Agricultura 6: 5-12 (2008)

Factors influencing on post-weaning performance of primiparous and multiparous sows: a review

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A review of the factors influencing the post-weaning performance of primiparous and multiparous sows was discussed. Factors examined included the breed, feeding, lactation length, body mass, gilt age at first mating, backfat thickness, season of the year, as well as the hormonal stimulation of estrus in young and primiparous sows. Insufficient feeding during lactation and a decrease in body mass, low backfat thickness at weaning, short/insufficient lactation, inadequate time of mating and a high environment temperature all had negative influences on the time between weaning and first re-mating of primiparous sows. Contradictory views over the ideal age at first mating of gilts and the impacts on their future fertility have been expressed in the literature. The hormonal induction of estrus in primiparous sows by PG600 at various points before weaning, at weaning or after weaning affects the productivity of sows during future parities in complex ways.

Key words: weaning-to-estrus interval, weaning-to-service interval, weaning-to-conception interval, fertility of sows

INTRODUCTION

The weaning-to-conception interval is an unproductive phase that lasts from weaning until first mating, plus any additional days needed to achieve successful conception. If the mating at first estrus results in conception, the length of the period from weaning until first mating is equivalent to the weaning-to-conception interval (Koketsu and Dial 1997). In addition to the age at which a sow has her first litter and the length of subsequent lactations, the weaning-to-conception interval is a factor that can be influenced by management. The only possibility of increasing the number of litters per sow per year thus seems to be through shortening the weaning-to-conception interval in a way that guarantees the maximum number of piglets born alive per sow per year. Post-weaning reproductive performance depends upon numerous factors, such as breed (Aumaitre et al. 1976, Le Cozler et al. 1997, Tantasuparuk et al. 2001), feeding (Ten Napel et al. 1995, Koketsu and Dial 1997, Koketsu and Dial 1998, O'Dowd et al. 1997), lactation length (Xue et al. 1993, Koketsu and Dial 1997, Le Cozler et al. 1997, Marois et al. 2000), the number of subsequent parities (Clark et al. 1986, Koketsu and Dial 1997), the season of the year in which farrowing occurs (Prunier et al. 1996, Koketsu and Dial 1997, Spencer et al. 2003) and the time of insemination (Weitze et al. 1994, Kemp and Soede 1996, Nissen et al. 1997, Vargas et al. 2006). Since the age of gilts when their first litter is born can be directly managed, the inclusion of young sows in a herd has a great influence on productivity, although their live weight and backfat depth are important (Brooks and Cole 1973, Brooks and Smith 1980, Tholen et al. 1996, Le Cozler et al. 1997, O'Dowd et al. 1997, Le Cozler et al. 1998, Sterning et al. 1998, Koketsu 1999, Yazdi et al. 2000, Clowes et al. 2003a, Tummaruk et al. 2007). Induction of estrus can be manipulated by a combination of 400 IU equine chorionic gonadotrophin and 200 IU human chorionic gonadotrophin (PG600), but the timing of administration is especially important.

The present review examines the factors that influence the post-weaning performance such as the length of the weaning-to-estrus, weaning-to-service and weaning-to-conception intervals in primiparous and multiparous sows, and discusses possible mechanisms for reducing these intervals.

INFLUENCE OF ESTRADIOL-17β AND BACKFAT THICKNESS ON ESTRUS

Steroid hormones are formed using cholesterol as a basis in the smooth endoplasmatic reticulum of cells in the sex glands (Withers 1992, Cunningham 1997). They melt in fats and permeate through the cell membrane to bind onto receptors in the cytoplasm (Ferraris and Palumbi 1996). The subcutaneous fat layer in female animals is not simply an energy reserve, because it also plays an important role in the transport of estrogens by the blood (Hühn 1997). These hormones stimulate folliculogenesis, thus improving the fertility and productivity of sows especially with a thicker backfat layer (Hühn 1996).

Estradiol-17β is the principal steroid hormone responsible for the mating reflex in sows (Cunningham 1997). The concentration of estradiol-17β in the follicular fluid depends upon the number of follicles with a diameter greater than 3

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mm (Wähner et al. 1993b). The concentration of estradiol-17β during proestrus and estrus in sows with a backfat of 2.5 cm or thinner averages 131.8 pmol/kg, whilst that in sows with a backfat 2.6 – 3 cm is 175.8 pmol/kg and is 213.1 pmol/kg in animals with a backfat greater than 3 cm. In addition, the highest concentrations of estradiol-17β in the follicular fluid can be found in cases where the backfat layer is greater than 3 cm (Wähner et al. 1993a). Data from blood samples taken during the period of 192 hours after the weaning shows that the estradiol concentration rises sharply and reaches a peak 48-96 hours after weaning (Bracken et al. 2006).

BREED

Landrace (L) and Yorkshire (Y) primiparous sows have a weaning-to-service interval 2.8 days longer than cross-bred L x Y primiparous sows (Tantasuparuk et al. 2001). The effect of weaning-to-conception interval was more pronounced in pure L than LW or crossbreed sows (L x LW). The sows of the L breed have on average 0.5 to 1.5 less piglets per litter and a longer weaning-to-conception interval than sows of LW and crossbreed (Le Cozler et al. 1997). With a 5 day weaning-to-conception interval, L sows have a smaller litter size than Y sows, but, with longer weaning-to-conception intervals, the differences between the breeds becomes more marked (Marois et al. 2000). Sows that returned to estrus later than 30 days after weaning had also lower lifetime production than sows that returned to estrus within 18 days after weaning. Moreover, crossbreed L x Y sows with weaning-to-service interval longer than 6 days had significantly higher risk of being culled than sows with weaning-to-service interval with 0-4 days (Tantasuparuk et al. 2001). In a more recent study Moeller et al. (2004) found that during 15 days long lactation sows Dekalb-Monsanto GPK347 had the shortest weaning-to-estrus interval in spite of weaned the largest litters, ate less feed in lactation and they lost more backfat and weight during lactation.

FEED INTAKE DURING LACTATION

Over the last few decades' selection for genotypes of pigs has increased growth rate and mature size, reduced levels of body fatness and induced greater prolificacy which was accompanied with greater milk production and nutrition demands especially during lactation (for reviews see Whittemore 1996, Eissen et al. 2000).

A higher daily feed intake during lactation reduced the probability of a prolonged weaning-to-estrus interval (Gourdine et al. 2006) and it improves efficiency benefit in both primiparous and multiparous sows (Yang et al. 1989). Sows which consume more than 6 kg of feed per day have the shortest weaning-to-conception intervals and the highest number of weaned piglets in the next litter (Koketsu and Dial 1997). Insufficient feed consumption during lactation can prolong the weaning-to-conception interval (Koketsu 1999). According to the literature, the most probable cause of the effect on the weaning-to-conception interval in primiparous sows is due to their poor physical condition as a consequence of the mobilisation of body tissues reserves during lactation at a period when such animals are themselves still growing (Ten Napel et al. 1995). Moreover, high enough level of body reserves needs to be maintained in the sow avoiding incidence of reproductive problems (Grandinson et al. 2005). Increasing sow feed intake in late gestation prevents reduction of sow backfat prior farrowing and later loss of fatness during the lactation and reproductive cycle (Miller et al. 2000). Energetically rich feeding during lactation increases the survival rate of embryos and results in an increase in litter size during the next parity (Koketsu and Dial 1998). Furthermore, it is suggested that increased feed intake during early and mid-lactation reduces weaning-to-service interval, but increased feed intake during mid-to late lactation increases litter weaning weights (Koketsu et al. 1997). This increase of feed intake is in a relationship with nutrition of sows during gestation. Sows with a high side fat thickness at the end of pregnancy realised a significantly lower feed intake during lactation ($r = -0.206$) and they have higher loss of side fat thickness ($r = -0.499$) than sows with worse body condition (Wähner et al. 2001).

DURATION OF LACTATION

Sows with a lactation of up to 7 days have a longer period from weaning to first mating (i.e. 22.3 days) and a weaning-to-conception interval of up to 25.8 days on average. A lactation of 8 to 22 days duration prolongs the length of the post-weaning interval that can last from 7 to 8 days (Koketsu and Dial 1997). Sows subject to short 13 days lactation have significantly longer weaning-to-estrus interval in comparison to the 31.5 days long lactation (Belstra et al. 2002). The service within the first 3 weeks post-farrowing results in reduced litter size and lower farrowing rate (Gaustad-Aas et al. 2004b). Sows with lactations longer than 21 days, a linear increase in subsequent litter size is observed (Marois et al. 2000). However, a lactation of more than 23 days decreases the post-weaning interval and, from the 29th day of lactation onwards, the weaning-to-conception interval lasts less than 6 days and is simultaneously associated with the largest litter sizes (Koketsu and Dial 1997). Therefore, a longer lactation period leads to a shorter weaning-to-service interval and a larger subsequent litter size (Tummaruk et al. 2000).

A sow with the lactation lasting 29 days or more achieve the shortest weaning-to-conception interval and, during the second lactation, but the interval is optimised after a slightly shorter lactation of 28 days (Le Cozler et al. 1997). On the contrary to this observation, conventionally weaned sows at day 24 of lactation tend to lose more body weight and to have lower IGF-I concentration and poorer body condition than sows weaned at day 14 of lactation (Willis et al. 2003). A sign of poorer body condition is amount of weight loss of sows during lactation. As lactation weight losses increases (>10%) subsequent reproduction performance decreases (Thaker and Bilkei 2005). One study showed no decline in lactation performance or ovarian function when a sow loses approximately 9 to 12 % of its parturition protein mass, but with progressively larger decreases of animal body protein mass decreases also sow reproduction performance (Clowes et al. 2003b). Backfat measurements could be valuable tool to monitor underfed or overfed sows and to improve their productivity and efficiency (Maes et al. 2004).

NUMBER OF SUCCESSIVE PARITIES

Primiparous sows typically require a weaning-to-first-service interval 2.3 days longer and a weaning-to-conception interval 2.9 days longer than sows in their second or subsequent parity. Thereafter, from the second to the tenth parity, the durations of both periods remain similar (Koketsu and Dial 1997). A negative effect of weaning-to-estrus interval on reproductive performance is clear in sows with very short weaning-to-estrus interval of 0-2 days and those with weaning-to-estrus interval of 6-12 days (Poleze et al. 2006). The effect of weaning-to-conception interval on subsequent litter size is more pronounced in parity 2 than in further parities (Le Cozler et al. 1997). Sows with backfat thickness less than 12 mm at weaning after parities 2 and 3 have greater culling rate (Young et al. 1991).

SUMMER INFERTILITY SYNDROME AND HOT AMBIENT TEMPERATURE

The influence of the season is mainly attributed to photoperiod and ambient temperature (for review see Quesnel et al. 2005). Sows differ in their metabolic status and appetite during lactation, but their appetite also depends upon the ambient temperature (Tantasuparuk et al. 2001). Sow lactating during hot whether eat less, lose more weight and backfat and take longer to return to estrus (Prunier et al. 1996). An increase in daily feeding frequency of sows during lactation in the hot season (June to September) has surprisingly negative influence on their return back into estrus within 7 days post-weaning (Imaeda and Yoshioka 2007). High temperature in the gestation rooms (i.e. above the thermoneutral zone) can negatively affect the number of newborn piglets, as well as their body mass at birth (Spencer et al. 2003). Independent of the parity and weight loss during lactation sows weaned in the period of July until September have longer weaning-to-estrus interval (Vesseur et al. 1994). In addition, farrowing during the summer period are characterised by longer periods from weaning-to-first-service (Sukumarannair et al. 2005) and longer weaning-to-conception intervals which are on average 2.8 days longer than the shorter interval in the autumn (Koketsu and Dial 1997). At an ambient temperature of 32 °C and lactation of 19 days, primiparous sows have a weaning-to-estrus interval 13.5 days longer than sows at 21 °C (Spencer et al. 2003).

Seasonal effects on fertility of domestic sows were investigated in northern region of Europe (Peltoniemi et al. 1999, Gaustad-Aas et al. 2004a). According to those authors, a risk of prolonged weaning-to-estrus beyond day 10 is the highest from August to October (Peltoniemi et al. 1999) and the litter size is lower after service during natural long photoperiod than during the rest of the year (Gaustad-Aas et al. 2004a). Even under tropical condition where day length is almost constant throughout the year the weaning-to-service and weaning-to-conception interval are prolonged for sows weaned during the hot season in Thailand and Guadeloupe (Tantasuparuk et al. 2000, Gourdine et al. 2006).

TIME OF MATING/INSEMINATION

In older sows, the optimum time of mating to achieve the highest litter size is 24 hours before ovulation occurs (Nissen et al. 1997), whilst for primiparous sows the best period is between zero and 12 hours before ovulation (Kemp and Soede 1996). Since ovulation cannot be directly observed, signs of estrus are used as an aid to the timing of insemination. The first insemination of primiparous sows must occur 12 hours after the onset of the mating reflex, and then be repeated again 12 hour's later (Vargas et al. 2006). Inseminating sows too late reduces the period when fertilisation is most likely to occur. This is a particular risk in sows that show their mating symptoms late after the piglets have been weaned (Weitze et al. 1994). Sows that show their readiness for mating before noon on the fourth day after weaning, and are still showing signs of receptivity before noon on the fifth day actually achieve the highest number of liveborn piglets when mated on the third day (Dewey et al. 1994, Hühn 2006b). Litter size is also reduced if the period from weaning-to-conception is longer than 6 days (Le Cozler et al. 1997, Koketsu and Dial 1998, Tantasuparuk et al. 2001). In more recent research, a significant reduction in litter size of primiparous sows has been noted if the period from weaning-to-estrus is greater than 5 days, than the litter size decreased below 10 (Poleze et al. 2006).

AGE, BODY MASS AND BACKFAT THICKNESS OF GILTS AT FIRST MATING AND PARTURITION

Selection during early sexual maturity can result in high productivity of the breeding herd (Holder et al. 1995). Litter size is one of the most important features of fertility and is therefore included in various selection programmes (for review see Rydhmer 2000). In sows, the smallest litter sizes are typically observed during the first parity, after which they increase until the fifth parity before slowly declining (Kroes and Van Male 1979).

There are conflicting views over the optimum age for mating gilts. Larger litters are obtained from 259 day old gilts at first conception than from younger animals (Kämmerer et al. 1998). The optimum litter size (11.25 piglets) seems to be achieved by successful mating of gilts at age between 260 and 280 days. Any lowering of the age at first mating causes a decrease of 1.5 to 2.0 newborn piglets per litter (Le Cozler et al. 1997). Gilts of the LW breed aged 425.9 days at their first parturition show an increase in the period from weaning to subsequent mating of 5.6 days. However, if they are only 3 days younger at their first parturition (i.e. 422.7 days), the interval from weaning to first estrus is about 0.3 days shorter (Sterning et al. 1998). Mating gilts at an older age has not been found to affect the total number of piglets born in parities three to five (Brooks and Cole 1973, MacPherson et al. 1977, Brooks and Smith 1980). It has been argued that the highest number of newborn piglets is achieved by gilts first giving birth at 374 - 394 days of age (Le Cozler et al. 1997).

In addition to the effects of age at first mating or first parturition on fertility described above, the body mass and backfat thickness during the first parturition also play important role (Yazdi et al. 2000). Koketsu (1999) has suggested that gilts should be 368 ± 1.3 days old at their first parturition, have an average body mass of 173.1 ± 2.5 kg and a backfat thickness of 19.3 ± 0.8 mm. On the contrary, however, others have found that larger litters are delivered by gilts allowed to reach 181 – 200 days of age at their first estrus, weighing between 110 and 120 kg and with a backfat thickness of between 13.1 and 15.0 mm (Tummaruk et al. 2007). A very similar data have been reported by Le Cozler et al. (1999). At 100 kg of live weight, *ad libitum* feed gilts are younger for 20 days and they have a thicker backfat for 2.3 mm than restrictive feed sows. At the first detected estrus, *ad libitum* feed gilts were younger (198 versus 203 days), heavier (127 versus 117 kg live weight) and fatter (17.8 mm versus 14.7 mm backfat thickness) than restrictive feed gilts. The gilts with a fat thickness of 13-18mm yielded higher farrowing rate and piglet numbers than the gilts with less fat thickness (Hühn 1997). A thicker backfat layer seems to positively affect the fertility and productiveness of gilts (O'Dowd et al. 1997, John et al. 2001, Bečková et al. 2005, Čechová and Tvrdoň 2006).

A high temperature in the pens during 19 day lactation is apparently responsible for a 38% decrease in feed consumption, substantial reduction in backfat thickness and the area of the *Longissimus dorsi* muscle, as well as negatively affects the body mass of animals at weaning (Spencer et al. 2003). A higher loss of body mass in primiparous sows during lactation significantly decreases their backfat thickness and the quantity of body fat (Clowes et al. 2003b). Backfat thickness tends to decrease to the next in line with the worsening of body condition (Hühn 2006a). The proportion of irregular return to estrus (>24 days after first mating) was significantly higher in primiparous than multiparous sows (69% versus 61%) (Tummaruk et al. 2001).

HORMONAL STIMULATION AND SYNCHRONISATION OF THE ESTRUS

Where hormonal disorders are suspected the hormonal stimulation and synchronisation of a sow's estrus is necessary (Höges 1990; for review see Wähner 2002). To correct disturbances in the estrous cycle, particularly during the summer months a combination of serum gonadotrophin (PMSG), chorion gonadotrophin (hCG) and vitamin E is administered at weaning. PMSG has an effect similar to FSH whilst hCG acts similarly to LH. Both gonadotrophins are necessary for the maturation of follicles and ovulation (Littmann 1997, Biedermann 1999). The negative effect of weaning during the summer on the estrus of primiparous sows can be avoided by the use of PMSG given in a 1000 IU dosage 24 hours after weaning. By this approach, more than 90% of primiparous sows show receptivity to mating on the 4th to 6th day after weaning (Wähner 2006). The synchronisation of estrus is also routinely used during the introduction of gilts to the breeding herd (Hühn 2000). The application of PMSG in weaned sows and gilts offers great advantages for the synchronisation of mating symptoms and ovulation when using artificial insemination, as confirmed by positive results in pig breeding (for review see König and Hühn 1997). After three to four weeks of lactation, between 750 and 1000 IU of PMSG need to be administer intramuscularly (Hühn 2002). The management of synchronisation and insemination is very important in order to achieve a weekly rhythm of weaning. For example weaning on a Wednesday and estrus synchronisation by PMSG on a Thursday allows the synchronisation of ovulation with GnRH 72 hours later in older sows or 78 – 80 hours later in gilts. This results in the majority of inseminations being performed on a Monday afternoon and on Tuesday morning (Wähner 2006).

If the PG600 (400 IU equine chorionic gonadotrophin and 200 IU human chorionic gonadotrophin) is given to the sows 2 days before weaning, this positively affects percentage of sows with mating symptoms, decreases the weaning-to-estrus interval by 1.6 days and increases the subsequent litter size. Application of PG600 4 days before weaning increases farrowing rates and decreases the weaning-to-estrus interval by 4 days in comparison to control sows (De Rensis et al. 2003). The stimulation of primiparous sows with PG600 on the day of weaning, regardless of the time of year, does not significantly increase the percentage of primiparous sows showing mating symptoms until the 7th day after weaning and does not affect the subsequent litter size. However, sows mated during induced estrus, tended to have lighter piglets at farrowing (Estienne and Hartsock 1998). Contrary to this observation, the stimulation with PG600 of primiparous and multiparous sows on the day of weaning in the autumn and winter can improve subsequent fertility and if they are weaned after 14 days of lactation farrowing rates should improve (Bates et al. 2000). The treatment of primiparous sows with PG600 24 hours after weaning causes the occurrence of mating symptoms in 94.8% of sows as soon as 4 to 6 days after weaning. Conversely, the percentage of sows those show mating symptoms in control group (not treated with PG600) amounts to only 79.7%. Consequently, treatment with PG600 has positive impacts on litter size and significant reduction in the weaning-to-estrus interval (Vargas et al. 2006).

The stimulation of gilts by PG600 does not increase the size of the litter in first three parities (Holtz et al. 1999). For gilts increasing dose of PG600 to 1.5x increases the number of *corpora lutea*, but dose not alter the proportion expressing estrus or ovulation (Breen et al. 2006).

During periods of high ambient temperature very often a delay in estrus after weaning is observed. One of possible solution to decrease weaning-to-estrus interval in such hot season is induction of estrus by PG600 (Estienne and Hartsock 1998).

CONCLUSIONS

The effectiveness of pig breeding largely depends upon the biological productiveness of sows as represented by the number of piglets weaned per sow per year. Shortening the weaning-to-estrus and weaning-to-conception intervals offers the only significant hope of reducing the number of unproductive days, particularly in primiparous animals.

Many factors are responsible for affecting post-weaning performance including the endocrine glands, steroid hormones, breed, feeding, lactation length, number of previous parities, season of the year, age at first mating, body mass, backfat thickness, hormonal stimulation and synchronisation of estrus and the timing of mating or artificial insemination.

The hormonal stimulation of estrus in gilts and primiparous sows by PG600 at various points before, at or after weaning affects the productivity of sows during future parities in complex ways.

ACKNOWLEDGEMENTS

This work was supported by research project grant of the Ministry of Education, Science and Sport and Ministry of Agriculture, Forestry and Food of the Republic of Slovenia (Project No. V4-0338).

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Received: March 30, 2008
Accepted in final form: August 14, 2008