estimates of cut point values for the division into the three different litter types, in the proportional odds model, were 0.00 and 2.04.

[b] One-sided test, on the ground of expected higher farrowing rate for day 4 sows compared with day 5 sows based on earlier results (Vesseur et al., 1994).

[c] Interaction between treatment and Meishan boar was not included in the models for *FR*, *L/S* and *L*.

*** $P \leq 0.001$; ** $P \leq 0.01$; * $P \leq 0.05$; ★ $P \leq 0.10$; NS, $P > 0.10$.

Weaning to oestrus interval (WOI).

Effects of WOI on the dependent variables are presented in Table 2. Farrowing rate was higher (P<0.05) for sows with a WOI of 4 days (92.4%) compared with sows with a WOI of 5 days (86.1%). Although there was no difference in the total number of live or live + stillborn piglets between sows with a WOI of 4 days and sows with a WOI of 5 days, sows with a WOI of 5 days had more (P<0.001) offspring from ins1 and less (P<0.001) offspring from ins2 compared with sows with a WOI of 4 days. The distribution after litter type was also different between sows with a different WOI (P<0.001). Sows with a WOI of 5 days had more litters completely from ins1, less litters completely from ins2 and a similar percentage of mixed litters, compared with sows with a WOI of 4 days.

Table 2: **Effect of weaning to oestrus interval (WOI) on farrowing rate, number of live (l) and live + stillborn (l+s) piglets, number of l and l+s piglets from ins1 and ins2 and on distribution of litters after litter type (completely from ins1, mixed, completely from ins2) as mean on the logistic scale and percentage on the original scale**

	WOI			SED
	4 days	5 days	6 days [a]	
N (inseminations)	136	231	14	
Farrowing rate (model)	92.4 a	86.1 b	78.6	
N (litters)	126	199	11	
l+s	11.9	11.7	12.1	0.32
l	11.2	11.2	11.7	0.31
l+s from ins1	5.0 p	7.3 q	9.0	0.61
l from ins1	4.7 p	7.1 q	8.6	0.59
l+s from ins2	7.0 p	4.4 q	3.1	0.62
l from ins2	6.6 p	4.1 q	3.1	0.59
Litter type (log scale)	1.34 p	0.33 q		0.24
Percent from ins1	24	43		
Percent mixed	40	38		
Percent from ins2	36	19		

[a] Data of sows with a WOI of 6 days were excluded from analysis; raw data are presented in this table.
Data in a row with different letters differ significantly (a,b, P<0.05; p,q, P<0.001).

Data of sows with a WOI of 6 days were excluded from analysis but the results were in line with the results of sows with a WOI of 4 or 5 days. Therefore, raw data of sows with a WOI of 6 days are also presented in Table 2.

Genotype of the sow

Effects of genotype of the sow on the dependent variables are presented in Table 3. In this experiment genotype YNFYN showed a higher (P<0.05) farrowing rate compared with genotype FYNFYN (93.5 and 84.1% respectively). Genotype NFYN showed intermediate results (90.2 %). Litter size was not different for the different genotypes. Genotype NFYN had less (P<0.05) offspring from ins1 (live and live + stillborn piglets) and more (P<0.05) offspring from ins2 compared with genotypes FYNFYN and YNFYN. The distribution after litter type differed between genotypes

Table 3: **Effect of genotype of the sow on farrowing rate, number of live (l) and live + stillborn (l+s) piglets, number of l and l+s piglets from ins1 and ins2 and on distribution of litters after litter type (completely from ins1, mixed, completely from ins2) as mean on the logistic scale and percentage on the original scale**

	Genotype of the sow			SED
	NFYN	YNFYN	FYNFYN	
N (inseminations)	110	137	120	
Farrowing rate (model)	90.2 ab	93.5 a	84.1 b	
N (litters)	99	127	99	
l+s	11.6	11.9	11.8	
l	11.2	11.2	11.3	
l+s from ins1	4.9 a	6.3 b	7.3 b	0.73
l born from ins1	4.7 a	6.0 b	7.0 b	0.70
l+s from ins2	6.7 x	5.6 y	4.6 y	0.74
l from ins2	6.5 a	5.2 b	4.3 b	0.70
litter type (log scale)	1.36 a	0.76 ab	0.38 b	0.29
Percent from ins1	24	35	42	
Percent mixed	40	39	38	
Percent from ins2	36	26	20	

Data in a row with different letters differ significantly (a,b, P<0.05; x,y, P<0.01).

NFYN and FYNFYN (P<0.05); genotype NFYN had fewer litters completely from ins1 and more litters completely from ins2 compared with genotype FYNFYN and genotype YNFYN showed intermediate results.

Parity

Effects of parity of the sow on the dependent variables are presented in Table 4. Farrowing rate differed non-significantly between parities. The number of piglets born per litter differed between parities. First parity sows produced less (P<0.05) live born piglets in the next litter, compared with second to fifth parity sows. The effect for live + stillborn piglets was similar in pattern and significance (P<0.05). First parity sows also tended to have less (P=0.07) live + stillborn piglets compared with sixth and higher parity sows.

Table 4: **Effect of parity on farrowing rate, number of live (l) and live + stillborn (l+s) piglets, number of l and l+s piglets from ins1 and ins2 and on distribution of litters after litter type (completely from ins1, mixed, completely from ins2) as mean on the logistic scale and percentage on the original scale**

	Parity of the sow at moment of insemination				SED
	1	2	3,4,5	≥6	
N (inseminations)	96	88	137	46	
Farrowing rate (model)	84.4	90.1	92.1	90.4	
N (litters)	79	78	126	42	
l+s	11.0 a	12.0 b	12.0 b	12.1 ab	0.42
l	10.6 a	11.6 b	11.5 b	11.2 ab	0.40
l+s from ins1	4.9 a	5.5 a	6.2 ab	8.0 b	0.76
l from ins1	4.7 a	5.3 a	6.1 ab	7.6 b	0.75
l+s from ins2	6.2	6.6	5.8	4.1	0.76
l from ins2	5.9 a	6.2 a	5.5 a	3.7 b	0.73
litter type (log scale)	1.20	1.16	0.82	0.17	
Percent from ins1	27	28	34	47	
Percent mixed	40	40	40	36	
Percent from ins2	33	32	26	17	

Data in a row with different letters differ significantly (a,b, P<0.05).

The number of piglets from ins1 increased with increasing parity number (P<0.05). Sixth and higher parity sows produced more (P<0.05) live born and more (P<0.05) live + stillborn piglets in their next litter compared with first and second parity sows. The number of piglets from ins2 tended to decrease (P=0.06) with increasing parity number. Sixth and higher parity sows produced less (P<0.05) live born piglets in their next litter compared with first to fifth parity sows. The distribution after litter type was not different for different parities.

Treatment, Meishan boar and interaction.

Effects of treatment and Meishan boar on the dependent variable litter size are presented in Table 5 and 6. Treatment (A, ins1 with GY boar and ins2 with MEI boar or B, ins1 with MEI boar and ins2 with GY boar) had no effect on the number of live born or live + stillborn piglets or on farrowing rate (A, 91.9%; B, 86.6%; P=0.10). MEI boar had no effect on farrowing rate. However, MEI boar was of influence on litter size: when boar MEI84 was used for ins1 or for ins2 this resulted in litters with less live born + stillborn piglets compared with boar MEI65 (11.3 and 12.3 respectively; P=0.01). The number of live born + stillborn piglets in litters of combinations with boar MEI83 was intermediate (11.7). The effect of Meishan boar on the number of live born piglets per litter showed similar results (P<0.01).

Semen quality was checked at the AI-station and semen was only distributed when it met the quality standard. All Meishan boars produced semen that always met the quality standard (at least 60% live and motile spermatozoa). The average percentage live and motile spermatozoa, however, was slightly lower in case of boar MEI84 (on average 73%) compared with MEI83 and MEI65 (both 79%).

Table 5: **Effect of treatment (A, ins1 GY and ins2 MEI; B, ins1 MEI and ins2 GY) on the number of piglets born (live + stillborn and live born)**

	Treatment A ins1 GY, ins2 MEI	Treatment B ins1 MEI, ins2 GY	SED
N (litters)	177	148	
Live + stillborn	11.8	11.7	0.32
Live born	11.3	11.2	0.31

Table 6: **Effect of Meishan boar on the number of piglets born (live + stillborn and live born)**

	Meishan boar			SED
	MEI 65	MEI 83	MEI 84	
N (litters)	142	89	94	
Live + stillborn	12.3 x	11.7 xy	11.3 y	0.39
Live born	11.7 x	11.1 xy	10.8 y	0.38

Data in a row with different letters differ significantly (x,y, P≤0.01).

Effects of the interaction between treatment and Meishan boar on the dependent variables are presented in Table 7. The interaction between treatment and Meishan boar was of influence on the number of live + stillborn piglets from ins1, on the number of live + stillborn piglets from ins2 and on the distribution of litters after litter type. The effect of the interaction between treatment and Meishan boar on the number of live born piglets from ins1 and from ins2 was similar to the effect on the number of live + stillborn piglets.

Table 7: **Effect of the interaction between treatment (A, ins1 GY and ins2 MEI; B, ins1 MEI and ins2 GY) and MEI boar on the number of live + stillborn (l+s) and live born (l) piglets from ins1 and ins2 and on the distribution of litters after litter type (completely from ins1, mixed, completely from ins2) as mean on the logistic scale and as percentage on the original scale**

	Interaction treatment X Meishan boar						SED
	A X MEI65	B X MEI65	A X MEI83	B X MEI83	A X MEI84	B X MEI84	
N (litters)	93	49	48	41	36	58	
l+s from ins1	6.1 a	7.1 ab	6.1 a	5.6 a	8.9 b	3.2 c	1.0
l from ins1	6.0 a	6.9 ab	5.8 a	5.4 a	8.5 b	3.1 c	1.0
l+s from ins2	6.2 a	5.2 a	5.5 a	6.4 ac	2.8 b	7.9 c	1.0
l from ins2	5.8 a	4.9 a	5.1 a	6.0 ac	2.7 b	7.5 c	1.0
Litter type	0.70 p	0.83 p	0.53 p	1.15 p	-0.32 q	2.13 r	0.40
Percent from ins1	35	32	39	27	57	13	
Percent mixed	42	43	40	42	32	35	
Percent from ins2	23	25	21	31	11	52	

Data in a row with different letters differ significantly (a,b,c, P<0.05; p,q,r, P<0.001).

The interaction between treatment and Meishan boar was completely caused by boar MEI84. When MEI84 was used for ins2 (treatment A) the number of offspring from ins2 is lower and the number of offspring from ins1 was higher compared with other combinations ($P<0.05$). When boar MEI84 was used for ins1 the number of offspring from ins1 was lower and that of ins2 was higher compared with other combinations ($P<0.05$). The distribution of litters after litter type of the combination: treatment A (ins1 GY, ins2 MEI) and MEI84, differed from the other combinations ($P<0.001$); the percentage of litters completely from ins1 was higher and the percentage litters completely from ins2 was lower. The combination of treatment B (ins1 MEI, ins2 GY) and MEI84 showed the reverse effect ($P<0.001$); the percentage of litters completely from ins2 was higher and the percentage litters completely from ins1 lower compared with other combinations. In both combinations with MEI84 the percentage mixed litters was low.

DISCUSSION

Weaning to oestrus interval (WOI)

The number of piglets born from ins1, from ins2 and the distribution of litters after litter type as found in this experiment, may help explaining the differences in litter size and farrowing rate between sows with a different WOI as found by Leman (1990) and Vesseur et al. (1994). Also in this experiment farrowing rate decreased as WOI increased.

With an increasing WOI the number of piglets from ins1 and the percentage litters completely from ins1 increased. It might be concluded that the moment of ovulation in relation to a fixed time of insemination during the day, as in this experiment, is earlier with an increasing WOI. For some animals with a WOI of 5 or 6 days the ins1 might be performed too late, with a small litter or return to oestrus as consequence.

Genotype of the sow

There are differences between genotypes found in farrowing rate and number of piglets from ins1 and from ins2 as well as in distribution after litter type. The genotype with the lowest farrowing rate showed the highest number of piglets from ins2. Ovulation seems to take place relative late in this genotype and may be too late in some cases leading to a depressed farrowing rate.

Parity

The effect of parity on litter size is well known from literature and reviewed by Clark and Leman (1986). In this experiment, parity also showed an effect on the number of piglets from ins1 and from ins2. Parity 6 and higher parity sows had more offspring from ins1 and less from ins2 in their next litter, compared with parity 1 and 2 sows. It might be concluded that older parity sows ovulate earlier, relative to a fixed time of insemination during the day as in this experiment.

Treatment and Meishan boar

An interaction between treatment and MEI boar on the number of offspring from ins1, ins2 and the distribution after litter type, is found. Also an effect of MEI boar on litter size is found. All these effects were caused by one of the MEI boars only. The fertility of this MEI boar seems to be lower than that of the other MEI boars and GY boars.

Martin and Dziuk (1977) and Robl and Dziuk (1988) reported the use of heterospermic inseminations to assess the fertility of boars by the use of mixed semen or matings with a 10 min interval. They showed that relative fertility of boars could be easily assessed by ranking the boars after the proportion of offspring sired.

In the present experiment the interval between inseminations was 24 h. Irrespective of whether the "low fertile" MEI boar was used for ins1 or for ins2, more offspring from the GY boars was found. The "extra" offspring from the other insemination was not enough to compensate the effect of the "low fertile" MEI boar completely. This resulted in the effect of MEI-boar on litter size as found in this experiment.

Timing and frequency of inseminations

Maximal reproductive performance is depending on the total period during which capacitated spermatozoa are available in the right concentration at the ampullaryisthmic junction to fertilise shed eggs. The length of this period seems to depend on time between inseminations and time between first and last insemination. From the data of Flowers and Esbenshade (1993) one can conclude that the time between first and last insemination is of importance. In their data there is also some evidence that the time between subsequent inseminations may be of importance. The optimal time between subsequent inseminations probably will depend on boar fertility, number of viable spermatozoa per dose, quality of the processing and of the diluent used and on transport and storage of the semen prior to insemination.

Results found in this experiment, in which 39% of the litters had offspring from both inseminations, seem to justify an interval between inseminations of 24 h as long as boar fertility is good.

CONCLUSIONS

A second insemination, 24 h after the first insemination and performed in the afternoon (about 14:00 h) of the second day of standing heat for the man, resulted in about 45% of the piglets born.

The number of piglets from second insemination and the distribution after litter type (completely from ins1, mixed or completely from ins2) was depending on: weaning to oestrus interval, genotype of the sow, parity (except for distribution after litter type) and boar (fertility).

ACKNOWLEDGMENTS

The authors wish to thank P.F.G. Vereijken of the Agricultural Mathematics group, Wageningen and G.P. Binnendijk of the Research Institute for Pig Husbandry, Rosmalen for their kind assistance with the analysis of the data. Euribrid B.V. is greatly acknowledged for having placed Meishan boars from the research population at the Agricultural University Wageningen at the authors disposal.

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CHAPTER 4

FACTORS AFFECTING THE WEANING TO OESTRUS INTERVAL IN THE SOW.

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Published in:
Journal of Animal Physiology and Animal Nutrition 72 (1994): 225-233.

FACTORS AFFECTING THE WEANING TO OESTRUS INTERVAL IN THE SOW.

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INTRODUCTION

In pig production the weaning to oestrus interval (WOI) is an important trait (Burgers, 1952; Van der Heyde et al., 1974; Aumaitre et al. 1976; Fahmy et al., 1979; Fahmy, 1981). Currently the average number of non productive days on farm level, caused by a prolonged WOI, is low, but ranges are wide. In 1990, 463 American users of the PigCHAMP program, an on farm Management Information System (MIS) with information exchange to a central database on a contract basis, produced a mean WOI of 7.7 days (SE between farms: 2.19; range between farms: minimum 4.1 and maximum 66.2, Marsh et al., 1992). In the same year, 660 Dutch users of the CBK program, a MIS with on farm or centralised working up of information and voluntary data exchange to the distributor (Siva-produkten BA), produced a mean WOI of 7.3 days (SE between farms: 1.74; range between farms: minimum 4.9 and maximum 18.6). In practice, sows with a prolonged WOI are often treated with PMSG (Pregnant Mare Serum Gonadotrophin) either alone or in combination with HCG (Human Chorionic Gonadotrophin), which is known to induce oestrus and shorten the WOI (Fahmy et al., 1979). This is an important factor explaining the relative good results in WOI in the data from PigCHAMP and CBK. Hemsworth et al. (1980) showed a higher incidence of the use of these hormones in first litter sows (19.2 -52.0 % and 22.2 - 69 %) compared with higher parity sows (8.1 - 15.7 % and 8.0 - 22.6 %) in different studies. An analysis on the effects of the WOI on sow production (Vesseur et al., 1994) showed clear differences in subsequent litter size, number of live born piglets and farrowing rate for different WOI's. The number of piglets born per first insemination decreased with an increasing WOI from day 4 to day 12 and increased with an increasing WOI after day 12.

Knowledge about the factors affecting the WOI will help to avoid a prolonged WOI and subsequent effects on sow production. It will also be of help in reducing the use of oestrus inducing hormones in future. In this paper therefore, data from a 390 sow pig unit are analysed to determine possible factors that may explain variation in WOI and variation in the need to use hormones to induce oestrus.

MATERIAL AND METHODS

Data from 5 years research at the 390 sow pig unit of the Research Institute for Pig Husbandry at Rosmalen were used in the analysis.

Description of the farm

On the closed farm, two types of crossings were used: 1. A three-way crossing with Dutch Landrace (N) and Duroc (D) sow lines to produce DN sows and 2. A rotation crossing formed with Dutch Landrace (N), Great Yorkshire (Y) and Finnish Landrace (F) sow lines, resulting in rotation crossing (R) sows. A Great Yorkshire boar line was used for slaughter pig production in both crossings.

During lactation sows were single housed in farrowing crates. The lactation period was planned at 28 days. After weaning sows continued to be housed individually in crates. To stimulate heat after weaning, sows were brought outside for 1 to 2 h on the day of weaning and on the next day to allow contact with each other and fence contact with a vasectomized teaser boar. Artificial insemination was performed by the farm staff. Sows showing standing heat for the man were inseminated on the same day, around noon. Sows still showing standing heat for the man the next day, were inseminated again, but this time before noon. Sows were transferred to the housing systems for gestating sows at about four weeks after AI. Three housing systems were used during gestation: girth tethering, crates and group housing in a large (60-70 sows) continuously changing group with electronic identification and feeding using two automatic feeder stations. The housing differed only during gestation. Sows always returned to the system they came from. The number of sows in each system was about 130.

The use of hormones to induce oestrus, 200 IU HCG and 400 IU PMSG (PG600; Intervet BV, Boxmeer), differed between first and higher parity sows; first parity sows not showing oestrus, were treated on day 15 after weaning and the higher parity sows on day 8 after weaning. Both, first and higher parity sows of the Dutch Landrace breed not showing oestrus were treated on day 22 after weaning.

The body weight of sows was measured at the moment of transfer to the farrowing house (about 1 week before farrowing), on the day after farrowing (in a limited number of sows) and on the day of weaning. The body weight of piglets, both after farrowing and at weaning was also measured. All production data were recorded.

Selection of data

From February until July 1991 the results on the farm were influenced by an outbreak of PRRS (Porcine Respiratory and Reproduction Syndrome) and therefore the inseminations performed in this period and those that would result in a farrowing in this period, were excluded from analysis. Some records were incomplete (n=4) or showed faulty data (0 weaned; n=34) and therefore had to be excluded. Data of 2948 farrowings, from June 1987 until May 1992, followed by a WOI, were used in this analysis. The number of sow records including all weight data, including the weight after farrowing, were limited (n=1495).

Statistical methods

First the possible factors of influence on the WOI (breed, parity, number of piglets weaned, body weight before farrowing, after farrowing and after weaning, body weight loss during lactation, season, housing system and lactation period) were analysed. Using SAS-GLM (SAS, 1989), the factors and interactions were tested for significance and omitted from the model in a stepwise fashion, leaving only significant factors and interactions ($p<0.10$). Since the distribution of the WOI was skewed, the data were first log transformed to obtain a more symmetrical distribution.

This procedure resulted in the following model:

$Y_{ijklmopqn} = \mu + B_i + P_j + W_k + L_l + S_m + H_o + F_p + G_q + e_{ijklmopqn}$

μ: overall mean

B_i: the effect of breed (i = N, DN or R)

P_j: the effect of parity (j = 1, 2, 3/4/5 or ≥6)

W_k: the effect of the number of piglets weaned after the preceeding lactation (k = 1-6, 7-8, 9-10, 11-12 or ≥13)

L_l: the effect of weight loss during lactation, in % of the bodyweight determined the day after farrowing (l = <0.0%, 0.0-5.0%, 5.1-7.5%, 7.6-12.5%, >12.5% or not measured)

S_m: the effect of season (m = January-March, April-June, July-September or October-December)

H_o: the effect of housing system (o = girth tethering, crate housing or group housing)

F_p: the interaction between parity and housing system

G_q: the interaction between parity and weight loss during lactation

$e_{ijklmopqn}$: random error of each observation,

where $Y_{ijklmopqn}$: = the individual log WOI of ith breed, jth parity, kth number of piglets weaned, lth weight loss during lactation, mth period of the year, oth housing system, pth interaction parity * housing system, qth interaction parity * weight loss during lactation and nth observation.

In the results the LS-means and the standard errors of the LS-means of the final model are given. The model was also run with the non-log-transformed WOI to present LS-means of the WOI in days.

Secondly the use of oestrus inducing hormones (400 IU PMSG and 200 IU HCG) was tested between classes of factors, significant in the first part of the analysis, using the X^2-test (SAS, 1989).

RESULTS AND DISCUSSION

A stepwise reduction of the model for factors of influence on the WOI resulted in a model with the factors breed ($p<0.001$), parity ($p<0.001$), number of piglets weaned ($p<0.001$), weight loss during lactation ($p<0.001$), season ($p<0.001$), housing system ($p<0.001$), the interaction between parity and weight loss during lactation ($p<0.05$) and the interaction between parity and housing system ($p<0.001$). On this farm the length of the lactation period had no effect on the WOI.

The model explains 31.2% (R^2) of the variation in length of the WOI ($p<0.0001$). The Root Mean Square Error of the model is 0.41 and the mean log WOI is 1.85 (WOI = 6.9 days).

The incidence of use of oestrus inducing hormones during the WOI was 12.3 % of the cases (n = 2948).

Length of the lactation period

The length of the lactation period (mean: 27.3, SD: 2.7) was not of influence on the length of the WOI. Van der Heyde (1974), Aumaitre et al. (1976), Hays et al. (1978), Britt et al. (1983), Leman and Fraser (1989) and Xue et al. (1993) found that shorter lactation periods caused longer WOI's. This effect was clearly present when intervals were as short as 1 or 2 weeks. On this farm weaning took place after a planned lactation period of 4 weeks and only exceptionally before 3 weeks (the minimum was 17 days) or after 5 weeks, which explains the absence of this effect.

Parity

Tables 1 and 2 show, respectively, the effect of housing system and weight loss during lactation, on WOI and on the percentage of sows treated with hormones to induce oestrus, for the different parities. The interactions between parity and housing system and parity and weight loss during lactation on WOI were significant ($p<0.001$ and $p<0.05$, respectively). However, it can be concluded from Tables 1 and 2 that the first parity sows showed a longer WOI than sows of parity 3 or more. The second parity sows showed an intermediate WOI. Despite the later time after weaning, oestrus inducing hormones (400 IU PMSG and 200 IU HCG) were used in first parity sows; more first parity sows were treated for anoestrus than third or higher parity sows. The later use of these hormones allows the WOI to lengthen, but, since the percentage sows treated with hormones is higher ($P<0.001$), the conclusion that first parity sows show more anestrus problems seems justified. The percentage of second parity sows treated with these hormones appeared to be intermediate. The conclusion that first and, to a lesser extent, second parity sows are more susceptible to a prolonged WOI is in agreement with the literature (Van der Heyde et al., 1974; Hurtgen and Leman, 1980; Karlberg, 1980; Fahmy, 1981; Clark et al., 1986; Leman, 1990; Xue et al., 1991).

The interaction between parity and housing system

The interaction between parity and housing system on the WOI is shown in Table 1. First parity sows in the group housing system showed a longer WOI (13.0 days) and a higher percentage of sows treated for anestrus (37.5%) than first parity sows housed in crates or girth tethered (WOI: 11.0 and 10.8 days, respectively, $P<0.001$; % treated: 25.0 and 26.4%, respectively, $p<0.01$). Second parity sows in the group housing system showed a longer WOI (7.8 days) and a higher percentage treated for anestrus (15.3%) than girth tethered second parity sows (WOI: 6.7 days, $P<0.01$; % treated: 7.9, $p<0.05$). The WOI of second parity sows housed in crates was intermediate (7.4 days) as was the percentage treated for anoestrus (11.1%). Third parity and higher parity sows showed a short WOI (≤6.4 days) and a low incidence of treatment for anestrus (≤3.4%) in all housing systems. The housing system of sows during gestation was of influence on the WOI in first and second parity sows. This effect could not be explained from body weight, body weight changes or other factors analysed. The influence of low social rank may have been of influence on the WOI in young sows in the group housing system while it is absent in young sows housed in crates or tethered. If this effect of low social rank or chronic social stress is involved, it must be a long term effect, since the housing situation and management during lactation and after lactation until 4 weeks of pregnancy was the same for all three housing systems. Varley (1991) reviewed the effects of stress on reproduction: both acute and chronic stress (in gilts and multiparous sows) due to aggressive interactions and stocking density (in gilts) can result in reproductive failure. Pedersen et al. (1993) found a relationship between postweaning aggression and social behaviour during oestrus in the sow (the more aggression the less social behaviour) but they found no relationship with hormone levels and this short term effect. Schuurman (1981) reported a reduction in circulating testosterone in lower rank male rats after repeated aggressive interactions, a phenomenon in which neuropeptides are proposed as playing a role influencing the secretion of pituitary hormones. A comparable mechanism may affect the reproductive performance of the first parity sows in the group housing system. In other species, such as cows, mice and monkeys, repressed signs of oestrus or anestrus is known among animals low in the social hierarchy (Pedersen et al., 1993).

Table 1. **The effect of housing system within parity class on the weaning to oestrus interval (WOI; days), LS-means (n = 2948 records) and the percentage of sows treated with hormones to induce heat per (parity * housing) class**

Parity		Housing system		
		group housing	crate housing	tethering
1	n	284	291	275
	WOI	13.0	11.0	10.8
	ln WOI ± SE	2.35 ± 0.03^{a}	2.18 ± 0.03^{b}	2.16 ± 0.03^{b}
	% treated	$37.5^{a,p}$	$25.0^{b,p}$	$26.4^{b,p}$
2	n	196	207	215
	WOI	7.8	7.4	6.7
	ln WOI ± SE	1.88 ± 0.03^{a}	$1.83 \pm 0.03^{a,b}$	1.77 ± 0.03^{b}
	% treated	$15.3^{y,q}$	$11.1^{y,z,q}$	$7.9^{z,q}$
3/4/5	n	365	348	384
	WOI	6.4	6.4	6.2
	ln WOI ± SE	1.74 ± 0.03^{a}	1.75 ± 0.03^{a}	1.72 ± 0.03^{a}
	% treated	$3.3^{a,r}$	$3.4^{a,r}$	$3.4^{a,q,r}$
≥6	n	124	136	123
	WOI	6.1	6.3	6.2
	ln WOI ± SE	1.70 ± 0.04^{a}	1.73 ± 0.04^{a}	1.69 ± 0.04^{a}
	% treated	$0.8^{a,r}$	$0.7^{a,r}$	$0.8^{a,r}$

^{a,b} Data with different letters within a row differ significantly (P<0.01)
^{y,z} Data with different letters within a row differ significantly (P<0.05)
^{p,q,r} Data with different letters within a column differ significantly (P<0.01)

The interaction between parity and weight loss during lactation

The interaction between parity and weight loss during lactation is shown in Table 2. The WOI was prolonged in first parity sows when the weight loss of the sow during lactation exceeded 7.5% (11.7 days), compared with a weight loss of 0.0 - 5.0 and 5.1-7.5% (9.5 and 10.0 days, respectively, $p<0.05$). The WOI was even more prolonged when the weight loss exceeded 12.5% (14.7 days, $p<0.05$). A weight loss during lactation of 12.5% in first parity sows corresponded with 31 kg, whereas, in parity ≥6, it corresponded with a body weight of 42 kg. Second parity sows losing over 12.5% of their body weight during lactation, showed a longer WOI (8.5 days) than second parity sows loosing less then 7.6% of their body weight (≤6.7 days, $p<0.05$). The WOI of second parity sows loosing between 7.6 and 12.5% of their body weight during lactation was intermediate (8.0 days). The WOI of third and higher parity sows was not influenced by weight loss during lactation and was on average 6.5 days or less.

Table 2. **The effect of body weight loss during lactation (as percentage of the body weight after farrowing) within parity on the weaning to oestrus interval (WOI; days) (n=1495 records) and the percentage of sows treated with hormones to induce oestrus per (weight loss * parity) class**

Parity		Weight loss during lactation %				
		<0.0	0.0-5.0	5.1-7.5	7.6-12.5	>12.5
1	n	33	30	29	73	122
	WOI	11.4	9.5	10.0	11.7	14.7
	ln WOI ± SE	2.19 ± 0.07 ^{ab}	2.07 ± 0.08 ^{a}	2.09 ± 0.08 ^{a}	2.26 ± 0.05 ^{b}	2.49 ± 0.04 ^{c}
	% treated	24.2 ^{x}	20.0 ^{x}	20.7 ^{x}	23.3 ^{x,p}	43.4 ^{y,p}
2	n	12	27	30	79	109
	WOI	6.5	6.7	6.7	8.0	8.5
	ln WOI ± SE	1.73 ± 0.12 ^{a}	1.77 ± 0.08 ^{a}	1.79 ± 0.08 ^{a}	1.87 ± 0.05 ^{ab}	1.97 ± 0.04 ^{b}
	% treated	0 *	3.7 ^{x}	6.7 ^{x}	11.4 ^{x,p}	23.9 ^{y,q}
3-5	n	49	121	132	238	168
	WOI	6.1	6.0	6.3	6.5	6.5
	ln WOI ± SE	1.72 ± 0.06 ^{a}	1.69 ± 0.04 ^{a}	1.73 ± 0.04 ^{a}	1.76 ± 0.03 ^{a}	1.77 ± 0.03 ^{a}
	% treated	2.0	1.7	3.0	3.4 ^{q}	6.0 ^{r}
≥6	n	34	60	47	67	35
	WOI	6.3	6.1	6.0	6.5	6.0
	ln WOI ± SE	1.72 ± 0.07 ^{a}	1.68 ± 0.06 ^{a}	1.69 ± 0.06 ^{a}	1.75 ± 0.05 ^{a}	1.68 ± 0.07 ^{a}
	% treated	0	1.7	0	1.5 ^{q}	0 *

^{a,b,c}; ^{x,y} Data with different letters within a row differ significantly ($p<0.05$)
^{p,q,r} Data with different letters within a column differ significantly ($p<0.001$)
* Empty cell in X^2-test

Analysis of the incidence of the use of hormones to induce oestrus showed a higher incidence in first parity sows (Table 2). The percentage of first parity sows treated for anestrus in the weight loss class >12.5% was significantly higher (43.4%) than the percentage of first parity sows treated in the other weight loss classes (between 20.0 and 24.2%, p<0.05). The parity effect on incidence of treatment for anoestrus within weight loss classes 7.6-12.5% and >12.5%, was highly significant (p<0.001) as is shown in Table 2. In the weight loss class 7.6-12.5%, more first and second parity sows had to be treated for anestrus (23.3 and 11.4%, respectively) than higher parity sows (between 1.5 and 3.4%, p<0.001). In the weight loss class >12.5%, more first (43.4%) than third or higher parity sows had to be treated for anestrus (between 0 and 6.0%, p<0.001) and the amount of second parity sows that had to be treated was intermediate (23.9%, p<0.001).

The results correspond with the literature in which induced reduction in feed intake during lactation results in a prolonged WOI (Fahmy, 1981; Reese et al., 1982, 1984; King and Williams, 1984a, b; Aherne and Kirkwood, 1985; King and Dunkin, 1986a; Kirkwood et al., 1987; Johnston et al., 1989; Aherne et al., 1990; Cole, 1990). Reduction in body weight and backfat thickness are found to be important factors in relation to the WOI. A reduced energy intake during lactation affects the WOI negatively (Reese et al., 1982; Aherne and Kirkwood, 1985; King and Dunkin, 1986b; King, 1987). Reduced protein intake also has a negative effect on the WOI, especially in young sows, and has a clear effect on body weight (King and Williams, 1984b; King, 1987). Reduction in body weight during lactation as percentage of body weight after farrowing seems to be a good indicator for the way the sows' metabolism is regulated after weaning.

Breed

The breed of the sow is a significant factor (P<0.001; Table 3). The rotation crossing (R) performed best (p<0.001). The difference between Dutch Landrace sows (N) and the other breeds (p<0.05) can not be ascribed to breed differences, since the Dutch Landrace sows were treated for anestrus in a different way (not before 22 days after weaning). Despite the fact that the Dutch Landrace sows were treated for anestrus so late, the percentage treated was relatively high (12.1%) in comparison with the other breeds. Pure line sows are likely to have a longer WOI compared with crossbred sows. Differences between breeds are also reported in the literature (Aumaitre et al., 1976; Fahmy et al., 1979; Fahmy, 1981; Hurtgen, 1981). The Duroc * Dutch Landrace crossing (DN) showed a significantly longer WOI than the rotation crossing (7.8 and 6.2 days, respectively, p<0.05) and the number of sows treated for anestrus was much higher in the Duroc * Dutch Landrace crossing than in the rotation crossing (19.1% and 8.9%, respectively, p<0.001). Differences between the breeds used in the crossings together with heterosis effects, explain the differences found in WOI.

Table 3. **Effect of breed on the weaning to oestrus interval (WOI; days) and the percentage sows treated with hormones to induce heat (n = 2948 records) N = Dutch Landrace, DN = Duroc * Dutch Landrace, R = rotation crossing (Finnish Landrace * Great Yorkshire * Dutch Landrace)**

breed	n	WOI	ln WOI ± SE	% treated
N *	199	9.67	1.99 ± 0.02 [(a)]	12.1
[p] DN	930	7.75	1.91 ± 0.03 [b]	19.1
R	1819	6.16	1.72 ± 0.02 [c]	8.9 [q]

[a,b,c]; [p,q] Data with different letters within a column differ significantly (p<0.05, p<0.001)
* Treated different with oestrus inducing hormones

Litter size at weaning

The number of piglets weaned after the previous lactation has an effect on the WOI (p<0.01), as is shown in Table 4. A litter size at weaning of 8 piglets or less resulted in a shorter WOI (≤7.5 days) than a litter size of 9 piglets or more (≥8.0 days, p<0.05). Since no interaction with weight loss or parity was found in this analysis, the effect of litter size on WOI is independent of parity and weight loss during lactation. The reduced WOI affected by a small litter size at weaning or a small litter size during the last week of lactation is described in the literature (Fahmy et al., 1979; Britt, 1986 and Matte et al., 1992). The reduction of the WOI is attributed to a decreased suckling intensity (and frequency) and its effects on hormonal regulation at the level of the central nervous system (Cox and Britt, 1982; Kunavonkrit, 1984;

Matte et al., 1992). In this analysis the incidence of treatment for anoestrus was not significantly different for the different litter sizes at weaning. Mahan (1993) found a reduction of the WOI of 3.5 days for sows that nursed four piglets for an additional week, while fed ad libitum (15% crude protein), and were weaned at 30 days compared with sows that were completely weaned by 23 days of lactation and were fed 1.8 kg (14% crude protein) per day. The effects on body weight were not measured in that research and the effects of different litter sizes during the last week of lactation at equal lactation periods were not researched either. Weaning some of the piglets several days before the rest of the piglets are weaned (split weaning) seems a practical method of reducing the WOI without prolongation of the lactation period. The effect of split weaning, a reduction of the suckling intensity and a reduction in loss in body weight during lactation, on the WOI in first and second parity sows needs further research. Another, less practical, method, which can result in a reduction in loss in body weight and can reduce the suckling frequency, could be the separation of sow and piglets for several hours each day during the last days of the suckling period.

Table 4. **Effect of the number of piglets weaned on the weaning to oestrus interval (WOI; days) and the percentage sows treated with hormones to induce heat (n = 2948 records)**

piglets weaned	n	WOI	ln WOI ± SE	% treated
1 - 6	172	7.25	1.81 ± 0.03^{a}	14.0^{a}
7 - 8	621	7.54	1.85 ± 0.02^{ac}	13.3^{a}
9 - 10	1283	7.96	1.89 ± 0.02^{b}	11.8^{a}
11 - 12	758	8.33	1.92 ± 0.02^{b}	12.5^{a}
≥ 13	114	8.21	1.92 ± 0.04^{bc}	8.8^{a}

^{a,b,c} Data with different letters within a column differ significantly (p<0.05)

Season

The effect of season of weaning on the WOI was significant (p<0.001) and is presented in Table 5. From April up to September, the WOI was significantly longer (8.1-8.2 days) than during the rest of the year (7.5-7.7 days, p<0.01). The percentage of animals treated with hormones to induce oestrus from July until September

(17.7%) was higher than during the rest of the year (9.2-11.1%, $p<0.05$). It is concluded, therefore, that the third quarter of the year produces the most anestrus problems. There was no interaction of season with parity, condition loss during lactation or with both of these. These factors can not, therefore, be held responsible for the prolonged WOI during the summer months. Season seems to have an effect of its own which is far less important than weight loss during lactation. It is not possible to differentiate between temperature and light intensity or daylength effects.

Table 5. **The effect of the season of weaning on the weaning to oestrus interval (WOI; days) and the percentage sows treated with hormones to induce heat (n = 2948 records)**

season of weaning	n	WOI	ln WOI ± SE	% treated
january - march	751	7.66	1.84 ± 0.02 [a]	9.2 [p]
april - june	628	8.19	1.92 ± 0.02 [b]	11.1 [p]
july - september	836	8.11	1.92 ± 0.02 [b]	17.7 [q]
october[p]- december	733	7.48	1.83 ± 0.02 [a]	10.4

[a,b; p,q] Data with different letters within a column differ significantly ($p<0.01$; $p<0.05$)

SUMMARY

Over a 5 year period, data were collected on a 390 sow pig unit and analysed for effects on the weaning to oestrus interval (WOI).

The length of the WOI was influenced by parity ($p<0.001$), breed ($p<0.001$), season ($p<0.001$), housing system ($p<0.001$), number of piglets weaned ($p<0.001$), reduction of the body weight during lactation ($p<0.001$), the interaction between parity and housing system ($p<0.001$) and the interaction between parity and weight loss during lactation ($p<0.05$).

Body weight loss during lactation had a clear effect on the WOI in first and second parity sows; over 7.5 % reduction in body weight during the first lactation and over 12.5 % during the second lactation prolonged the WOI ($p<0.05$). Group housing during gestation in a large continuously changing group also prolonged the WOI in first and second parity sows ($p<0.01$). Independent of parity and weight loss during

lactation, the WOI was prolonged when the litter size at weaning exceeded 8 piglets ($p<0.05$). Also independent of parity and weight loss during lactation was the effect of season; sows weaned in the period from july until september were most likely to have a prolonged WOI ($p<0.01$) or to be treated with oestrus inducing hormones ($p<0.05$). The WOI was also dependent on the genotype of the sow. The use of oestrus inducing hormones masked the effect of factors prolonging the WOI, in 12.3 % of the cases these hormones were used.
Key words: breed, hormones, housing, parity, reproduction, season, pig.

ZUSAMMENFASSUNG

Der Einfluß unterschiedlicher Faktoren auf die Lehrzeiten von Sauen

Auf einem Betrieb mit 390 Sauen wurden während einer Periode von 5 Jahren Daten gesammelt und der Einfluß verschiedener Faktoren auf die Länge der Lehrzeiten (WOI) untersucht. Sie wurde signifikant ($p<0{,}001$) beeinflußt von Anzahl der Würfe, Rasse, Saison, Haltungssystem, Anzahl der entwöhnten Ferkel, Lebendmasse(LM)-Verlust während der Säuge periode, der Interaktion zwischen Anzahl der Würfe und Haltungs-system sowie der Interaktion zwischen Anzahl der Würfe und LM-Verlust während der Säuge-periode ($p<0{,}05$). Ein LM-Verlust während der Laktation von >7,5% bei Erstlingssauen und von >12,5% bei Sauen nach dem 2. Wurf verlängerte die WOI signifikant ($p<0{,}05$). Gruppenhaltung während der Trächtigkeit in einer großen, dauernd wechselnden Gruppe, verlängerte ebenfalls die WOI von Sauen mit erstem oder zweitem Wurf ($p<0{,}01$). Unabhängig von der Anzahl der Würfe oder vom LM-Verlust während der Säugeperiode wurde die WOI verlängert, wenn beim Entwöhnen die Anzahl der Ferkel größer als 8 war ($p<0{,}05$). Unabhängig von der Anzahl der Würfe, dem LM-Verlust während der Säugeperiode war ein Einfluß der Saison auf die WOI vorhanden: bei Sauen, deren Würfe von Juli bis September abgesetzt wurden, war die Wahrscheinlichkeit für ein längere WOI oder auf eine Behandlung mit brunstinduzierenden Hormonen größer ($p<0{,}05$). Die WOI war auch abhängig vom

Genotyp der Sau. Die Applikation von brunstinduzierenden Hormonen verschleierte die Einfluß von anderen die WOI-verlängerenden Faktoren; in 12,3% der Fälle wurden diese Hormone verwendet.

Schlüsselworte: Rasse; Hormone; Haltungssystem; Wurfzahl; Reproduktion; Saison; Sau.

ACKNOWLEDGEMENTS

The authors wish to thank R.H.J. Scholten and G.P. Binnendijk for their kind assistance and T. van der Lende for his careful reading and critical comments on the manuscript.

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CHAPTER 5

EFFECT OF SPLIT-WEANING IN FIRST AND SECOND PARITY SOWS ON SOW AND PIGLET PERFORMANCE.

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Published in:
Livestock Production Science: accepted for publication.

EFFECT OF SPLIT-WEANING IN FIRST AND SECOND PARITY SOWS ON SOW AND PIGLET PERFORMANCE

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ABSTRACT

The effect of split-weaning (SW) on: weaning to oestrus interval (WOI), sow reproductive performance, piglet growth and body weight and backfat development, was studied in 319 first and second parity sows. In sows of the control group (C) piglets were weaned at about 4 weeks of age. In the SW sows the heaviest piglets were weaned at about 3 weeks, leaving 6 piglets with the sow to be weaned at 4 weeks of age. SW and parity affected the WOI; the WOI was reduced in SW sows and in second parity sows. Body weight loss and reduction in backfat may explain the effects on WOI as found. Second parity SW sows showed a higher farrowing rate compared with second parity C and first parity sows. No effect of SW on the size of the next litter was found. The growth of piglets during the fourth week of lactation was higher in piglets of the SW sows. Piglet growth during a six week rearing period was worse in SW piglets weaned at three weeks. However, when reared up to the same age, the growth of these piglets was comparable with that of piglets weaned at four weeks. SW in first and second parity sows should be considered in current sow farming to improve sow production.

Key words: sows, split-weaning, weaning to oestrus interval, performance traits.

INTRODUCTION

The average weaning to oestrus interval (WOI) in current sow farming is close to 7 days. In 1990, in the Netherlands the average WOI was 7.3 days among users of the CBK® program (Siva-produkten b.a., Wageningen, the Netherlands) and in the United States and Canada it was 7.7 days among users of the Pig CHAMP® program (Marsh et al., 1992). First and second parity sows are more susceptible to a prolonged WOI compared with higher parity sows (van der Heyde et al., 1974; Hurtgen and Leman, 1980; Karlberg, 1981; Fahmy, 1981; Clark and Leman, 1986; Leman, 1990; Xue et al, 1991; Vesseur et al, 1994[b]), but in current sow farming this effect is (partially) masked by the use of oestrus inducing hormones (Vesseur et al., 1994[b]). Reduction of the length of the WOI in primiparous and second parity sows seems relevant because the use of oestrus inducing hormones is undesired and because sows with a WOI between 6 and 12 days show a depressed production compared with sows with a WOI of 4 or 5 days (Leman, 1990; Vesseur et al, 1994[a]; Dewey et al., 1994; Dewey et al., 1996; Tubbs and Dyer, 1996).

Both suckling frequency and suckling intensity are important factors in relation to the length of the WOI (Cox and Britt, 1982; Matte et al., 1992). Suckling frequency decreases with age of piglets and can be manipulated by removing the piglets during part of each day: "interrupted suckling", "restricted suckling" or "partial weaning" (Matte et al, 1992). Suckling intensity is depending on both the number of piglets with the sow and the weight of these piglets. Suckling intensity can be manipulated by permanent removal of part of the litter during a certain period before complete weaning: "split-weaning" (SW), "fractionated weaning" (Matte et al., 1992) or "partial weaning" (English et al., 1987). Matte et al. (1992) reviewed data on split-weaning and concluded that optimal treatment effect in reduction of the WOI, is to be expected when the litter size is reduced to three piglets for a preweaning period of 4.7 days. According to Matte et al. (1992) this conclusion was based on a limited number of experiments with a wide diversity among the studies. Matte et al. (1992) also concluded that the effect of split-weaning on future reproductive performance is not well documented and remains to be investigated.

In the data reviewed by Matte et al. (1992), no effect of split-weaning on the growth of piglets remaining with the sow was found in case split-weaning was applied for short periods of time (7 days) at the end of a lactation period of 28-35 days. Some authors reported an increased weight gain of the lightest piglets, remaining with the sow, compared with corresponding piglets in an intact litter, but all differences in average live weight of intact or split-weaned litters had disappeared two weeks after final weaning (Matte et al., 1992).

The objective of this study was to determine the effect of a method of split-weaning of sows on WOI and subsequent reproductive performance (farrowing rate and litter size) as well as on body weight and backfat loss during lactation. The effect of SW on piglet performance, both during lactation and during a six week rearing period, was also determined to evaluate the method.

MATERIALS AND METHODS

Experimental animals and design

On an experimental farm, 170 first parity and 149 second parity Yorkshire x Dutch landrace crossbred sows, weaned between March 31, 1994 and May 26, 1995, were allotted to this experiment. During gestation sows were housed in stalls. Within two days after farrowing the litter size was equalized to 11 piglets, with a minimum of 10 and a maximum of 12 piglets. Piglets were not moved between sows during the rest of the lactation period. After transfer to the farrowing house, first and second parity sows were randomly allotted to either of two treatment groups: split-weaning (SW) and control (C). From the C sows all piglets (C4) were weaned on day 28 ± 3 after farrowing. From the SW sows, part of the piglets (SW3) was weaned at day 21 ± 3, one week before final weaning, in order to reduce the litter to six piglets. The SW3 piglets were the heaviest piglets within a litter. The six piglets (SW4) remaining with the SW sows for another week were weaned at day 28 ± 3. At the day of weaning and during the next day sows were allowed to have fence contact with a boar and they were let outside during 3-4 h. Check for oestrus signs was performed twice daily by farm staff. Sows were inseminated by farm staff during the first day of standing heat. A second insemination was performed 24 h later when the sow still showed standing heat. Yorkshire sire line semen from a commercial AI-centre (3×10^9 spermatozoa per 80 ml dose) was used for inseminations. Weight and backfat thickness of sows was measured within 48 h after farrowing and at the day of weaning. Backfat thickness was the mean of three measuring points on the back, 5 cm out of the median. Starting 15 days after weaning, oestrus inducing hormones (PG600®; Intervet, Boxmeer, the Netherlands) were used for those sows not seen in oestrus yet.

After weaning piglets were moved to rooms with 12 rearing pens for 10 piglets each. Piglets weaned in the same week (C4, SW3 and SW4) were housed in the same room. The length of the rearing period after weaning was, for all piglets, six weeks. The weight of the piglets was measured at birth, at three and four weeks of age and at the end of the six week rearing period. Clinical disease data of the individual piglets treated against diseases like arthritis, pneumonia and diarrhoea, were recorded.

Housing and diets

During the lactation period sows received twice daily a commercial sow diet (per kg: 12.93 MJ ME and 156 g crude protein); starting about one week before farrowing with 3.5 kg per day. On the day of farrowing 1 kg of this diet per day was fed, this amount of feed was increased after farrowing with 0.5 kg per day up to day 10 to 12 until sows were fed to appetite (up to about 7 kg per day). After weaning and during gestation sows received a second commercial sow diet (per kg: 12.55 MJ ME and 138 g crude protein). Directly after weaning sows received 3.5 kg of this diet per day and after insemination 2.4 kg. During gestation, the feed allowance was increased in three steps from 2.4 to 3.5 kg per day. Feed intake was recorded per sow.

During the lactation period no creep feed was provided to the piglets. After weaning, during a six week rearing period, piglets were fed a commercial prestarter diet (per kg: 13.8 MJ ME and 164 g crude protein) during the first four weeks after weaning, followed by a commercial starter diet (per kg: 13.3 MJ ME and 175 g crude protein) during the last two weeks.

Statistical methods

Linear regression models containing the factors treatment (SW and C), parity (1 and 2) and their interaction as explaining variables, were fitted to the data of the following dependent variables: log transformed WOI, litter size, piglets born alive, litter weight gain during the fourth week of lactation, piglet weight at birth, piglet weight at three weeks of age, piglet weight at four weeks of age and piglet weight gain during the fourth week of lactation (model 1). Data on WOI were log transformed to make them normally distributed. In the results the means of the non-log transformed WOI are presented.

Model: $y = \mu + x_1 + x_2 + x_1.x_2 + e$ (1)

y = dependent variable

μ = overall mean

x_1 = treatment (SW, C)

x_2 = parity (1,2)

$x_1.x_2$ = interaction between x_1 and x_2

e = error

Data on weight of the sow, backfat of the sow, percentage reduction in bodyweight, percentage reduction in backfat, feed intake during lactation and litter weight gain, were analysed with model 1 and the sow as experimental unit, after addition of the length of the lactation period as covariable. Data on growth performance of the piglets were analysed with model 1, after addition of week of weaning and proportion of castrates as covariables. To analyse the binary farrowing data and the fraction of sows showing oestrus spontaneously, linear logistic regression models were fitted with the same explanatory factors as in model 1. To analyse the relationship between WOI and the factors treatment and parity, the WOI was divided into 6 classes; $\leq$ 3, 4, 5, 6, 7 and 8-16 days, and the proportional odds model after McCullagh (McCullagh, 1980; McCullagh and Nelder, 1989) was used.

Linear regression models containing the factor treatment at weaning (SW3, SW4 and C4) were fitted to the data of the dependent variables: piglet weight at weaning, piglet weight at the end of the rearing period and feed intake during rearing.
Clinical disease data and piglet mortality were tested between the three groups of piglets after weaning (SW3, SW4 and C4) using the χ^2-test.
Statistical analyses were conducted using GENSTAT 5 (Genstat 5 Committee, 1993).

RESULTS

Of the 319 sows allotted to this experiment 10 first parity and 6 second parity sows were culled directly after weaning. This culling was because of locomotion disorders (9), respiratory disorders (3), aggressive towards the piglets (2) and prolapsus ani (2). The data of these sows were excluded. Of the 303 remaining sows, 297 sows showed oestrus after weaning and were inseminated and 6 sows stayed anestric. Piglet performance after weaning was analysed on 213 SW3 piglets housed in 22 pens, 283 SW4 piglets housed in 29 pens and 493 C4 piglets housed in 50 pens.

PERFORMANCE OF SPLIT-WEANED SOWS

Treatment effects during the lactation period

The length of the lactation period was 27.8 days (sd: 1.3 days). In the first parity SW sows, 4.2 piglets were weaned after three weeks of lactation and 6.0 piglets after four weeks. In the first parity C sows 10.3 piglets were weaned after four weeks. In the second parity SW sows 4.4 piglets were weaned after three weeks and 6.0 after four weeks. In the second parity C sows 10.5 piglets were weaned after four weeks. Weight loss during lactation, as percentage of the weight of the sow after farrowing, was 13.1 and 15.0% for the SW and C first parity sows, and 11.0 and 14.5% for the SW and C second parity sows, respectively (Table 1). Both treatment and parity influenced the weight loss during lactation ($P<0.05$ and $P<0.01$ respectively).

Reduction in backfat during lactation as percentage of the backfat thickness after farrowing, was 28.3% for both SW and C first parity sows, and 22.4 and 34.6% for the SW and C second parity sows, respectively (Table 1). Treatment affected the reduction in backfat, but there was an interaction with parity ($P<0.05$). In the first parity sows no effect of SW on reduction in backfat thickness was found.

Feed intake during lactation was not different between treatment groups, but a tendency towards a higher feed intake in the SW sows was found ($P<0.10$; Table 1). Feed intake during lactation did show a parity effect: it was 13.0 kg higher in second parity sows as compared with first parity sows ($P<0.0001$).

Weight gain of the litter during the fourth week of lactation, as measure for sow production during lactation, showed both a treatment and a parity effect ($P<0.0001$ and $P<0.05$ respectively). It was 3.3 kg less in SW sows compared with C sows (Table 1). The parity effect was smaller; it was 1.1 kg higher in second parity sows compared with first parity sows. The total litter weight gain during lactation in this

Table 1. **Effect of treatment (split-weaning and control) and parity (1 or 2) on sow body weight (BW) and backfat (BF) changes and litter weight gain (LWG).**

parity	parity 1		parity 2		LSD
treatment	split-weaned	control	split-weaned	control	
n sows	78	82	71	72	
BW after farrowing (kg)	177^{x}	180^{x}	203^{y}	204^{y}	5
BW-loss d. lactation (%)	13.1^{a}	15.0^{b}	11.0^{c}	14.5^{ab}	1.4
BF after farrowing (mm)	16.9	16.8	16.4	16.5	0.6
BF-loss d. lactation (%)	28.3^{a}	28.3^{a}	22.4^{b}	34.6^{c}	3.6
feed/sow d. lactation (kg)	109.4^{a}	112.1^{a}	123.5^{b}	122.4^{b}	3.6
n piglets weaned at 3 weeks	4.2	0	4.4	0	
n piglets weaned at 4 weeks	6.0	10.3	6.0	10.5	
LWG week 4(kg)	10.9^{x}	13.7^{y}	11.4^{x}	15.3^{z}	0.7

Data in a row with different superscript differ significantly (a,b,c,d, $P<0.05$; x,y,z, $P<0.001$)

trial was: 52.5 kg in first parity SW sows , 55.1 in first parity C sows, 58.3 in second parity SW sows and 64.7 kg in second parity C sows, respectively (treatment and parity effect both: P<0.0001).

Effect of treatment on weaning to oestrus interval (WOI)

The percentage of sows showing oestrus spontaneously within a fortnight after weaning was 77.6% (mean) and not different between treatment groups. More second parity sows (87.4%) than first parity sows (68.8%, P<0.05) showed an oestrus spontaneously (WOI<15 days). Of the 68 sows treated with hormones (WOI≥15 days), 75% showed oestrus within 5 days after treatment, without differences between SW and C sows or between parities (Table 2).

Table 2. **Weaning to oestrus interval (WOI) in sows treated with oestrus inducing hormones and anestric sows per parity and treatment group**

parity	parity 1		parity 2		LSD
treatment	split-weaned	control	split-weaned	control	
n (sows weaned)	78	82	71	72	
anestric sows (after horm.)	1	3	1	1	
oestrus after hormones)[1]	25^{a}	21^{a}	8^{b}	8^{b}	
spontaneous oestrus)[1]	52^{a}	58^{a}	62^{b}	63^{b}	
WOI, mean:					
- all sows showing oestrus	10.7^{a}	9.7^{a}	6.4^{b}	7.3^{b}	1.6
- only spontaneous oestrus	5.6^{a}	5.9^{a}	4.6^{b}	5.4^{a}	0.5
distribution of sows after WOI:	pq	p	q	p	
≤3 days	1	0	2	0	
4 days	16	10	23	9	
5 days	20	22	30	38	
6 days	4	16	4	10	
7 days	5	4	3	2	
8-16 days	6	6	0	4	

Data with different superscript within a row differ significantly (a,b, P<0.05);

Distributions with different character differ significantly (p,q, P<0.01)

)[1] tested as fraction of n.

In Table 2 the average weaning to oestrus interval (WOI) for all sows and for sows showing spontaneous oestrus, are presented. In the data of all sows no significant effect of treatment on WOI was found, but there was an effect of parity. Parity 2 sows had a 3.3 day shorter WOI, compared with parity 1 sows ($P<0.001$). Within the group of sows that showed spontaneous oestrus after weaning, both parity and treatment showed an effect on the WOI. SW sows had a shorter WOI compared with the C sows (5.1 and 5.6 days, respectively, $P<0.01$) and second parity sows had a shorter WOI compared with first parity sows (5.0 and 5.8 days, respectively, $P<0.01$). The treatment effect in the first parity sows seems less pronounced, but there was no significant interaction between treatment and parity. The distribution of sows that showed a spontaneous oestrus (WOI$\leq$15 days), after WOI, was depending on treatment ($P<0.001$), not on parity. The distribution of the SW second parity sows after their WOI was different from that of the C second parity sows ($P<0.01$). The distribution of the SW first parity sows after WOI tended to be different from the control group ($P < 0.10$). More SW sows with a WOI of $\leq$4 days were found and less with a WOI of 6 and 5 days, compared with C sows (Table 2).

Effect of treatment on subsequent farrowing rate and litter size

The farrowing rate out of first insemination after weaning showed an interaction between treatment and parity ($P<0.05$). Second parity SW sows had a higher farrowing rate from first insemination compared with second parity C sows ($P<0.05$,

Table 3. **Farrowing rate and litter size of the next litter per parity and treatment of split- weaned and control sows.**

parity	parity 1		parity 2		LSD
treatment	split-weaned	control	split-weaned	control	
n inseminated	77	79	70	71	
farrowing rate	84.1^{a}	87.2^{a}	97.2^{b}	86.3^{a}	
litter size (total)	10.9^{a}	11.5^{ab}	12.6^{c}	12.2^{bc}	0.7
born alive	10.7^{a}	11.0^{ab}	11.6^{bc}	11.8^{c}	0.7

Data with different letters within a row differ significantly (a,b, $P<0.05$)

Table 3). Between first parity SW and C sows no significant differences in farrowing rate were found. SW had no effect on the size of the subsequent litter (total born or born alive, Table 3). The size of the subsequent litter, both total born and born alive, was smaller in first parity sows (11.2 total born; 10.8 born alive) as compared with second parity sows (12.4 total born, P<0.01; 11.7 born alive, P<0.05, Table 3).

PERFORMANCE OF PIGLETS FROM SPLIT-WEANED SOWS

Performance of piglets during lactation

Piglets of second parity sows were 60 gram heavier at birth than piglets of first parity sows (P<0.05, Table 4). Piglets of second parity sows at the age of three weeks were also heavier than three week old piglets of first parity sows (6.1 and 5.7 kg respectively, P<0.001). At three weeks (21.1 days, sd: 2.0) the heaviest piglets were weaned from the SW sows. The weight was lower in first parity sows than in second parity sows (6.5 and 6.9 kg respectively, P<0.01, Table 4). Weaning of the heaviest piglets at the end of the third week in SW sows resulted also in a difference in weight of the remaining piglets between SW sows and C sows (0.4 kg in first parity sows and 0.8 kg in second parity sows) and even in an interaction between treatment and parity (P<0.05). The weight of piglets at the end of the fourth week still showed an interaction between treatment and parity (P<0.05). The smaller piglets in litters of SW sows grew faster during the fourth week of lactation compared with piglets of C sows (1.9 kg and 1.4 kg respectively, P<0.001, Table 4). The increase in body weight of piglets during the last week of lactation also showed a parity effect (P<0.05): piglets in litters of second parity sows grew during this fourth week faster (0.2 kg, P<0.05) compared with piglets in litters of first parity sows.

Piglet mortality was not different between SW and C sows or between parities. During the fourth week of lactation no piglet mortality was found.

Performance of piglets after weaning

C4 piglets were weaned at 28.2 days (sd: 1.8), SW3 piglets were weaned at 21.1 days (sd: 2.0) and SW4 piglets were weaned at 28.1 days (sd: 1.8). The weight at

Table 4. **Effect of treatment (SW:split-weaning; C: control) and parity on piglet weights and piglet growth during lactation (SW3: split-weaned piglets weaned after 3 weeks; SW4: split-weaned piglets weaned after 4 weeks; C4: piglets from the control group weaned after 4 weeks).**

parity	parity 1		parity 2		LSD
treatment	SW	C	SW	C	
n litters	78	82	71	72	
weight at birth of live born piglets (kg)	1.47^{a}	1.47^{a}	1.52^{b}	1.54^{b}	0.05
litter size (at start of the trial)	11.1	11.4	11.4	11.4	
SW3; weight at weaning (kg)	6.5^{p}	-	6.9^{q}	-	0.3
SW4 and C4; weight at 3 weeks (kg)	5.2^{a}	5.6^{b}	5.4^{ab}	6.2^{c}	0.2
SW4 and C4; weight at weaning (kg)	7.0^{a}	6.9^{a}	7.3^{b}	7.7^{c}	0.2
piglet weight gain during week 4 (kg)	1.8^{a}	1.3^{b}	1.9^{a}	1.5^{c}	0.1

Data in a row with different superscript differ significantly (a,b,c, $P<0.05$; p,q, $P<0.01$).

Table 5 : **Piglet performance during a 6 week rearing period**

treatment	split-weaned		control	LSD
age at weaning	3 weeks	4 weeks	4 weeks	
n piglets	213	283	493	
weight at weaning (kg)	6.7^{p}	7.2^{q}	7.5^{q}	0.4
age at end of rearing (days)	63	70	70	
weight at end of rearing (kg)	21.9^{p}	23.6^{q}	24.0^{q}	1.0
piglet growth (gr/day)	361^{p}	386^{pq}	401^{q}	25
feed intake (kg/day)	0.55^{a}	0.59^{ab}	0.61^{b}	0.04
feed conversion ratio	1.52	1.52	1.51	0.06
piglet mortality (%)	4.7	2.1	3.7	
piglets treated for disorders (%)	19.7^{x}	7.8^{y}	14.2^{z}	

Data in a row with different superscript differ significantly (a,b,c, $P<0.05$; p,q, $P<0.01$; x,y,z, $P<0.001$).

the start of the rearing period was lower in the SW3 piglets compared with the SW4 and C4 piglets; 6.7 versus 7.2 and 7.5 kg respectively (P<0.01). At the end of the six week rearing period, the SW3 piglets were still lighter than the SW4 and C4 piglets: 21.9 (sd: 3.9) versus 23.6 (sd: 4.1) and 24.0 (sd: 4.3) kg, respectively (P<0.01). Piglet growth, feed intake and feed conversion were lower in the SW3 piglets compared with the C4 piglets (P<0.01, P<0.05 and P<0.05, respectively), whereas the SW4 piglets showed intermediate results. The C4 piglets can be divided in heavy (C4h) and light (C4l) piglets in the same way as done for the SW piglets. Results of comparable weight groups of SW and C piglets can be compared this way. In Figure 1 the weights of SW3, SW4, C4h and C4l piglets, at the different weighing moments, are presented. At 10 weeks the weight of the C4h and C4l piglets was 25.4 (sd 3.8) and 23.0 (sd: 4.2) kg, respectively. The growth of piglets between 3 and 10 weeks of age for the SW4, C4l and C4h piglets was 369 (sd: 72), 357 (sd: 72) and 388 (sd: 68) gram per day, respectively. The with the C4h comparable SW3 piglets grew, between 3 and 9 weeks, 361 (sd: 75) gram per day.

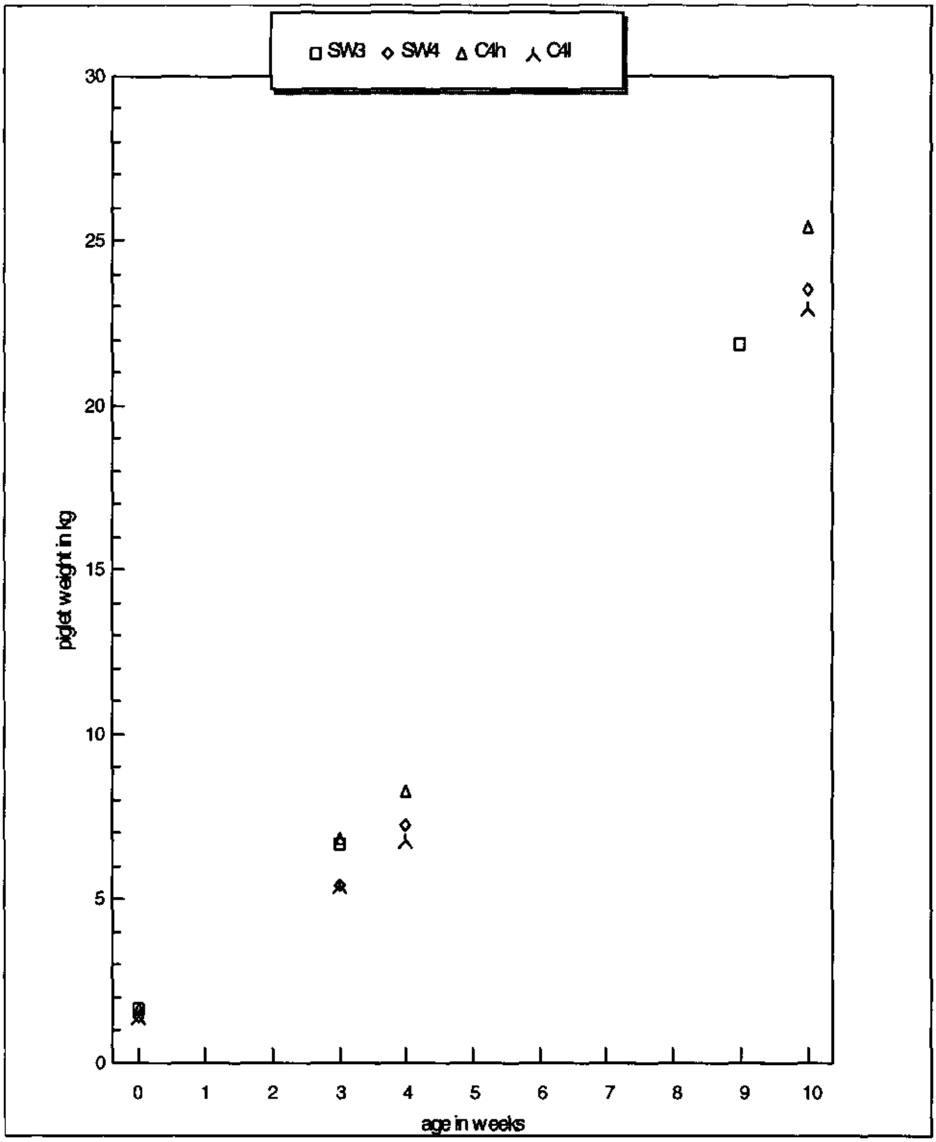
Piglet mortality was not different between the three groups of piglets. The percentage piglets treated for clinical health problems was higher in the SW3 piglets than in the SW4 piglets (19.7 and 7.8 % respectively, P<0.001; Table 5). The percentage C4 piglets treated for health problems (14.2%) was lower than in SW3 piglets, but higher than in SW4 piglets (P<0.001).

DISCUSSION

Effect of split-weaning on sow performance

In this study, SW did not result in substantial effects on the WOI; it was 0.5 day shorter WOI in SW sows that came into oestrus spontaneously as compared with C sows. The distribution of sows after WOI was different between SW and C sows and did not show a significant parity effect. The more pronounced effect on WOI in SW second parity sows can be explained with the more pronounced effect on body weight and backfat loss in these second parity sows as compared with first parity

Figure 1. **Weight development of the piglets: SW3, split-weaned at three weeks of age; SW4, split-weaned at four weeks of age; C4h, heavy piglets weaned at four weeks from the control sows; C4l, light piglets weaned at four weeks from the control sows.**



sows. In the discussion whether the mechanism of SW on reduction of the WOI is body condition related or refers to a neural component such as the suckling stimulus (Cox et al., 1983), this experiment points towards a body condition related effect. Various authors have also related a prolonged WOI, increased anoestrus, lower farrowing rates and a smaller litter size to increased sow weight and backfat loss (Reese et al., 1984; Aherne and Kirkwood, 1985; Vesseur et al., 1994[b]). In this research, however, no significant effect of SW on size of the subsequent litter was found, but an interaction between parity and treatment on farrowing rate was found. In the second parity sows the farrowing rate of the SW sows was higher than that of the C sows. The improved farrowing rate of the second parity SW sows can be explained with the improved body condition, but also with the increase in number of sows with a WOI of 4 days and the decrease in number of sows with an interval of 6 days (Vesseur et al., 1996). This research showed that SW, leaving the six smallest piglets with the sow, can result in less weight loss and less backfat loss during lactation in sows fed to appetite. The effect was more pronounced in second parity sows than it was in first parity sows. The greater difference in weight and backfat loss between SW and C in second parity sows, as compared with first parity sows, can not be explained by a greater difference in litter weight gain during the last week of lactation. Litter weight gain during the last week of lactation was higher in the C sows than in the SW sows, due to the higher number of piglets nursed by the C sows. There was also a higher litter weight gain during the last week of lactation in second parity sows than in first parity sows. The difference in litter weight gain during the last week of lactation between SW and C sows, however, was in both parities 3.3 kg. Feed intake was higher in second parity sows which is in agreement with literature (Britt, 1986). In this trial, a tendency towards a higher feed intake in the SW sows was found. The limited feed intake in first parity sows compared with second parity sows and the small difference between parities in litter weight gain during the last week of lactation, in combination with the higher body reserves in second parity sows seem to be responsible for the more pronounced effect of SW on percentage body weight loss and percentage backfat loss in second parity sows as compared with first parity sows.

Effect of split-weaning on piglet performance

During the last week of the lactation period, the smaller piglets left in the litters of the SW sows grew faster than the piglets in the litters of the C sows. At final weaning, the difference between the weight of piglets of SW sows and piglets of C sows, as was present at week three (0.4 kg), had disappeared in the first parity sows. In the second parity sows the difference present at the start of the fourth week (0.8 kg) was reduced with 0.4 kg at the end of the fourth week. Besides the treatment effect, a parity effect was found regarding the weight of the piglets at birth, three weeks and at four weeks of age; piglets of second parity sows were heavier. During lactation there were no differences found in piglet mortality or number of piglets with clinical disorders.

During the six week rearing period after weaning the SW3 piglets seemed to perform worse than the SW4 and C4 piglets, but these piglets were a week younger at the end of the rearing period. When the average growth of the SW3 piglets during the rearing period (361 g) is calculated for an extra week (which is an underestimation), these piglets are with a weight of 24.4 kg at the age of ten weeks comparable with the C4 piglets (24.0 kg). It can not be concluded from the data whether the SW3 piglets grew, compared with the heavy C4 piglets (C4h), faster during the rearing period or not. The weight of the SW4 piglets at the age of ten weeks was 23.6 kg. The performance in growth, feed intake and feed conversion during the six week rearing period of the, at three weeks of lactation smaller SW4 piglets, was not different from the C4 piglets. The light C4 piglets (C4l) showed the lowest figures for weight at 4 and at 10 weeks of age and for growth between 3 and 10 weeks, but these figures were not significantly different from those of the SW4 piglets. The practice of SW shows no adverse effects on the growth of the piglets, which is in agreement with the results found by Matte and Close (1987) in an experiment in which SW took place in the fifth week of lactation. Piglet mortality did not differ between the three groups of piglets. SW3 piglets were more often treated for clinical disorders compared with C4 piglets, but the SW4 piglets were treated less often for clinical disorders compared with C4 piglets. The percentage piglets treated for clinical disorders was not different between all SW piglets and the C piglets. It can be questioned whether there is a relationship between piglet growth performance and incidence of clinical health problems. It can not be excluded that early weaning is predisposing piglets to have more clinical health problems and that the smaller litter during the last week of lactation is predisposing for less clinical health problems.

CONCLUSIONS

In this trial, split-weaning of first and second parity sows did show effects on sow production. Split-weaning resulted in a reduction of body weight loss and backfat loss. These effects were more pronounced in second parity sows as compared with first parity sows. The weaning to oestrus interval was reduced with 0.5 day and the farrowing rate of split-weaned second parity sows was higher compared with that of control and first parity sows. No effect of split-weaning on size of the next litter was found. It can be concluded that split-weaning is beneficial for reproductive performance of first and second parity sows, although in first parity sows effects on farrowing rate or litter size were absent.

Split-weaning seems beneficial for the growth of the smaller piglets within a litter, but at the age of ten weeks no clear advantage of split weaning on piglet performance was detected.

ACKNOWLEDGEMENTS

The authors wish to thank the farm staff of the research farm Sterksel, G.P. Binnendijk of the Research Institute for Pig Husbandry, Rosmalen and P.F.G. Vereijken of the Agricultural Mathematics group, Wageningen, for their assistance.

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CHAPTER 6

EFFECTS OF INSEMINATION AT FIRST OR SECOND OESTRUS AFTER WEANING IN FIRST PARITY SOWS ON SOW PERFORMANCE

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EFFECT OF INSEMINATION AT FIRST OR SECOND OESTRUS AFTER WEANING IN FIRST PARITY SOWS ON SOW PERFORMANCE.

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ABSTRACT

In total, 56 first litter sows were inseminated at first (F) and 44 at second (S) oestrus after weaning. The weaning to service interval was 6.0 and 27.2 days, respectively. The size of the second litter was 1.3 piglet higher in S than in F (12.3 and 11.0 total born, and 11.8 and 10.6 live born piglets, respectively). Farrowing rate was 15% higher in S than in F (86% and 71%, respectively). The size of the third litter was, although not significant, 0.9 piglet higher in S than in F (11.4 and 10.5 total born, and 10.6 and 10.3 live born piglets, respectively). Differences between F and S in body weight and backfat thickness up to day 21 after weaning were not found. However, the change in body weight between weaning and 21 days after weaning differed between S and F (S: +2.8 kg and F: -2.8 kg). The change in backfat thickness between weaning and 21 days after first weaning showed a decrease in both treatments and differed between treatments (F: -1.1 mm and S: - 0.4 mm). A small percentage of sows did not show a second oestrus spontaneously (6.3%; n=3) and caused extra non-productive days. However, delay of breeding in primiparous sows until second oestrus after weaning, improves sow reproductive performance in such a way, that it is worth to consider the method for use in current sow husbandry.

Key words: sows, weaning to service interval, metabolic state, reproduction.

INTRODUCTION

An observational study by Vesseur et al. (1994[a]) showed that sows with a weaning to oestrus interval (WOI) of 19 days or more subsequently produced a 1.8 piglet larger litter (both total born and live born) compared with sows that had a WOI of 5 days. Compared with sows with a WOI of 9-12 days the litter size of sows with a WOI of 19 days or more was even 2.4 (total born) to 2.5 (live born) piglets larger (Vesseur et al., 1994[a]). Delay of breeding to second oestrus after weaning may be beneficial for sow reproductive performance. Love (1979) compared mating results of first parity sows bred before day 12 after weaning (bred at first oestrus) with those deliberately bred for the first time after day 12 after weaning (sows with a prolonged WOI and sows bred at second oestrus). It resulted in a weaning to service interval of 5.6 and 28.3 days, respectively, and 1.0 live born and 1.3 total born piglets more in the "delayed" sows (Love, 1979); the farrowing rate was not different (87.8% and 91.2%, respectively). Morrow et al. (1989) and Clowes et al. (1994) found an increase in litter size (total born) of, respectively, 3.3 and 2.4 (first and second parity sows) piglets when bred at second oestrus after weaning and Morrow et al. (1989) found an increase in farrowing rate of 12.4%. Clowes et al. (1994) found the effect of skipping an oestrus on litter size most pronounced in first parity sows, less in second parity sows and absent in parity 3-8 sows. It is not investigated whether there were long-term effects on sow reproductive performance, e.g. farrowing rate and litter size of the second litter after treatment.

The present experiment was designed to investigate the effect of breeding of primiparous sows during second oestrus after weaning, compared with breeding during first oestrus after weaning, on size of the second and third litter, on farrowing rates, on body weight and backfat thickness and on changes in body weight and backfat thickness.

MATERIALS AND METHODS

Animals and experimental design

On an experimental farm 119 primiparous Yorkshire x Dutch landrace sows, weaned between September 1994 and June 1996, were randomly allotted to one of the two experimental groups; breeding at first oestrus after weaning (F) and breeding at second oestrus after weaning (S). After weaning, sows were housed in stalls. To stimulate oestrus, sows of both experimental groups were brought outside for several hours per day on the first two days after weaning together with higher parity sows and, at the same time, offered a possibility for fence contact with a boar. Sows were checked, at 8.00 h and 14.00 h, for oestrus signs; at 14.00 h with a teaser boar in their presence. About two and a half week after their first oestrus, sows of S were mixed with the newly weaned sows and treated equally. Sows of F were inseminated during their first oestrus after weaning and sows of S during their second oestrus after weaning. Sows of S and F, not in heat within 14 days after weaning, and sows of S, not in heat within 26 days after the first oestrus, were treated with oestrus inducing hormones (PG600®, Intervet, Boxmeer, the Netherlands). Results of these sows were not used in the analysis.

Artificial insemination (AI) was performed with pooled semen of Yorkshire sire line boars. Semen doses were produced at a commercial AI-centre ($3x10^9$ spermatozoa per 80 ml dose). Sows were inseminated on the first day of standing heat of the first (F) or second (S) oestrus. Inseminations took place in the afternoon. A second insemination was performed 24 h after the first, when sows were still showing standing heat for the man. Oestrus detection and insemination strategy in the second parity sows was similar to that of primiparous sows, but they were all bred at first oestrus post weaning.

Body weight and backfat thickness were measured within 2 days after farrowing, on the day of weaning and, in primiparous sows, also on day 21 after weaning. Backfat thickness was measured similar to the method described by Verstegen et al. (1979).

Sow diets

From one week before farrowing until weaning, sows were fed a lactation diet (13.55 MJ ME and 156 g crude protein per kg). Sows during lactation were fed to appetite. After weaning until one week before farrowing, a gestation diet (12.17 MJ ME and 127 g crude protein per kg) was provided. All sows received 3.5 kg/sow/day of the gestation diet from weaning until first oestrus. The feeding scheme increased during gestation in three steps from 2.2 to 3.4 kg/sow/day. Sows in S received 3.0 kg/sow/day of the gestation diet between first and second oestrus. The actual feed intake during and after lactation was recorded.

Statistical methods

Linear regression models were fitted to the data on litter size, weaning to first oestrus interval (WOI), weaning to first service interval (WSI), body weight and backfat thickness (at farrowing, at weaning, and at day 21 after weaning) and changes in body weight and backfat thickness (from farrowing to weaning, from farrowing to day 21 after weaning and from weaning to day 21 after weaning). To the binary farrowing data linear logistic regression models were fitted.

The following model was used: $Y = \mu + T + e$.

Y : value of dependent variable

μ : overall mean

T : treatment (inseminated at first spontaneous oestrus, inseminated at second spontaneous oestrus)

e : random error of each observation

The effect of treatment was analysed in one direction, the hypothesis being: litter size increases when breeding during second oestrus after weaning. The statistical analyses were conducted using GENSTAT 5 (Genstat 5 Committee, 1993).

RESULTS

First parity sows

First parity sows were allotted just after farrowing to either F: breeding at first oestrus after weaning, or S: breeding at second oestrus after weaning (F: 65 and S: 54 sows; Table 1). Of these sows, 16 did not show their first oestrus after weaning within a fortnight and were treated with PG600® (9 in F and 7 in S). In 12 sows this treatment was followed by an oestrus. The weaning to first service interval (WSI) of these 12 sows was 19.1 days, the farrowing rate 67% and the litter size (n=8) 13.1 piglets total born and 12.0 piglets born alive.

Table 1. **Numbers of sows per treatment group**

Treatment, breeding planned at:	first oestrus	second oestrus
Sows allotted to the experiment	65	54
Sows not showing first oestrus spontaneously	9	7
Parity 1 sows bred at first spontaneous oestrus (F)	56	-
Sows not in oestrus within 26 days after first oestrus	-	3
Parity 1 sows bred at second spontaneous oestrus (S)	-	44
Parity 2 sows bred at first spontaneous oestrus	28	28

The remaining number of sows was 56 in F and 47 in S. Three sows in S did not show a spontaneous second oestrus within 26 days after the first. These sows were treated with PG600® and excluded from analysis. Two of these sows showed oestrus within 4 days after this treatment, were inseminated but returned to oestrus. One sow did not respond to the treatment with PG600®, but returned to oestrus 42 days after the second oestrus and was successfully inseminated.

The average duration of the first lactation period was 31 days (sd: 2.3). The average number of piglets weaned after the first lactation was 9.9 and not significantly different between treatment groups. The weaning to oestrus interval (WOI) was 6.1 days. The weaning to service interval (WSI) differed 21.4 days between F and S (F: 6.0 and S: 27.4, P<0.0001), which is corresponding with the imposed treatment of skipping the first oestrus in S, to breed during the second.

Table 2. **Performance of sows in the control group (F): bred at first spontaneous oestrus (n=56) and in the treatment group (S): bred at second spontaneous oestrus (n=44) and standard error (se).**

	F	(se)	S	(se)	LSD
First litter after weaning (before treatment)					
Weaning to oestrus interval (days)	6.0	(2.1)	6.2	(2.2)	0.9
Weaning to insemination interval (days)[1]	6.0 [p]	(2.1)	27.4 [q]	(2.3)	0.9
Second litter (first litter after treatment)					
Second litters (n)	40		38		
Farrowing rate from first insemination (%)	71 [a]		86 [b]		
Litter size (n total born)	11.0 [a]	(3.0)	12.3 [b]	(3.0)	1.2
Live born piglets (n)	10.6 [a]	(2.9)	11.8 [b]	(2.9)	1.2
Weaning to oestrus interval (days)	5.4	(3.2)	6.0	(3.1)	1.4
Third litter (second litter after treatment)					
Third litters (n)	22		24		
Farrowing rate (%)	79		86		
Litter size (n total born)	10.5	(3.8)	11.4	(3.8)	2.3
Live born piglets (n)	10.3	(3.6)	10.6	(3.6)	2.1

Data in a row with different letters differ significantly (a, b, P<0.05; p,q, P<0.001)
[1], the induced treatment.

Data regarding sow body weight, body weight changes, backfat thickness and changes in backfat thickness are presented in Table 3. Sow body weight after first farrowing (170 kg), at first weaning (150 kg) and 21 days after first weaning (149 kg) as well as the body weight loss during lactation as percentage of the body weight after farrowing (12.3%) and the body weight loss between farrowing and first service (F: 12.2% and S: 10.6%, ns), were not different between F and S (see Table 3). The body weight 21 days after weaning was not different from the body weight at weaning, both in F and in S. The change in body weight from weaning to 21 days after weaning, however, was different between F and S (F: -2.8 kg and S: +2.8 kg, P<0.01).

Table 3. **Body weight, backfat thickness, body weight loss, loss in backfat thickness and feed intake of sows of the control group (F): bred at first spontaneous oestrus (n=56), and of the treatment group (S): bred at second spontaneous oestrus (n=44) and standard error (se).**

	F	(se)	S	(se)	LSD
parity 1 (before treatment)					
body weight after farrowing (kg)	172	(13)	169	(13)	5.2
body weight at weaning (kg)	151	(15)	148	(16)	6.0
weight 21 days after weaning (kg)	148	(16)	150	(15)	6.1
weight loss during lactation %	12.2	(6.0)	12.4	(6.2)	2.4
weight loss farrowing-service %	12.2	(6.0)	10.6	(6.3)	2.5
backfat after farrowing (mm)	17.1	(2.6)	16.5	(2.6)	1.0
backfat at weaning (mm)	12.9	(2.6)	12.1	(2.6)	1.0
backfat 21d after weaning (mm)	11.8	(2.5)	11.7	(2.4)	1.0
backfat loss during lactation (%)	24.3	(10.3)	26.4	(10.2)	4.0
backfat loss farrowing-service (%)	24.3[a]	(10.4)	28.6[b]	(10.2)	4.1
average daily feed intake d. lactation (kg)	4.6	(0.6)	4.8	(0.6)	0.3
parity 2 (after treatment)					
body weight after farrowing (kg)	195	(14)	200	(14)	8.2
body weight at weaning (kg)	172	(13)	177	(14)	8.1
weight loss during lactation (%)	11.6	(3.9)	12.1	(4.1)	2.3
backfat after farrowing (mm)	16.9	(2.6)	16.6	(2.5)	1.5
backfat at weaning (mm)	12.2	(2.4)	12.5	(2.4)	1.4
backfat loss during lactation (%)	27.6	(7.1)	25.4	(7.0)	4.1
average daily feed intake d. lactation (kg)	5.3	(0.4)	5.3	(0.4)	0.2

Data within a row with different letters differ significantly (a,b, P<0.05)

Backfat thickness after first farrowing (16.8 mm), at first weaning (F: 12.5 mm) and 21 days after first weaning (11.8 mm) and the loss in backfat thickness during lactation, as percentage of the backfat thickness after farrowing (25.3%), were not different between F and S (see Table 3). Backfat thickness at moment of first insemination (measured at weaning in F and at 21 days after weaning in S) was less in S than in F (F: 12.9 mm and S: 11.7 mm, $P<0.05$). Loss in backfat thickness between farrowing and first insemination as percentage of the backfat thickness after farrowing, tended to be higher in S compared with F (F: 24.3% and S: 28.6%, $P=0.06$). A difference between backfat thickness at weaning and backfat thickness at 21 days after weaning was found in F (12.9 and 11.8 mm, respectively, $P<0.05$) and not in S (12.1 and 11.7 mm, respectively, ns). The change in backfat thickness between weaning and 21 days after weaning was different between F and S (F: -1.1 mm and S: -0.4 mm, $P<0.001$). The reduction in backfat thickness after weaning was less in S.

Second parity sows

The analyses were performed with 56 sows in F and 44 in S (Table 1). The duration of the second lactation period was on average 30 days (sd: 2.3). Breeding of first parity sows during second oestrus after weaning resulted in a 15% higher farrowing rate compared with breeding during first oestrus after weaning (F: 71% and S: 86%, $P<0.05$; Table 2) and in an improvement of the litter size with 1.3 piglets total born (F: 11.0 piglets and S: 12.3 piglets, $P< 0.05$). The improvement in number of live born piglets, when breeding during second oestrus after weaning, was 1.2 (F: 10.6 piglets and S: 11.8 piglets, $P< 0.05$). The body weight of the live born piglets was higher in F than in S (1.65 kg, sd: 0.22 and 1.56 kg, sd: 0.21, respectively; $P<0.05$).

Third parity sows

The analyses were performed with 28 sows in F and 28 sows S (Table 1). The difference between F and S of 7% in farrowing rate of inseminations after weaning of the second litter was not significant (F: 79% and S: 86%, Table 2). The difference between F and S in size of the second litter after treatment, the third litter of the sow, of 0.9 piglets total born and the 0.3 piglets born alive, was not significant (total born: F: 10.5 and S: 11.4 piglets, P= 0.22 and live born: F: 10.3 and S: 10.6 piglets, P<0.38; Table 2).

DISCUSSION

First parity sows

After weaning, 13% of the first parity sows did not show oestrus spontaneously within 14 days. Compared with results found by Vesseur et al. (1994[a]) this percentage is low. A second spontaneous oestrus after a first spontaneous oestrus was not found in 6.3% of the sows. The extra days caused by this an- or suboestrus may form a matter of concern, when considering the method of delaying breeding until second oestrus after weaning in primiparous sows for practical use.

The difference between F and S in changes in body weight and backfat thickness after weaning, may be explained from the difference between F and S in feeding after weaning; sows in S were fed 0.8 kg per day more during the 21 days between first and second oestrus. The loss in backfat thickness between weaning and 21 days after weaning, which was found in F (-1.1 mm) and was not significant in S (-0.4 mm), does not seem to correspond with the expected positive energy balance of these sows after weaning. Fat deposition may be expected in these non-lactating sows and this does not seem to correspond with a reduction in backfat thickness. However, the fatty tissue may have become more hydropic during lactation and may become less hydropic after weaning and, therefor, less thick, while the total fat content may even increase. Rozeboom et al. (1996) also found a reduction in backfat thickness between weaning and rebreeding, although only in second and third and not in first parity sows.

Second parity sows

In this experiment, breeding first parity sows during second oestrus after weaning (S) compared with breeding them during first oestrus after weaning (F), resulted in a larger size of the second litter; 1.3 piglets total born and 1.2 piglets born alive more. This effect was comparable with the results found by Love (1979), but less than found in experiments in which first breeding was also postponed by skipping the first oestrus to use the second for breeding (Morrow et al., 1989; Clowes et al., 1994). Looking at the results of sows with a WOI of 19 days or more and comparing them with those of sows with a WOI of 4 or 5 days (Vesseur et al., 1994[a]; Dewey et al., 1994: Dewey et al., 1996; Tubbs and Dyer, 1996), the increase in litter size was somewhat more than found in this experiment. Experiments, in which a progestagen was used to delay the first oestrus after weaning, also show an increase in litter size (Johnston et al., 1992; Forgerit et al., 1995). In these experiments the increase in litter size was about 0.1 piglet per extra day of delay. In this experiment of skipping the first oestrus, the effect on litter size seems somewhat smaller than may be expected as based on the results of other research.

Skipping the first oestrus in first parity sows, to breed during the second oestrus, improved the farrowing rate with 15%, from 71 to 86%. An effect on farrowing rate, comparable with the present results, was found by Morrow et al. (1989), but not by Love (1979) and Clowes et al. (1994). The combination of effects of skipping the first oestrus, improvement of both litter size and farrowing rate, showed an increase of 2.8 piglets total born (F: 7.8 and S: 10.6) per performed first insemination and of 2.7 piglets born alive (F: 7.5 and S:10.2) per performed first insemination. The improved piglet production makes the method of interest for current sow husbandry.

The enhanced litter size when breeding during second oestrus after weaning, may be caused by an increased ovulation rate or an increased embryo survival (Dyck, 1974). An increase of both ovulation rate and embryo survival may be caused by effects of the metabolic state during the early development of follicles: "follicular imprinting" (Foxcroft et al., 1996). In F, the early follicular development took place during lactation, which is a catabolic situation for the sow, whereas in S it was after weaning, which is a more anabolic situation.

Third parity sows

Litter size and farrowing rate in the second litter after treatment seemed better in S, but differences between F and S were not significant. In this trial the number of sows per treatment group that produced a third litter was too small to find a difference of less than one piglet to be significant. Further research into the long-term effect of the method of breeding during second oestrus is therefore recommended.

CONCLUSIONS

Breeding first parity sows during second oestrus after weaning, compared with breeding during first oestrus after weaning, resulted in a 1.3 piglet enhanced total litter size and in a 1.2 increased number of live born piglets. Together with the with 15% enhanced farrowing rate from first insemination in sows bred during second oestrus and a possible long-term effect in the third litter, the method seems of interest for use in current pig husbandry. The 6.3% sows that did not show a second oestrus after weaning spontaneously, however, is limiting the advantage of breeding during second oestrus after weaning in first parity sows.

ACKNOWLEDGEMENTS

The authors wish to thank the staff of the research farm Raalte, G.P. Binnendijk of the Research Institute for Pig Husbandry, Rosmalen and P.F.G. Vereijken of the Agricultural Mathematics Group, Wageningen for their assistance.

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CHAPTER 7

GENERAL DISCUSSION

GENERAL DISCUSSION

INTRODUCTION

The research for this thesis was started after finding indications that variation in weaning to oestrus interval (WOI), although not a problem in terms of extra days, has serious consequences for sow production in terms of litter size and farrowing rate. A first observational study showed the consequences of variation in WOI for subsequent sow reproductive performance (Chapter 2) and a second observational study revealed causes of variation in WOI (Chapter 4). Three experimental studies (Chapter 3, 5 and 6) were focussed on the explanation of WOI-related differences in sow reproductive performance and on possibilities to influence the WOI or weaning to service interval (WSI), subsequent reproductive performance or both.

Based on the length of the WOI after a lactation period of three to five weeks, as is found in the majority of second and, certainly, third and higher parity sows (Chapter 1), it is proposed that the normal length of the WOI in individual sows is four or five days. In current pig husbandry the mean length of the WOI is rather close to this normal length (Chapter 1) and in terms of non-productive or extra days the length of the WOI does not seem to be a problem. The length of the WOI, however, appeared to be associated with differences in sow production (litter size and farrowing rate; Chapter 2 and 3). The variation in WOI as found in current pig husbandry is therefore still of importance.

Based on the results of Chapter 2 three interesting categories of sows can be distinguished: sows with a WOI of 4 to 6 days, sows with a WOI of 9-12 days and sows with a WOI of 19 days or more.

★ *Sows with a WOI of 4 to 6 days.*

Second and higher parity sows with a WOI of 4 days had a 5.8% higher farrowing rate (FR) compared with similar parity sows with a WOI of 5 days (Chapter 2). First parity sows with a WOI of 6 days had a 11.7% lower FR compared with first parity sows with a WOI of 5 days (Chapter 2). The number of live born piglets in sows with a WOI of 6 days was 0.3 less than in sows with a WOI of 5 days (Chapter 2). In Chapter 3, the FR of sows with a WOI of 4 days was 6.3% higher than of sows with a WOI of 5 days and sows with a WOI of 6 days had a 7.5% (ns) lower FR compared with sows with a WOI of 5 days. In current sow husbandry over 85% of the sows show a WOI of 4, 5 or 6 days (Chapter 1). These rather small differences in WOI between these sows are associated with differences in reproductive performance.

★ *Sows with a WOI of 9-12 days.*

Sows with a WOI of 9-12 days had 0.8 piglets less compared with sows with a WOI of 5 days and a 20% lower FR (Chapter 2). The percentage of sows with a WOI of 9-12 days, however, is small; about 2%.

★ *Sows with a WOI of 19 days or more.*

These sows showed to have a litter size of 1.8 piglet above that of sows with a WOI of 5 days and are therefore of interest. The percentage of sows allowed to have a WOI of 19 days or more, with a spontaneous oestrus, is small in current sow husbandry, since most anestrous sows are treated within about 14 days after weaning.

Variation in the length of the WOI is also associated with variation in the percentage of sows treated with oestrus inducing hormones (Chapter 4) and culling rates of sows due to reproductive problems are high: failure to conceive and anoestrus cause 25.2 to 31.0 % of the total annual culling (Dagorn and Aumaitre, 1979; Dijkhuizen et al., 1989). These effects also contribute to the motivation to pay extra attention to the WOI.

In this chapter, the hormonal regulation of the WOI, the regulatory processes that cause variation in WOI and possible mechanisms explaining the consequences of variation in WOI, in terms of sow reproductive performance, are addressed. Focussing on the three categories as described, possibilities to improve sow reproductive performance, based on the results of the research for this thesis, are discussed.

HORMONAL REGULATION OF THE WOI

During lactation, at least during the first four to six weeks of lactation, sows generally remain anestrous (Burger, 1952; Stevenson et al., 1981; Cox and Britt, 1982; Britt et al., 1985; Britt, 1986; Matte 1992). During lactation a limited release of gonadotrophin releasing hormone (GnRH) is responsible for the suppression of the release of luteinising hormone (LH) from the anterior pituitary (adeno-hypofyse). A resulting low mean LH level and a low LH pulse frequency (Stevenson et al., 1981) is preventing the occurrence of lactational oestrus. The LH release during lactation, although low, may influence the follicular development, or the shift from small sized to medium and large sized follicles, during lactation (Britt et al., 1985). Follicular development during lactation is resulting in a population of antral follicles which is maintained in a state of readiness, capable to respond to changes in the secretion of gonadotropins: LH and follicle stimulating hormone (FSH) (Britt et al., 1985). The GnRH release during lactation is not suppressed by the, during lactation elevated, levels of prolactin or oxytocin, but seems te be mediated through suckling induced neuro-endocrine reflexes acting at central nervous system (CNS) level (Varley and Foxcroft, 1990). According to Foxcroft (1992) this GnRH - LH inhibitory mechanism is, at least partly, opioid dependent. Sow condition or metabolic state may sort an indirect effect on CNS level, mediated through key metabolic signals on the hypothalamo-pituitary-ovarian axis (Foxcroft, 1992).

The LH and FSH secretion after weaning is responsible for the recruitment and maturation of follicles, from antral to preovulatory follicles (Hunter, 1980). The increase in plasma LH after weaning, mean level and pulse frequency, is important for the start of the oestrus cycle (Cox and Britt, 1982; Shaw and Foxcroft, 1985; Tokach et al., 1992; van de Wiel and Booman, 1993; Kemp et al., 1995[b]).

The LH pattern as found around weaning in sows with a WOI of 4 to 5 days, is shown in Figure 1 (stylized after Shaw and Foxcroft, 1985). In Figure 2 and 3 the patterns of LH before and after weaning, for sows with a WOI of respectively 6 and >11 days are presented (stylized after Shaw and Foxcroft; 1985). A high mean level, high pulse frequency and low pulse amplitude of LH, starting directly after weaning, results in a short WOI (Shaw and Foxcroft, 1985; Kraeling and Barb, 1990). The number of high amplitude LH surges during a 12 h period in the third and fourth week of lactation is negatively correlated with the length of the WOI (Shaw and

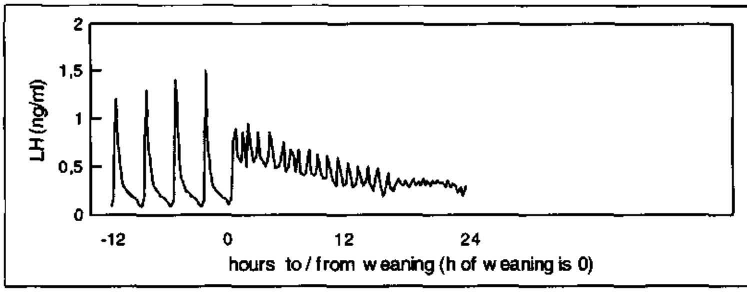

Figure 1. **LH pattern, before and after weaning, in sows with a normal weaning to oestrus interval of 4 or 5 days; stylized after Shaw and Foxcroft (1985).**

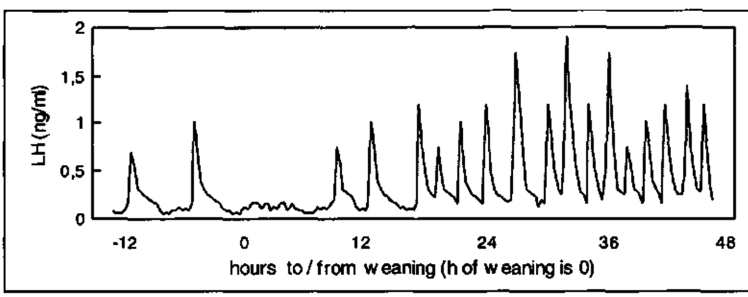

Figure 2. **LH pattern, before and after weaning, in sows with a weaning to oestrus interval of 6 days; stylized after Shaw and Foxcroft (1985).**

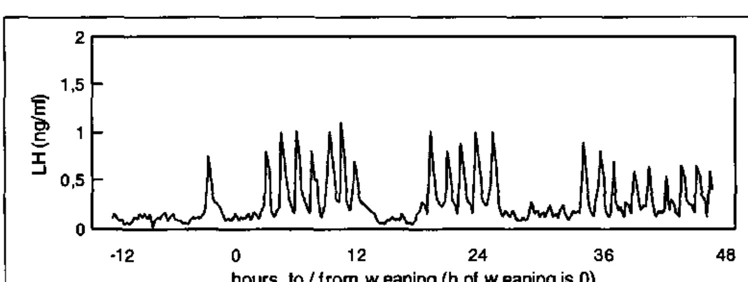

Figure 3. **LH pattern, before and after weaning, in sows with a weaning to oestrus interval of >11 days; stylized after Shaw and Foxcroft (1985).**

Foxcroft, 1985; Tokach, 1992; Kemp et al., 1995[a]). Factors responsible for variation in WOI may sort their effect through effects on LH release, thus affecting follicular development, but direct effects of these factors on the ovary were not excluded by Britt et al. (1985), Cosgrove et al. (1992) and Foxcroft and Cosgrove (1996).

CAUSES OF VARIATION IN WOI

Factors of influence on the WOI, related to the suckling of piglets, sow nutrition, season, social environment of the sow and breed or crossing of the sow, are addressed in this section. Several factors known to influence the length of the WOI, are also known to have an effect on LH level, LH pulse frequency and LH pulse amplitude. Those effects are found during lactation, after lactation or both during and after lactation. The effect these factors have on LH may explain for a great part the effect of these factors on the WOI.

Suckling frequency and suckling intensity

Both suckling frequency and suckling intensity have their effect on the length of the WOI (Cox and Britt, 1982; Matte et al., 1992). Suckling frequency is negatively correlated with the age of the piglets (Stevenson, 1981), but can be influenced by the management method: "restricted suckling" or "interrupted suckling"; i.e. the removal of all piglets from the sow during a part of each day (Matte et al., 1992). Suckling intensity is depending on the number of piglets with the sow and the milk intake of these piglets, which is positively correlated with their weight. Suckling intensity can be influenced by "split-weaning"; i.e. the weaning of a part of the litter several days before the rest is weaned (Matte et al., 1992; Chapter 5). Higher LH levels during lactation in sows nursing small litters (2-4 piglets) compared with sows nursing normal litters (7-12 piglets), were found by Kunavongkrit (Britt et al., 1985). Split-weaned sows, compared with non-split-weaned sows, showed an increase in plasma LH: a higher pulse frequency after split-weaning and a further increase after complete weaning (Kunavongkrit et al., 1985, and Gilbertson et al., 1989, in: Matte et al., 1992). According to Varley et al. (1996), manipulation of the stimuli from the piglets to the sow, or the "neural input", seems, from a practical point of view, even more important to enhance fertility after weaning than nutrient manipulations, unless sows become seriously catabolic during lactation. However, this statement was based on results of trials in which food restriction during and after lactation in multiparous sows, did not result in an effect on WOI or LH. Effects of feed restriction on WOI in multiparous sows are generally found to be low (Hughes, 1989). The suckling stimulus may sort (part of) its effect directly, transmitted by the nervous system, on the CNS; modulating gonadotrophin secretion mediated through endogenous opioid peptides (EOP's) like: endorphins, enkephalins and dynorphins (Krealing and Barb, 1990). Effects acting directly at CNS level influencing the GnRH release from the hypothalamus and, consequently, the LH release from the pituitary and thus affecting follicular development and WOI, are also proposed by Varley and Foxcroft (1990). Manipulation of suckling frequency or suckling intensity may also have an effect on milk production and thus on sow condition or metabolic state, sorting an indirect effect at CNS level by key metabolic signals acting at different levels on the hypothalamo-pituitary-ovarian axis (Foxcroft, 1992).

In the observational study into factors affecting the WOI (Chapter 4), an effect of litter size, corrected for the effect of weight change of the sow during lactation, on the length of the WOI was found, but the effect was rather small. The split-weaning experiment described in this thesis (chapter 5) showed an effect on the length of the WOI. Also effects on body condition parameters, that may explain the effect, were found. Direct effects of the suckling stimulus on the WOI seem to be rather small (Chapter 4 and 5).

Factors related to sow nutrition

Fahmy (1981), Reese et al. (1982, 1984), King and Williams (1984[a],[b]), Britt et al. (1985), Kirkwood et al. (1987), Aheme (1985) and Hughes (1989) found effects of nutrition during lactation on the length of the WOI. In poorly fed sows the WOI was prolonged. MacLean (1969) reported a positive effect of feed deprivation during 24 hours after weaning on the WOI, but this was questioned in later research (Allrich et al., 1979; Tribble and Orr, 1982). Brooks and Cole (1972) found a reduction in WOI with an increased feed intake after weaning in first parity sows, but this was not found in higher parity sows (Brooks et al.,1975). Several studies question the effect of postweaning feed intake on length of the WOI (Dyck, 1972, 1974; Fahmy and Dufour, 1976; Tribble and Orr, 1982; King and Williams, 1984[a],[b]). In general it can be stated that nutrition during lactation has a far greater impact on WOI as compared with nutrition after weaning. In during lactation poorly fed sows, lower basic LH levels during lactation (Kirkwood et al., 1987) and lower mean LH concentrations after weaning (Baidoo and Aherne, 1988) were found, as compared with normally fed sows. Mean LH at day 21 of lactation is reduced by restrictions of either protein (King and Martin, 1989; Tokach et al., 1992) or energy intake (Tokach et al., 1992). Cosgrove and Foxcroft (1996) suggest that low feeding levels during lactation might affect development, recruitment and selection of preovulatory follicles as a direct effect by metabolites or metabolic hormones on the ovary.

A prolonged WSI, prolonged by skipping the first oestrus and breeding during the second, resulted in better reproductive performance, which may be explained by the improved metabolic state of the sows (Chapter 6). Split-weaning (Chapter 5) also resulted in enhanced body condition parameters and thus an improved metabolic state. In second parity sows, not in first parity sows, the reproductive performance of the split-weaned sows was improved. Feeding and body condition, or metabolic state, seem to be of great importance for the WOI and reproductive performance of sows. In the research for this thesis, an effect of sow weight loss during lactation on the length of the WOI was found (Chapter 4).

Factors related to season

Season is found to be a cause of variation in WOI (Chapter 4; Fahmy, 1981; Britt et al., 1985). The effect of season on WOI may be caused by an effect on feed intake of sows during the summer period caused by high environmental temperatures. This would explain the rather mild effect of season, and the more pronounced effect of weight loss during lactation, on the WOI as found in Chapter 4. Love et al. (1993) found higher melatonin levels in feed restricted sows maintained under a long photoperiod, but not in ad libitum fed sows. They concluded that other environmental factors interact with photoperiod in the problem of summer-autumn infertility and that nutrition may be the most potent of these factors (Love et al., 1993). Prunier et al. (1996) also concluded that ambient temperature has a stronger implication in summer infertility than long light periods and that an undernutrition derived inhibition of LH explains the seasonal effect on sow fertility. High ambient temperature can cause stress and elevated levels of cortisol. High levels of cortisol can block ovulation, delay the onset of oestrus and cause cystic ovaries (Barb et al., 1982).

Although season has an effect on WOI, this effect can be explained for a great part by effects of season on feed intake and body condition, and thus on the metabolic state of the sow around weaning.

Factors related to the social environment of the sow

Factors related to the social environment of the sow may influence the follicular development, the expression of oestrus or both. Delayed follicular development will delay the start of the oestrous cycle and when follicular development does not start at all these non-cycling sows will remain anestrous. In cycling sows the start of expression of oestrus may be somewhat delayed and even anoestrus, as caused by the absence of detectable oestrous behaviour, may occur. Parity and boar exposure are factors influencing follicular development in the sow (Britt et al., 1985) as well as variation in WOI (Chapter 4; Fahmy, 1981). Housing, as factor that may influence effects of social rank and behaviour, is also of influence on the length of the WOI (Chapter 4). Social rank and behaviour of the sow and boar contact are factors that may, like suckling stimulus, sort (part of) their effect directly on the CNS, modulating gonadotrophin secretion as mediated through EOP's (Kraeling and Barb, 1990), thus affecting follicular development and WOI. Effects at CNS level may also act by influencing the oestrous behaviour of the sow. Both follicular development and oestrous behaviour may be influenced at the same time. Rojkittikhun et al (1992) showed, in a study in primiparous sows with a WOI between 3 and 8 days, a longer interval between rise in oestradiol-17β and onset of oestrus in sows with a longer WOI (Sterning, 1995). Oestradiol-17β is produced in the preovulatory follicles and induces oestrous behaviour (Signoret, 1967). A positive correlation was found between WOI and duration of pro-oestrus, and a negative correlation between WOI and duration of standing oestrus (Rojkittikhun et al., 1992; Weitze et al.. 1994; Sterning, 1995). High social rank of the sow (Pedersen et al., 1993), possibilities for social behaviour and boar contact (Signoret, 1970, Sterning et al., 1994) stimulate the expression of oestrous behaviour. Aggressive interactions and low social rank may suppress oestrous behaviour. The social history of the sow, previous contact with other sows and humans may be of importance (Hemsworth and Barnett, 1990). Postweaning aggression is known to have an adverse effect on sow behaviour during oestrus, without an effect on hormone levels (Pedersen et al.,1993). Boar contact is stimulating sows to express oestrus.

In this thesis, a greater effect on the length of the WOI was found in first and second parity sows sows in a group housing system, as compared with two systems for single housing. In the group housing system, the sows were sequential fed and the first and second parity sows were kept together with higher parity sows. The composition of the group changed weekly. The effect on WOI, found after weaning, was caused during the previous gestation period and is proposed to be an effect of the low social rank of first and second parity sows, compared with higher parity sows (Chapter 4). In other species depressed signs of oestrus or even anoestrus is known to occur in animals low in the social hierarchy (Pedersen et al., 1993).

Factors related to the breed of the sow

Breed and heterosis effects are found to be important factors too, explaining variation in WOI (Chapter 4; Burger, 1952; MacLean, 1969; Legault, 1975; Dyck. 1971, 1972, 1974; Fahmy and Dufour, 1976; Bisperink, 1979; Fahmy et al. 1979; Fahmy, 1981; Ten Napel, 1996).

In the research for this thesis, small differences in WOI between different crossings were found (Chapter 4). In one of the experiments (Chapter 3), differences in the proportion of offspring from each of two inseminations, performed with a 24 h interval on a fixed time of the day, were found. These differences in proportion of offspring may be explained from differences in oestrus expression between breeds.

A difference in oestrus expression may also result in a small difference in WOI between breeds.

Over the years the management on sow farms has been optimized by using the outcomes of research and this explains the reduction in WOI over the years (Chapter 1). The remaining variation in WOI, however is, although small, still of importance because of its consequences for sow reproductive performance.

CONSEQUENCES OF VARIATION IN WOI

In Chapter 2 it was shown that variation in WOI had consequences for subsequent sow production. Both litter size and farrowing rate vary with the length of the WOI. In data from the period before 1980, in which a WOI at farm level of over 13 days was common (Chapter 1; Van der Heyde et al., 1974; Aumaître et al., 1976; Bisperink, 1979; Fahmy et al., 1979) a positive correlation between WOI and litter size was shown by Love (1979). This positive correlation was also found by King et al. (1982). Van der Heyde et al. (1974) showed a decreased farrowing rate in sows with a WOI of 8 days or more as compared with sows with a WOI of 5 days. Leman (1990) found, when analysing into PigCHAMP® data, results comparable with those found in the research for this thesis and in more recent literature effects on litter size, farrowing rate or both as a consequence of variation in WOI, comparable with those found in Chapter 2 of this thesis and by Leman (1990), are described too (Dewey et al, 1994; Dewey et al., 1996; Tubbs and Dyer, 1996; Chapter 3).

The porcine uterus after parturition takes three to four weeks to fully restore to its pre-breeding weight, whereas the epithelium is fully regenerated within 21 days (Palmer et al., 1965 in: Hunter, 1980). Since the lactation periods within the trials for this thesis had a duration of about 28 days, effects of incomplete uterus restoration were considered not to be of influence on the results found in this thesis.

The consequences of variation in WOI, in terms of litter size and farrowing rate, seem to be caused by differences in ovulation rate, fertilization rate and embryo survival rate.

Ovulation rate and embryo survival

Differences in ovulation rate and embryo survival as a consequence of variation in WOI, may mainly be explained by differences in follicular development, influenced by the LH release during lactation or after weaning (Britt et al., 1985), and for a smaller part by direct effects of key metabolic signals on the ovary (Foxcroft, 1992). According to Hughes and Pearce (1989) both ovulation rate and WOI are dependent on follicular development. A suppressed follicular development may result in less developed follicles at the moment of ovulation (Britt et al., 1985), and hence in lower fertilization rates or higher embryo mortality. High feed intake in gilts, up to the time of first mating, maximizes ovulation rate (Aherne and Kirkwood, 1985). A poor luteïnisation of follicles after ovulation may also be the consequence of a suppressed follicular development before ovulation (Kirkwood et al., 1987). A lowered progesteron production as result of this poor luteinization, may increase embryo mortality (Kirkwood et al., 1987). Suppressed follicular development might also result in more atretic follicles and, hence, in a depressed ovulation rate (Hughes and Pearce, 1989). A decrease in ovulation rate may result in a decreased average litter size (Van der Lende and Schoenmakers, 1990). Dewey et al. (1996) counted the number of corpora lutea and the number of live embryo's at day 28 to 33 of gestation at slaughter and concluded that ovulation rate explained part of the decrease in litter size as found in sows with a WOI between 6 and 10 days. Early embryonic death, which was low on day 5 and high on days 6 to 12, may also be involved (Dewey et al., 1996).

The production of offspring may depend on the metabolic state or change in metabolic state of the sow during subsequent periods of the production cycle: lactation period, period between weaning and ovulation (insemination) and first month after ovulation (insemination). The mechanisms by which the metabolic state is influencing fertility after weaning are still unclear (Foxcroft, 1992). Important key metabolic signals influencing the hypothalamo-pituitary-ovarian axis may be insulin, glucose, cortisol, insulin-like growth factor 1 (IGF-1) and growth hormone (Foxcroft, 1992). Exogenous insulin during follicular growth increases ovulation rate (Cox et al., 1987). A correlation between insulin during early lactation and LH during early lactation was found by Tokach et al. (1992) and Helmond et al. (1994). Results found by Koketsu et al. (1996) indicated that energy intake during lactation influences circulating insulin and glucose levels, as well as LH pulse frequency and amplitude during mid lactation and during the postweaning period.

The consequences of a *WOI of 19 days or more* (Chapter 2) and the effect of breeding at second oestrus after weaning (Chapter 6; Clowes, 1994) on litter size may be explained by an improvement of the metabolic state of the sow. Prolongation of the WOI enables the restoration of the metabolic state. Both increased embryo survival and increased ovulation rate may play a role (Dyck, 1974). Slightly prolonged WOI's, however, may still allow negative effects of the metabolic state on sow production, resulting in smaller litters and a lower farrowing rate. In fact, when the WOI is artificially prolonged using a progestagen, it results in an increased litter size (Johnston, 1992; Forgerit et al., 1995). Young growing animals, like first parity sows, seem more prone to a catabolic state and subsequent prolonged WOI. In full-grown adult animals a more catabolic state may lead sooner to a reduced litter size or reduced farrowing rate, whereas the WOI is hardly affected.

Fertilisation rate

Like ovulation rate and embryo survival, fertilization rate may be responsible for the consequences of variation in WOI. Fertilisation rate may be influenced by the insemination moment relative to the ovulation moment. Soede et al. (1995[a]) concluded that an insemination performed too early or too late relative to the ovulation moment as determined using ultrasound, may result in reduced litter size and farrowing rate as based on fertilization rate and the ratio between normal and degenerating embryos. Nissen (1996) who determined litter size and farrowing rate in sows in a similar experimental design, also using ultrasound to determine ovulation moment, came to a similar conclusion. In the experiments by Soede et al. (1995[a]) and Nissen (1996), inseminations performed between 24 to 0 h before ovulation and between 27 h before ovulation and 3 h after ovulation, respectively, did not lead to depressed results. When the insemination moment was earlier before ovulation or later after ovulation, fertilisation was less (Kemp and Soede, 1996;

Nissen, 1996).

The lower farrowing rate with an increasing WOI, in *sows with a WOI of 4 to 6 days*, as found in this thesis (Chapter 2 and 6), may, based on the distribution after offspring from two inseminations with a 24 h interval (Chapter 3), be caused by an earlier ovulation moment relative to the insemination moment. The inseminations were performed at a fixed time on the first day and on the second day of standing heat. Inseminations seem to be performed closer to ovulation and more often too late after ovulation in sows with a slightly prolonged WOI. The smaller litter size as found in sows with a slightly increased WOI (Chapter 2) may also be explained by this poor tuning between insemination moment and ovulation moment. Kemp and Soede (1996) came to the same conclusion. They suggest that, in *sows with a WOI of 3 to 6 days*, poor fertility is not the cause of a smaller litter and a lower farrowing rate with an increasing WOI, but that these effects are caused by a suboptimal insemination time. In sows inseminated between 24 and 0 h before ovulation, no differences in day 5 embryo quality were found between sows with a different WOI. However, sows with a longer WOI ovulate earlier after onset of oestrus (Kemp and Soede, 1996). The results of *sows with a WOI of 9-12 days* may also be partly explained with this poor tuning between insemination and ovulation moment.

Other factors of influence on the distribution of offspring after first and second insemination, 24 h after the first, were breed and parity (Chapter 3). These factors also seem to influence the fertilisation rate by influencing the ovulation moment relative to the insemination moment, which was at a fixed time on the first and second day of standing heat.

Social rank and behaviour, suckling stimulus and boar contact may influence oestrus behaviour and therefor the onset of oestrus after weaning and the onset of standing heat relative to ovulation moment after weaning. Poor timing of insemination(s) relative to the ovulation moment may be the result. This way, a rather small effect on the WOI may have serious consequences for the result of an insemination. The smaller litters in sows with a WOI of 6 days compared with litters of sows with a WOI of 4 or 5 days (Chapter 2) are proposed to be the consequence of a lower fertilisation rate as caused by a poor timing of the insemination moment. Which in turn may be due to a decreased expression of oestrus behaviour. The lower farrowing rate (76.1%) of first parity sows with a WOI of 6 days as found in Chapter 2 may be explained with a poor timing of ovulation relative to insemination as caused by depressed oestrus behaviour. In an extra analysis, a three way interaction between parity, housing system and WOI was found. First parity sows with a WOI of 6 days from the group housing system had a farrowing rate of 62.5%, whereas first parity sows with a WOI of 6 days from two individual housing systems had a farrowing rate of 83.3%.

PRACTICAL IMPLICATIONS OF THE RESULTS OF THIS THESIS

Variation in weaning to oestrus interval (WOI) was associated with differences in litter size and farrowing rate (Chapter 2). The litter size and farrowing rate of *sows with a WOI of 4, 5 and 6 days* decreased with an increasing WOI. *Sows with a WOI of 9-12 days* had the smallest litters and the lowest farrowing rate. With a further increasing WOI, these production traits became better. Sows with a *WOI of 19 days or more* produced more piglets per litter than sows with a shorter WOI.

Sows with a increasing WOI from 4 to 6 days, produced more offspring from the first and less from the second insemination, performed 24 h later (Chapter 3). Sows with a slightly prolonged WOI seem to ovulate sooner after detection of oestrus. This effect may help to explain the decrease in farrowing rate and litter size of sows with a slightly increasing WOI: more of these sows were inseminated too late. Sows with a WOI of 6 days and possibly sows with a WOI of 7 or 8 days, should, therefore, be inseminated as soon as possible after detection of standing oestrus. Other factors that affected the number of offspring from each of the inseminations, were breed and parity. Finnish Landrace and Great Yorkshire sows seem to ovulate sooner than Dutch Landrace sows and higher parity sows (≥ parity 6) sooner than lower parity sows and it therefore seems indicated to inseminate these sows sooner after detection of standing oestrus. About 40% of the litters in this experiment (Chapter 3) had offspring from both inseminations. One of the boars used resulted in less offspring. But since the number of offspring from the other insemination, 24 h sooner or later, was increased, only a small effect on litter size was found. These results support the results of Kemp and Soede (1996) and support the theory that the interval between subsequent inseminations may be as long as 24 h. However, when the quality of the insemination dose is less than the standard 3×10^9 normal motile spermatozoa per dose, or when the fertilization ability of the semen is reduced, a shorter interval between subsequent inseminations may be indicated.

Severe weight loss during lactation and sequential fed large dynamic groups of gestating sows, should be avoided to prevent a prolonged WOI in first and second parity sows (Chapter 4). A high number of piglets during lactation up to weaning, may, independent from the weight loss during lactation, also prolong the WOI.

Split-weaning in first and second parity sows, as method to reduce the WOI and improve the reproductive performance, showed to be effective in second parity sows only. The farrowing rate improved with 11% and the WOI was reduced with 0.8 days in the split-weaned second parity sows as compared with not split-weaned second parity sows (Chapter 5). A 1.3 piglet enhanced litter size was found in primiparous sows when bred during the second oestrus after weaning (Chapter 6). This is close to the enhancement of 1.8 piglets as was found in *sows with a WOI of 19 days or more* when compared with sows with a WOI of 4 or 5 days (Chapter 2). The farrowing rate was also 15% better in the sows bred during their second oestrus after weaning (Chapter 6). Based on the results of Chapter 2, the effect of breeding during second oestrus might be greater in sows with a WOI between 6 and 12 days compared with sows with a WOI of 4 or 5 days. The number of observations of sows with a WOI between 6 and 12 days in the skip-a-heat experiment, however, was too small to draw conclusions. This aspect may be addressed in future research.

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SUMMARY

First parity sows often have a prolonged weaning to oestrus interval (WOI), are treated with oestrus inducing hormones or are not showing oestrus at all. Many young sows are culled because of fertility problems. Of the annual culling of sows, 25 to 30% is because the sow is not showing oestrus or not pregnant. The WOI in current pig husbandry is, with an average of 7 days or less, rather short. The research into causes and consequences of a prolonged WOI was started because of possible consequences of even little variation in WOI for sow reproductive performance. Later research was focussed on mechanisms explaining consequences of a variation in WOI. Finally some possibilities to improve sow reproductive performance were investigated.

The overall objective of this study was to determine the causes of variation in sow production traits as associated with differences in WOI and to develop strategies to improve sow production.

An observational study was conducted to determine the consequences of variation in WOI for sow production (Chapter 2). An increase in *WOI from 4 to 6 days* went with a decrease in litter size (0.4 piglet) and a decrease in farrowing rate (5% in higher parity sows and 9% in first parity sows with an increase from 5 to 6 days). With a further increasing WOI, litter size decreased further. Sows with a *WOI of 9-12 days* produced about 0.8 piglets less in their next litter. The farrowing rate of these sows was also 29% lower than sows with a WOI of 5 days. Sows with a further prolonged WOI produced better. Sows with a *WOI of 13-18 days* produced a number of live born piglets, comparable with that of sows with a WOI of 5 days. Sows with a *WOI of 19 days or more*, clearly produced more piglets in their next litter compared with sows with a shorter WOI; 1.8 piglets more than sows with a WOI of 5 days and 2.5 piglets more than sows with a WOI of 9-12 days.

The outcome of this study was, that variation in WOI is associated with clear differences in sow production traits.

Based on this first observational study, research into the causes of the depressed reproduction results that are associated with a small increase in WOI, was indicated. The question to be answered was, whether there are possibilities to prevent the depressed production associated with a slightly prolonged WOI.

Because of the negative effects on sow production of a further prolongation of the WOI, It was also indicated to investigate how a prolonged WOI can be prevented. Research into the causes of a prolonged WOI in current pig husbandry, therefore, was indicated.

Based on the results of this first study it also was indicated to look for management methods to achieve an increase in litter size as found for sows with a very long WOI.

An experiment was designed with sows in oestrus between 4 and 6 days after weaning to determine the causes of the consequences of little variation in WOI in terms of litter size and farrowing rate (Chapter 3). During oestrus two inseminations were performed on a fixed time during the day (around 14.00 h), with an interval between subsequent inseminations of 24 h. The first insemination was performed on the first day the sow was showing standing heat. Boars of two different breeds were used for subsequent inseminations within one oestrus, to make it possible to classify the offspring after the boar used for first or second insemination. The results showed that sows with a WOI of 4 days had less offspring from first insemination and more from the second. With an increasing WOI more offspring from the first insemination was born and less from the second. In this experiment, litter size itself was not influenced by WOI. The distribution after litter type - completely from first insemination, mixed or completely from second insemination - showed comparable results. Sows with a WOI of 4 days had less litters completely from first insemination, an equal percentage mixed litters and more litters completely from second insemination compared with sows with an WOI of 5 days. An explanation for the differences found is, that sows with a longer WOI ovulate sooner relative to the insemination moment (and relative to the start of the oestrus, when checked as described).

With the results of this experiment the lower farrowing rate and smaller litter size in sows with a somewhat prolonged WOI (6 days) may be explained. Sows with a somewhat longer WOI should, based on these results, be inseminated a little sooner to increase their production.

An effect of genotype of the sow and parity, on the number of offspring from each off the two inseminations, was also found in this experiment. Finnish Landrace and Great Yorkshire sows should be inseminated sooner than Dutch Landrace sows and sows of parity 6 or higher should be inseminated sooner than lower parity sows.

A second observational study was performed to determine the causes of prolongation of the WOI (Chapter 4). This study showed an increase in WOI and use of oestrus inducing hormones (PG600®) in first and second parity sows increased with an increasing body weight loss during the preceding lactation. In third and higher parity sows no effect of increase in body weight loss during lactation on WOI or use of PG600® was found. The housing system in which sows were housed during gestation (from one month after service until one week before farrowing) also showed to be of influence on the WOI and use of PG600®. The WOI of first and second parity sows in the group housing system was longer than that of first and second parity sows in two individual housing systems and the use of PG600® was higher. The effect of body weight loss during lactation and housing system was greater in first than in second parity sows. Other factors showed, independent from parity, a difference in length of the WOI and use of PG600®, but this difference was smaller than the differences found for parity and housing system. These other factors were: breed, number of piglets weaned and season.

Based on the results of the observational studies, the second and third experiment were designed (Chapter 5 and 6). The objective was to influence the WOI and/or subsequent reproductive performance in a positive way. These experiments were performed with young sows, because in these animals the largest effect can be expected. It seems very promising to influence the body weight loss during lactation. The restoration of body weight after weaning by giving extra time between weaning and first insemination, seems a good alternative. Also because the litter of sows with a very long WOI was so much larger.

In the second experiment it was investigated whether the weight loss during lactation of first and second parity sows could be reduced by reduction of the litter size to 6 piglets, during the last week of a four week lactation period (split-weaning; Chapter 5). Both factors weight loss during lactation and litter size at weaning, are of influence on the length of the WOI (Chapter 4) and may be influenced at the same time by the lay out of this experiment. An effect of split-weaning on body weight loss, but also on backfat loss, during lactation was effected in the second parity sows only. In the first parity sows the differences in weight loss and backfat loss during lactation were not significant. A significant effect of split-weaning on WOI was found in second parity sows only, a reduction in WOI of 0.8 day. The distribution of sows after WOI changed by the treatment: more sows with a WOI of 4 days, an equal part with a WOI of 5 days and less sows with a WOI of 6 days or more. Consequences for subsequent reproduction were also only found in second parity sows: the FR in the split-weaned second parity sows increased from 86% to 97%. In first parity sows a more severe reduction in litter size, or a longer period of reduction in litter size, may be necessary to influence the weight loss during lactation and through this the WOI and subsequent production.

A third experiment was designed with the purpose to investigate whether a prolongation of the weaning-to-insemination interval to over 19 days, improves the litter size. By skipping the first oestrus after weaning in first parity sows to breed during the second, the weaning-to-insemination interval was prolonged with 21 days (the length of an oestrous cycle) to 27 days. Compared with breeding during first oestrus, this resulted in a increase in litter size of 1.2 live born piglets (from 10.6 to 11.8 piglets; Chapter 6) and an increase in farrowing rate of 15%. In this experiment, indications were found for a possible long term effect of this treatment. The higher farrowing rate and a larger litter size of the third litter of sows bred at second oestrus after first weaning, however, was not significant.

In the general discussion (Chapter 7) the results found in this thesis are discussed from possible underlying physiological processes.

According to the literature a prolonged WOI is associated with a shorter duration of the oestrus and an ovulation moment earlier after the start of oestrus. It is also described that as long as the interval between insemination and ovulation is between 24 and 0 h, no effect was found on number and quality of the embryo's. A bad synchronisation between insemination moment and ovulation moment, associated with small increase in WOI, may cause a reduced percentage fertilized eggs or no fertilization at all. This, whereas the fertility of the sows is normal. The reduction in litter size and farrowing rate of sows with a slightly increased WOI (from 4 to 6 days) seems to be the consequence.

Variation in farrowing rate and litter size may also be explained as the consequence of the metabolic state of the sow in during the period preceding ovulation. A catabolic state during follicular growth is unfavourable for the quality of follicles and/or eggs and thus for ovulation rate and embryo survival. The smaller litter size and lower farrowing rate of sows with a WOI of 9-12 days, may be explained this way; a very catabolic state of the sow leads to both a prolongation of the WOI and a less favourable follicular development, which already had started in the period the sow was catabolic. The larger litter size and higher farrowing rate in sows with a WOI of 19 days or more and the smaller litter size and lower farrowing rate of sows with a WOI of 9-12 days may also be explained from the metabolic state during follicular development. Follicular development in sows with a very prolonged WOI takes place during the period after weaning and, therefore, under favourable circumstances. This may result in a better follicle and egg quality and this may explain the higher farrowing rate and larger litter.

Season itself was hardly of influence on the WOI, but high ambient temperatures during the summer may reduce the feed intake during lactation and thus the metabolic state may be influenced. So season may, indirectly, have important effects on the WOI and litter size and farrowing rate. The depressed reproductive performance of sows in late summer and autumn, after a hot summer period, may be explained this way.

Group housing (with a large dynamic group of sequential fed sows) was associated with a prolonged WOI in young sows. This effect may be explained by an effect of social rank during gestation on oestrus expression after weaning. Effects of social rank on oestrus expression, depressed display of oestrus or no oestrus at all, are also known in other species. Sows low in social rank and therefore showing their oestrus somewhat later, may subsequently be inseminated too late (sows with a WOI of 6 days). In an extra analysis, the lower farrowing rate found in first parity sows with a WOI of 6 days found in Chapter 2, turned out to be caused for a great part by the first parity sows from the group housing system and for a smaller part by sows from the two individual housing systems.

Main conclusions.

The length of the WOI has a pronounced effect on subsequent farrowing rate and litter size. With an increasing WOI up to 12 days the farrowing rate and litter size are decreasing. With a further increasing WOI, however, litter size is increasing again and sows with a WOI of 19 days or more even produce 1.8 piglets per litter more than sows with a WOI of 4 to 5 days.

The reduction in litter size with a small increase in WOI, a WOI between 4 and 8 days, may be explained by a poor synchronisation of insemination and ovulation moment. This effect on litter size may be prevented by an adjustment of the insemination strategy: inseminating sows that show oestrus later after weaning, sooner during that oestrus.

First and second parity sows showe an increase in WOI when the weight loss during lactation is increasing. Housing gestating sows in large, instable, sequential fed groups, also causes a prolongation of the WOI of first and second parity sows. The number of piglets nursed, breed or crossing of the sow and season are also of influence on the length of the WOI, but the effect of these factors is smaller.

Split-weaning of first and second parity sows to improve both WOI, subsequent litter size and farrowing rate, has been found only beneficial in second parity sows. The second parity sows show a reduction of the WOI and an increase in farrowing rate of 11%. The effect of this treatment is not enough to influence WOI or subse-

quent farrowing rate and litter size of first parity sows.

By skipping the first oestrus after weaning in first parity sows, the litter size can be improved with 1.2 live born piglet and the farrowing rate with 15%. Furthermore, there are indications that the next farrowing rate and the size of the third litter is certainly not worse compared with that of sows in which the first oestrus is not skipped.

SAMENVATTING

Eersteworpszeugen laten nogal eens een verlengd interval spenen-bronst (ISB) zien, geven aanleiding tot het gebruik van bronst-inducerende hormonen of worden zelfs helemaal niet berig. Fertiliteitsproblemen leiden er toe dat teveel jonge zeugen vroegtijdig vervangen worden. Van de totale jaarlijkse afvoer van zeugen wordt 25 tot 30% vanwege "niet berig" of "niet drachtig" afgevoerd. Het ISB in de huidige varkenshouderij is, met een gemiddelde lengte van 7 dagen of minder, kort te noemen. Een aanwijzing dat een geringe toename van het ISB ernstige gevolgen voor de reproductie zou kunnen hebben was de aanleiding tot onderzoek naar oorzaken en gevolgen van variatie in ISB. Vervolgens is onderzoek uitgevoerd met als doel de gevolgen van verschillen in ISB te verklaren. Tenslotte zijn enkele mogelijkheden onderzocht om de reproductie van zeugen te verbeteren.

De algemene doelstelling van dit onderzoek was het bepalen van de oorzaken van variatie in productie-parameters van zeugen, geassocieerd met verschillen in ISB, en het ontwikkelen van methoden om de productie van zeugen te verbeteren.

Om de gevolgen van variatie in het ISB voor de productie van zeugen te bepalen werd een observationele studie uitgevoerd (Hoofdstuk 2). Een toename in *ISB van 4 tot 6 dagen* ging gepaard met een daling van de worpgrootte (0,4 big) en een daling van het partuspercentage (5% voor meerdereworpszeugen en 9% voor eersteworpszeugen met een ISB dat van 5 naar 6 dagen toenam). Met een verder toenemend ISB daalde de worpgrootte verder. Zeugen met een *ISB van 9-12 dagen* produceerden 0,8 levend geboren big minder in hun volgende worp. Ook hadden deze zeugen een partuspercentage dat 29% lager was dan dat van zeugen met een ISB van 5 dagen. Zeugen met een nog langer ISB produceerden weer beter. Zeugen met een *ISB van 13-18 dagen* produceerden een aantal biggen dat vergelijkbaar was met dat van zeugen met een ISB van 5 dagen. Zeugen met een *ISB van 19 dagen of meer* produceerden duidelijk meer biggen in hun volgende worp dan zeugen met een korter ISB; 1,8 big meer dan zeugen met een ISB van 5 dagen en 2,5 big meer dan zeugen met een ISB van 9-12 dagen.

Variatie in ISB is dus geassocieerd met duidelijke verschillen in productieparameters.

Op grond van deze eerste observationele studie was onderzoek geïndiceerd naar de oorzaken van minder goede reproductieresultaten bij een gering verlengd ISB. De vraag was of er mogelijkheden zijn de tegenvallende productie door een geringe toename van het ISB te voorkomen. Daarnaast was het, gezien de zeer nadelige gevolgen voor de productie van een verder verlengd ISB, van belang na te gaan op welke wijze een verlenging van het ISB voorkomen kan worden. Onderzoek naar de oorzaken van een verlengd ISB in de huidige varkenshouderij was daarom nodig. Tenslotte was het op grond van deze eerste studie zinvol na te gaan of de duidelijk grotere worp, zoals gevonden voor zeugen met een zeer lang ISB, door middel van een aangepast management ook kan worden verkregen.

Om de oorzaak van het gevolg van een geringe variatie in ISB voor de toomgrootte en het partuspercentage te achterhalen is een experiment opgezet met zeugen die tussen 4 en 6 dagen na spenen berig werden. Tijdens de oestrus werden twee inseminaties op een vast moment van de dag (rond 14.00 uur), met een interval van 24 uur, uitgevoerd (Hoofdstuk 3). De eerste inseminatie werd uitgevoerd op de dag dat de zeug voor het eerst de stareflex vertoonde. Er werden beren van twee verschillende rassen, op grond waarvan de nakomelingen konden worden onderscheiden, voor de opvolgende inseminaties gebruikt. Uit de resultaten bleek dat er bij zeugen met een ISB van 4 dagen minder nakomelingen van de eerste inseminatie en meer van de tweede geboren werden. Met een toenemend ISB nam het aantal nakomelingen van de eerste inseminatie toe en dat van de tweede inseminatie af. De worpgrootte zelf werd in dit onderzoek niet door het ISB beïnvloed. De verdeling van worpen naar toomtype - volledig van eerste inseminatie, gemengde toom of volledig van tweede inseminatie - liet een soortgelijk beeld zien. Zeugen met een ISB van 4 dagen hadden minder tomen volledig van eerste inseminatie, een gelijk percentage mengtomen en meer tomen volledig van tweede inseminatie dan zeugen met een ISB van 5 dagen. Een verklaring voor de gevonden verschillen is, dat zeugen met een langer ISB vroeger ovuleerden ten opzichte van het inseminatiemoment (en dus ten opzichte van de op deze wijze waargenomen start van de oestrus).

Met de resultaten van dit experiment kan dan ook verklaard worden waarom zeugen met een wat langer ISB (6 dagen) een lager partuspercentage en een kleinere worp kunnen hebben. Zeugen met een gering verlengd ISB moeten op grond van deze resultaten iets eerder worden geïnsemineerd om de productie te verbeteren.

In dit experiment bleken genotype en pariteit overigens ook een effect op het aantal nakomelingen van elk van de twee inseminaties te hebben. Fins Landras- en Groot Yorkshire-zeugen zouden wat eerder geïnsemineerd moeten worden dan Nederlands Landras-zeugen. Zeugen met pariteit 6 of hoger zouden eerder moeten worden geïnsemineerd dan zeugen met een lagere pariteit.

Met als doel de oorzaken van een verlengd ISB te bepalen, werd een tweede observationele studie uitgevoerd (Hoofdstuk 4). Uit deze studie bleek dat het ISB en het gebruik van bronst-inducerende hormonen (PG600®) bij eerste- en tweedeworpszeugen toenam met een toename van het gewichtsverlies tijdens de eraan voorafgaande zoogperiode. Bij derde- en meerdereworpszeugen werd geen significante relatie gevonden tussen de toename van het gewichtsverlies tijdens de zoogperiode en het ISB en het PG600®-gebruik. Het huisvestingssysteem waarin de zeugen gedurende de dracht (vanaf een maand na dekken tot een week voor werpen) werden gehouden, was ook van invloed op het ISB en het PG600®-gebruik. Het ISB van de eerste- en tweedeworpszeugen uit het groepshuisvestingssysteem was langer dan dat van eerste- en tweedeworpszeugen uit twee systemen voor individuele huisvesting. Het PG600®-gebruik was hoger. Het effect van gewichtsverlies tijdens de zoogperiode en van huisvestingssysteem was groter voor de eerste- dan voor de tweedeworpszeugen. Andere factoren lieten, onafhankelijk van pariteit, ook een verschil in ISB en PG600®-gebruik zien, maar dit verschil was geringer dan het verschil dat voor gewichtsverlies tijdens de zoogperiode en huisvestingssysteem gevonden is. De bedoelde factoren waren ras, aantal gespeende biggen en seizoen.

Op grond van de resultaten van de twee observationele studies zijn het tweede en derde experiment opgezet, met als doel het ISB en/of de erop volgende productie gunstig te beïnvloeden (Hoofdstuk 5 en 6). Deze experimenten zijn met jonge zeugen uitgevoerd, omdat daarvan het grootste effect verwacht mocht worden. Het leek verder veelbelovend het gewichtsverlies gedurende de lactatie te beïnvloeden. Herstel van het gewicht na spenen, door het geven van extra tijd tussen spenen en eerste inseminatie, leek een goed alternatief, ook omdat de worp van zeugen met een ISB van 19 dagen of meer zoveel groter was.

In het tweede experiment dat is uitgevoerd, is nagegaan of het gewichtsverlies van eerste- en tweedeworpszeugen tijdens de zoogperiode verminderd kon worden door de toomgrootte, gedurende de laatste week van de vierweekse zoogperiode, terug te brengen naar 6 biggen (split-weaning; Hoofdstuk 5). De factoren gewichtsverlies gedurende de zoogperiode en toomgrootte bij spenen waren beide van invloed op het ISB (hoofdstuk 4) en zouden door deze opzet beide tegelijk beïnvloed kunnen worden. Het bleek dat een vermindering van gewichtsverlies en spekdikteverlies tijdens de zoogperiode, door gedeeltelijk spenen, alleen bij de tweedeworpszeugen werd gerealiseerd. Bij de eersteworpszeugen waren de verschillen in gewichts- en spekdikteverlies tijdens de zoogperiode niet significant. Een significante invloed van gedeeltelijk spenen op het ISB werd ook alleen bij de tweedeworpszeugen gevonden: het ISB werd 0,8 dag korter. De verdeling van zeugen naar ISB veranderde door de proefbehandeling in: meer zeugen met een ISB van 4 dagen, een gelijk aandeel met een ISB van 5 dagen en minder zeugen met een ISB van 6 dagen of meer. Gevolgen voor de productie werden ook alleen bij de tweedeworpszeugen gevonden: het partuspercentage nam door gedeeltelijk spenen toe van 86 tot 97%. Bij eersteworpszeugen moet, om het gewichtsverlies tijdens de zoogperiode, het ISB en de erop volgende productie te beïnvloeden, het aantal biggen mogelijk verder teruggebracht worden of de toomgrootte gedurende een langere tijd verkleind worden.

Het derde experiment is uitgevoerd om na te gaan of een verlenging van het interval spenen - insemineren tot meer dan 19 dagen ook een verbetering van de worpgrootte geeft. Van eersteworpszeugen is, door het overslaan van de eerste bronst na spenen en door te insemineren gedurende de tweede bronst na spenen, het interval spenen-insemineren met 21 dagen (de lengte van een oestruscyclus) toegenomen tot 27 dagen. Dit gaf, in vergelijking met het insemineren tijdens de eerste bronst, een toename van de worpgrootte met 1,2 levend geboren big (Hoofdstuk 6) en een toename van het partuspercentage met 15%. Er zijn ook aanwijzingen gevonden voor een mogelijk langetermijneffect van deze behandeling. De toename van zowel het partuspercentage als de worpgrootte van de derde worp van de zeugen die tijdens de tweede bronst na de eerste keer spenen werden geïnsemineerd, was echter niet significant.

In de algemene discussie (Hoofdstuk 7) zijn de resultaten uit dit proefschrift bediscussieerd aan de hand van mogelijke onderliggende fysiologische processen.

Een langer ISB gaat volgens de literatuur gepaard met een kortere duur van de oestrus en een vroeger ovulatie-moment na de start ervan. Ook is beschreven dat, zolang het interval tussen inseminatie en ovulatie varieert tussen 24 en 0 uur, er geen effect is op de aantallen en de kwaliteit van embryo's. Een slechte synchronisatie tussen inseminatiemoment en ovulatiemoment, geassocieerd met een geringe toename in ISB, heeft mogelijk een verlaagd percentage bevruchte eicellen of helemaal geen bevruchting tot gevolg, terwijl deze zeugen wel normaal vruchtbaar zijn. De afname van het partuspercentage en de worpgrootte van zeugen bij een geringe verlenging van het ISB (van 4 tot 6 dagen), lijkt het gevolg daarvan.

Variatie in partuspercentage en worpgrootte kan mogelijk ook verklaard worden als een gevolg van de metabole status van de zeug gedurende de aan de ovulatie voorafgaande periode. Een katabole situatie gedurende de follikelgroei is ongunstig voor de follikel- en/of eicelkwaliteit en daardoor voor ovulatiegraad en embryonale overleving. De kleinere worpgrootte en het lagere partuspercentage van zeugen met een ISB van 9-12 dagen zou op deze wijze verklaard kunnen worden; een sterk katabole situatie van de zeug heeft zowel een verlenging van het ISB als een minder gunstige follikelontwikkeling, die al tijdens de katabole situatie was begonnen, tot gevolg. De grotere worp en het hogere partuspercentage van zeugen met een ISB van 19 dagen of meer kan mogelijk ook met de metabole status tijdens de follikelgroei verklaard worden. Follikelgroei bij zeugen met een sterk verlengd ISB vindt pas in de periode na spenen plaats, dus onder gunstiger omstandigheden. Dit kan een betere follikel- en eicelkwaliteit tot gevolg hebben en daarmee zou het hogere partuspercentage en de grotere worp verklaard kunnen worden.

Seizoen was op zich nauwelijks van invloed op het ISB. Door hoge temperaturen in de zomerperiode kan de voeropname tijdens de zoogperiode echter beïnvloed worden, en daardoor het gewichtsverlies tijdens de zoogperiode en ook de metabole status. Seizoen kan indirect dus wel belangrijke effecten op het ISB, de toomgrootte en het partuspercentage hebben. Op deze wijze kan de reproduktieproblematiek die, na een warme zomerperiode, in de nazomer en het najaar wordt gezien, verklaard worden.

Groepshuisvesting (met een grote dynamische groep en een vorm van sequentieel voeren) liet een verlenging van het ISB van jonge zeugen zien. Dit effect kan mogelijk verklaard worden door de invloed van de sociale rangorde tijdens de dracht op de bronstexpressie na spenen. Ook bij andere diersoorten zijn effecten van sociale rangorde op de bronstexpressie bekend: het minder goed of zelfs niet tonen van de bronst door ranglage dieren. Zeugen die laag in de sociale rangorde staan en daardoor net iets later berig worden, worden hierdoor mogelijk te laat geïnsemineerd (zeugen met een ISB van 6 dagen). Het lage partuspercentage, zoals gevonden in Hoofdstuk 2 voor eersteworpszeugen met een ISB van 6 dagen, bleek bij een verdergaande analyse in sterkere mate te worden veroorzaakt door zeugen uit het groepshuisvestingssysteem en in mindere mate door zeugen uit twee systemen voor individuele huisvesting.

Belangrijkste conclusies

De lengte van het interval spenen-bronst (ISB) heeft een duidelijk effect op het erop volgende partuspercentage en op de worpgrootte. Met een toename van het ISB tot

12 dagen, nemen het partuspercentage en de worpgrootte af. Bij een verdere toename van het ISB neemt de worpgrootte echter weer toe: zeugen met een ISB van 19 dagen of meer produceren zelfs 1,8 big meer per worp dan zeugen met een ISB van 4 á 5 dagen.

De afname in worpgrootte bij een geringe toename van het ISB (een ISB tussen 4 en 8 dagen) is mogelijk te verklaren door een slechte synchronisatie van inseminatie- en ovulatiemoment. Mogelijk kan dit effect op de worpgrootte voorkomen worden door een aanpassing van de inseminatiestrategie: een zeug die later na spenen berig wordt, kan beter eerder gedurende de berigheid geïnsemineerd worden.

Eerste- en tweedeworpszeugen vertonen met een toename van het gewichtsverlies tijdens de zoogperiode een toename van het ISB. Het huisvesten van dragende zeugen in een grote, niet stabiele, sequentieel gevoerde groep, heeft ook een toename van het ISB van eerste- en tweedeworpszeugen tot gevolg. Het aantal biggen dat gezoogd wordt, ras of kruising van de zeug en seizoen, zijn ook van invloed op de lengte van het ISB, maar het effect van deze factoren is kleiner.

Gedeeltelijk spenen van eerste- en tweedeworpszeugen, als methode om zowel het ISB als het erop volgende partuspercentage en de worpgrootte te verbeteren, is alleen als effectief voor tweedeworpszeugen gevonden. De tweedeworpszeugen laten een afname van het ISB en een toename in partuspercentage van 11% zien. Voor eersteworpszeugen was het effect van deze behandeling onvoldoende om het ISB, de worpgrootte of het partuspercentage te verbeteren.

Door het overslaan van de eerste bronst na spenen van eersteworpszeugen kunnen de worpgrootte met 1,2 levend geboren big en het partuspercentage met 15% verbeterd worden. Daarnaast zijn er aanwijzingen dat het volgende partuspercentage en de grootte van de derde worp in ieder geval niet slechter zijn dan die van zeugen waarvan de eerste bronst niet is overgeslagen.

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DANKWOORD

Allereerst wil ik de begeleidingscommissie, die bestond uit Jos Noordhuizen, Bas Kemp en Leo den Hartog, bedanken voor hun inzet en inbreng. Jos, jou wil ik bedanken voor het aangeven van de grote lijnen in het begin, terwijl je in de laatste fase vooral voor een goede structuur in het geheel gezorgd hebt. Ook de rust die je uitstraalde en het vertrouwen in de voortgang, met zo nu en dan een zeer motiverend woord, heb ik zeer gewaardeerd. Ook wil ik je bedanken voor de ruimte die je Bas hebt gegeven voor de begeleiding van dit onderzoek. Bas, met jou heb ik zeer prettig kunnen samenwerken. Je hebt enorm veel tijd in discussies willen steken en doordat je zelf ook actief met onderzoek betreffende de reproductie van het varken bezig bent, hebben we denk ik een goed team kunnen vormen. Ik heb in ieder geval zeer veel aan jouw inbreng gehad. Leo, je bent een echte optimist en ziet niet zo snel problemen. Als perfectionist had ik weleens moeite met het reeds aanbieden van manuscripten waarover ik nog niet tevreden was. Bovendien had ik, zeker aanvankelijk, het idee dat alles wat ook maar ooit van belang zou kunnen zijn niet onvermeld gelaten mocht worden. Zonder jouw inbreng zou een en ander mogelijk te detaillistisch en onoverzichtelijk geworden zijn. Ik ben je ook zeer erkentelijk voor het feit dat je het uitvoeren van dit promotie-onderzoek naast mijn functie als afdelingshoofd en programmaleider eerder als een extra uitdaging dan als een mogelijk probleem zag.

De totstandkoming van dit proefschrift is, zeker niet in de laatste plaats, mede te danken aan alle personen die enthousiast hebben gereageerd toen ik hiermee wilde beginnen en die enthousiast gebleven zijn terwijl ik ermee bezig was. Met name geldt dit voor Mieke, Esther en Karin. Mieke, jouw vriendschap, gezelligheid, waardering, enthousiasme en de ruimte die je me hebt gegeven, hebben in belangrijke mate bijgedragen aan de totstandkoming van dit proefschrift. Esther en Karin, jullie zijn zulke lieve en zelfstandige meiden, dat het voor mij wel heel eenvoudig was mijn werkzaamheden te plannen of afspraken te maken. Jullie hebben ook altijd erg positief op mijn werk gereageerd. Voor mij was dat heel fijn en op die manier hebben jullie me enorm geholpen.

In de aanvangsfase van dit promotie-onderzoek heeft Tette van der Lende een belangrijke bijdrage geleverd aan het bepalen van de grote lijn van het onderzoek. Helaas heb jij, Tette, vanwege je andere werkzaamheden al vrij vroeg na de start enige afstand moeten nemen. Diverse keren heb je echter toch nog tijd gevonden om opbouwende kritiek te geven, hetgeen ik zeer waardeer. Pieter Vereijken wil ik speciaal bedanken voor de statistische ondersteuning. Pieter, in enkele gevallen hebben we meer gedaan dan uiteindelijk voor het proefschrift nodig was, maar dat heeft in ieder geval bijgedragen aan onze kennis en begrip. Enkele losse eindjes moeten we nog verder uitwerken om ze ten goede te laten komen aan het praktijk-onderzoek. Klaas Frankena heeft vooral in het begin de statistische aanpak mede ondersteund; bedankt Klaas. Alle medewerkers van de proefbedrijven van het Praktijkonderzoek Varkenshouderij te Raalte, Rosmalen en Sterksel, wil ik hierbij bedanken voor hun inzet bij de uitvoering van de proeven. Gisabeth Binnendijk wil ik bedanken voor de samenwerking en de hulp die zij heeft geboden bij de controle en de verwerking van de data. Gisabeth, dank je wel voor je grote inzet.

De Maatschap Onderzoek van de Bond KI en Varkensverbetering Zuid hebben de uitvoering van de "Meishan-proef" mede mogelijk gemaakt. Vooral de inzet van Henk Grooten en Hans Olyslagers wil ik hierbij noemen. Ook het feit dat de Meishan-beren door Euribrid beschikbaar gesteld zijn en dat de Vakgroep Veefokkerij van de LUW zo vanzelfsprekend heeft bijgedragen wil ik hier noemen. Luc Janss en Piet de Groot hebben informatie uit het Meishan-project van de Vakgroep Veefokkerij voor mij uitgezocht en aan mij ter beschikking gesteld. Bovendien heb jij je, Piet, op de LUW ingezet voor het organiseren van enkele uitvoeringsaspecten, waarvoor ik je zeer erkentelijk ben.

Tenslotte wil ik vrienden en familie bedanken voor hun begrip, omdat veel van mijn vrije tijd is besteed aan dit proefschrift en de contacten daardoor wat minder zijn geweest. Ook mijn collega's verbonden aan het Praktijkonderzoek Varkenshouderij wil ik in dit kader bedanken voor hun collegiale opstelling op die momenten waarop ik hogere prioriteit gegeven heb aan de voortgang van het promotie-onderzoek dan aan andere zaken. Een ieder die op enige andere wijze heeft bijgedragen aan de totstandkoming van dit proefschrift wil ik hierbij daar ook voor bedanken.

CURRICULUM VITAE

Peter (Petrus Cristoffel) Vesseur werd op 6 november 1954 geboren te Woubrugge in Zuid-Holland. In 1972 behaalde hij het HBS-B-diploma aan het Bonaventura College te Leiden. Na aanvankelijk te zijn uitgeloot voor de studie diergeneeskunde, kon hij door een relatief gunstige loting datzelfde jaar toch aan de Rijksuniversiteit Utrecht met deze studie beginnen. Tijdens de studie heeft hij onder andere het keuze-co-assistentschap "de Tropencursus" gevolgd. In 1981 heeft hij gedurende zes maanden onderzoek uitgevoerd in het West-Afrikaanse land Gambia, met als doel het productiepotentieel te bepalen van de nationale rundveestapel, die hoofdzakelijk bestond uit het trypanosomen tolerante veeslag de N'dama. In 1982 is hij geslaagd voor het dierenartsexamen.

Hij is daarna, als dierenarts verbonden aan een kuikenbroederij, in de pluimveesector gaan werken. In 1986 is hij naar de varkenssector overgestapt door een functie te aanvaarden bij Varkens Onderzoek Centrum Nieuw Dalland, destijds onderdeel van de Nederlandse Unileverbedrijven BV. In 1989 is hij als dierenarts in de algemene praktijk in en rond Someren gaan werken, verbonden aan het Veterinair Centrum Someren. Vanaf 1991 is hij als hoofd van de Afdeling Reproduktie en Kwaliteit werkzaam voor het Proefstation voor de Varkenshouderij. Binnen deze functie heeft hij zich onder andere beziggehouden met het onderzoek dat heeft geresulteerd in dit proefschrift.