Influence of backfat thickness, body weight and body condition score of sows during gestation and lactation on the vitality of pre-weaned piglets and litter performance.

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Thesis Report

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Terborg, 02 October 2012

Applied Animal Science
Van Hall-Larenstein, Wageningen
Thesis period 04-04-2011 – 16-09-2011
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Abstract

The number of weaned piglets per sow per year is an important parameter for the productivity of sows in pig production. This number depends on several parameters of which in many cases the sow has a central role. To improve the sow's reproduction it is important to keep the sow's body condition optimal. However, clear recommendations towards sow body condition and feeding levels, and knowledge about the exact influence on piglet vitality are scarce. Literature regarding these subjects mainly originates from the 1980's and is probably not in line with recent housing conditions, reproductive performance of the sow, and genetics. Therefore research was carried out in order to investigate the exact influence of 3 parameters of sow body condition (body weight, backfat thickness and body condition score) on a number of piglet vitality parameters: average birth weight, litter size, stillbirth ratio, weight gain during lactation, and litter size and average weight at weaning.
Research was carried out on 286 Topigs 20 sows and litters on two farms; one in Germany and one in the Netherlands. Sow body weight, body weight and body condition score was measured and assessed at day 108 of gestation and at weaning. Data on piglet vitality measures were gathered at moment of birth and weaning.

The main objective of this research was to find correlations between sow factors and vitality of piglets. Possible relations between sow factors (backfat thickness, body weight, body condition score, and backfat and weight losses) and piglet vitality (litter size, average birth weight, ratio live born: stillborn and weight gain during the lactation period were investigated.

A linear increase in body weight during the first 5 parities was seen on both farms, and it could be concluded that body weight is highly dependent on the parity number. Therefore, body weight can be used as tool to evaluate the body condition and development of the sow.
Body condition score is a subjective method and shows large variations between assessors. No relation was found in body condition score at the different moments in the reproductive cycle of the sow, and due to large variations between sows the body condition score is not an accurate tool to assess sow body condition. More objective methods should be used to assess the sow's condition.
Between the two trial farms of this study large differences were seen between the sow's body condition and the reproductive performance. On the one farm, backfat thickness and body weight increased with parity, while in the other farm backfat levels remained relative constant, with only a small increase with parity. This shows the importance of using a good tool for condition evaluation. Backfat thickness measurements are recently the most objective method to asses sow body condition, as the farm with increasing levels used the body condition score, and the other farm measured backfat thickness to evaluate sow body condition. Changes on the first farm would have been recognized earlier with an objective tool.

It should be investigated whether adapting feeding schedule to the individual sow will decrease variation between sows and optimize the reproduction of the sow. Also more information is necessary on the optimal condition of the sow per breed and parity number, as recent literature mentions many different recommendations and backfat thickness depends on the type of breed.
When correct nutrient and energy levels are feed, dependent on housing conditions, breed type and reproductive performance, the exact growth coefficient per breed can be determined. Sow breeding farms then can evaluate their feeding schedule based on the body weight and backfat thickness of their sows.

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1. Introduction

The total number of weaned piglets per sow per year is an important parameter for the productivity of sows in pig production. This parameter is influenced by several factors, including the fertility of the sow and boar, perinatal and pre-weaned deaths and farm management.
Due to increased litter sizes, to meet the demand of higher numbers of weaned piglets per sow per year in recent years, the average birth weight of the piglets has become lower. This results in declined piglet vitality and increasing risk of perinatal and pre-weaning mortality. The average pre-weaning piglet mortality on Dutch breeding farms was 11.9 percent and the average number of weaned piglets per sow was 28.1 in 2010 (TOPIGS, 2010).
Most pre-weaning deaths occur during the first four days after birth, mainly as a result of non-infectious causes. Causes or risk factors in those first four days can be related to the sow and piglets, and/or the environment (Loncke et al., 2008).

Stillbirth and pre-weaning mortality is associated with major economic losses for the pig production. Although it becomes a more important welfare issue as well, only little information is available on the influences of sow body condition on the vitality of the piglets. Due to the serious economic impact, numerous surveys have been conducted to improve piglet birth weight and decrease pre-weaning mortality. However, these studies mainly focus on improvement of the birth weight and the number of live born piglets to decrease pre-weaning mortality (Lobke et al., 1983; Johnson et al., 1999; Hermesch et al., 2001; Lund et al., 2002; Robinson and Quinton, 2002; Högberg and Rydhmer, 2008; Bunther, 2009; Barker and Clark, 1997; Bell, 2006; and Wu et al., 2006). Keeping live-born piglets alive becomes an important goal, whereas previously the focus was on increasing litter size. However, increasing litter size is often associated with an increased incidence of light, low vitality piglets (Lawlor, 2004). Do we have to reposition the focus to improve overall piglet production?

Only little research has been carried out on sow condition and influences of sow factors on the vitality of piglets. Studies which have been carried out mainly originate from the 1980's, and probably are not in line with recent situations or production levels.
Especially the influence of the condition and nutrition of the sow on the vitality of the piglets is not investigated enough. Recent knowledge is based on practical experiences, old genotypes and individual housing.

This research focuses on the influence of the sow's condition and nutrition on the vitality of the piglets in modern housing and with recent genetics. The objective of this research was to evaluate if there is a relation between the backfat thickness (BF), body condition score (BCS) and body weight (BW) of sows during gestation and lactation on the vitality of the piglets. Other objectives of this research were to find out if backfat thickness and weight losses during lactation, and backfat and weight gain during gestation influence average birth weight and litter size. The objective regarding nutrition was to find out if the intake of energy and digestible lysine influences the factors mentioned earlier of piglets.
It was expected that sows with a low body weight and or backfat thickness were younger than sows with a high body weight or backfat reserve. In addition it was expected that backfat thickness and body weight were somewhat related.
Piglet vitality is expected to be influenced by the condition of the sow. Too thin and too fat sows both will have negative effects. This is influenced in the periods of birth, milk production, feed intake of the sow and eventually durability of these sows.

The first part of this research focuses on literature and previous studies related to the subjects of this research. After description of the materials and methods, the research findings are described. In the discussion chapter, the discussion and conclusions are combined. In the chapter conclusions/recommendations, the most important conclusions and recommendations are highlighted.

2. Literature review

2.1 Piglet vitality

Stillbirth and pre-weaning mortality is associated with major economic losses for pig production, with approximately 1/5th of all foetuses fully formed at the end of gestation die before weaning. 3-8% of losses are a result of stillbirth and generally >10% of the piglets per sows die in de pre-weaning period (van der Lende et al., 2001; van Rens et al., 2005). In 2010 the average piglet mortality in the lactation period was 11.9 percent (Topigs, 2011). Piglet vitality and reducing pre-weaning mortality become more important in Dutch pig husbandry these days, because indications show that the number of live-born piglets still improve and consequently pre-weaning mortality will still increase. Piglet vitality is influenced by several factors. Causes of risk factors for pre-weaning deaths and stillbirths can be related to the sow, the environment of the piglet itself (Loncke et al., 2008). Most pre-weaning deaths are a result of non-infectious factors. Examples of causes for pre-weaning mortality of piglets are crushing by the sow, environmental stressors, dystocia, low birth weight and starvation. Many of the causes of pre-weaning mortality are linked with each other.

2.1.1 Litter size

The sow contributes to basic factors that can cause pre-weaning mortality in piglets. These factors include gestation length, farrowing duration, litter size, mother behaviour (aggression and crushing), and lactation performance.
The total number of weaned piglets per sow per year is one of the most important economical parameters of pig production. However, direct sow selection for litter size at weaning is not possible as a result of cross-fostering, improvement of litter size at weaning is achieved by sow selection on live-born piglets at birth (Lobke et al., 1983; Johnson et al., 1999; Hermesch, 2001; Lund et al., 2002; Robinson and Quinton, 2002; Högberg and Rydhmer, 2008; Bunther, 2009) and selection for functional teats. Selection for litter size at birth has been successful (Southwood and Kennedy, 1991; Bidanel et al., 1994; Estany and Sorensen, 1995). However, it has been shown that the number of produced pigs per year is also dependent on the survivability after birth. Due to increasing litter sizes in recent years, the average birth weight of the piglets has become lower, leading to declined piglet vitality and increasing the risk of pre-weaning mortality (Milligan et al., 2002; Foxcroft et al., 2006; Su et al., 2007). Litter sizes can also influence piglet survival during lactation. Research has shown that piglet losses are bigger in large litters (Fahmy and Bernard, 1971; Dyck and Swierstra, 1987; Merchant et al., 2000). In consequence, the sow does not have enough functional teats to nutrition all piglets. The number of functional teats is important for good milk supply towards the litter. In recent years, an increasing frequency of sows with udder lesions has been observed (Christensen, 2007). In addition, milk production is very important as well. Although milk production increased as well during the years, milk production showed a smaller increase compared with the litter size, resulting in a smaller amount of milk per piglet (Esley, 1971; Etienne et al., 2000).
Question is if above mentioned factors of sows have become better towards piglet vitality in the last ten years?

Within-litter variation in piglet body weight is the main factor causing pre-weaning mortality (Merchant et al., 2000).
Although the number of live born piglets is economically important, the risk for pre-weaning mortality increases. Is it still profitable to select on litter size, or has the sow become the limiting factor and is it necessary to reposition piglet production objectives?

2.1.2 Birth weight and within-litter-variation

Piglets with a low birth weight are particularly at risk for pre-weaning morbidity and mortality. Low-birth-weight piglets are mainly at risk for hypothermia, as a result of a greater body surface-to-volume ratio and reduced energy storage (English and Morrison, 1984). A newborn piglet utilizes its energy stores in 11 to 12 hours without nutritional intake (Herpin and LeDividich, 1995). Piglets with a birth weight less than 800 gram have a survival rate of 32% compared with 97% of piglets with a birth weight of 2000 gram or more (Gardner et al., 1989). It should be noted that this research is executed 22 years ago and outcomes may be not in line with recent sow performance and genetics.
It is difficult to select directly for weaning weight, though, birth weight of the piglets is the start of having a successful weaning weight. Therefore it is important to improve birth weight of piglets. Influencing the weaning weight focuses on the nutrition and lactation performance of the sow, but a high birth weight and smaller within-litter variation has a more positive influence on the weight at weaning.
Several factors influence birth weight of the piglets, such as sow health and body condition, nutrition, and parity number. These factors are described in more detail in the following subchapters.
High wiithin-litter variation in piglets is associated with higher pre-weaning losses (English et al., 1982; Marchant et al., 2000; English and Smith, 1975; Roehe and Kalm, 2000; Tuchscherer et al., 2000). At the moment the variation is becoming bigger. Piglets with a low birth weight are at disadvantage compared with large piglets within the same litter, because they are more susceptible to cold (body volume-surface ratio), have less energy storage, and have more difficulties in competing at the udder (Lay et al., 2002). Some sows are better at ensuring a small within litter variation of their piglets during lactation than others. Knowledge on the genetic influence of the sow, and the effect on piglet survival are very limited (Damgaard et al., 2003). Literature is indicating that within-litter variation and low birth weight will increase pre-weaning mortality. Questions remain if recent practical situations are confirming these expectations, and if so, if it is possible to decrease the within-litter variation during the lactation period by means of management or nutrition of the sow?

2.2 Influences of the sow on piglet vitality

2.2.1 Parity number

The number of total born piglets is dependent on the number of ripe follicles ovulated, the fertilization rate and the number of embryonic or foetal survival. This number is highly correlated with the size of the sows' uterus (Pârez-Enciso et al., 1996). Research has shown that a smaller uterine size contributes to an increase in the number of mummified foetuses (Wu et al., 1998). According to Imboonta et al. (2007), heritability of litter size is low, environmental factors however, are important factors on variation in litter size. In most cases, parity number is the most important factor influencing litter size in sows (Tummaruk et al., 2000, 2004, 2010). Litter size is generally smallest in the first parity and is largest in parity numbers 3 to 6, after which the litter sizes slowly declines as parity number increases further (Tummaruk et al., 2000). The number of ripe follicles ovulating increases during the first three oestrus cycles after reaching puberty, after that it remains relatively constant (den Hartog and van Kempen, 1980). This indicates that vitality can be different per parity, when only number of piglets born per litter is taking into account.

2.2.2 Oestrus period and early gestation

A low feed intake in the pre-ovulatory period is related to a decreased follicle development and a decreased quality of the follicles (Zak et al., 1997; Yang et al., 2000; Ferguson et al., 2003) and a decreased embryonic survival (Cosgrove et al., 1992; Ashworth et al., 1999; Almeida et al., 2000). Several studies have been carried out to investigate the influence of sow nutrition on perinatal mortality, and embryonic and foetal development. Both overfeeding and underfeeding the sow have a negative effect on the placental blood flow and decrease foetal growth (Wu et al., 2004). Maternal undernutrition influences foetal and placental developments negatively, in both animals and humans (Bell and Ehrhardt, 2002; Barker and Clark, 1997). Foetal growth is most susceptible for maternal nutrient deficiencies (Wu et al., 1998; Sudgen and Holness, 2002; Waterland and Jirtle, 2004). On the other hand, a study of Wallace et al (2003) in sheep concluded overfeeding has also showed to reduce placental and foetal growth and increases neonatal mortality (Wallace et al., 2003).
Optimal feeding schedule in which sows are not fed too little but not too much as well is therefore very important.
Several factors influence the ovulation rate. The number of ovulations is often not the limiting factor for litter size (Hazeleger, 2011), as the number of ovulations in second parity and older sows are on average above 20. As litter sizes are often smaller, other factors limit litter size. Perinatal mortality is an important cause of variation in litter size.
Only about 50% of the foetuses will result in a weaned piglet at the end of lactation (Taverne and van Hout-van Dijk). Perinatal mortality can be divided into embryonic mortality (day 0-35 of gestation) and foetal mortality (from day 35). Especially variation in embryonic mortality is an important factor for litter size, as losses mainly occur during the embryonic mortality. Pope (1994) concluded, based on several studies that mortality occurred in 20-30% of fertilized follicles during the embryonic phase, especially between day 13 and 20. (Taverne and van Hout-van Dijk).
Nutrition is reported as important when reducing embryonic mortality. A study of Zak et al. in 1997 showed that sows with a restricted feeding level during the last week of lactation, had lower numbers of large follicles, and the maturation capacity of these follicles was reduced. Although research has been carried out to investigate the influence of maternal feed intake, the optimal nutrients levels are still unknown. This is in line with a study of Almeida et al. (2000) who investigated the influence of a restricted feed intake of gilts during days 8-15 of gestation. These sows had a lower embryonic survival rate compared to sows not restricted in feed intake. In contradiction with these studies, den Hartog and van Kempen (1980) concluded that a high feed intake during early gestation increased embryonic mortality. This contradiction is stating no conclusion, and again the figures from old studies are not reliable for recent production figures and pig production.

2.2.3 Weaning to oestrus interval

Loss days in sow reproduction consist of the interval weaning-to-oestrus interval, abortions, number of non-gestating sows and number of undetected unfertilized sows (Xue et al., 1997).
The weaning-to-oestrus interval influences the annual farrowing rate, and thus should be kept as low as possible.
After weaning antral follicles grow out to ovulatory sizes, resulting in post-weaning oestrus and ovulation between 4-7 days after weaning. During lactation the reproduction system has to be restored to allow good reproductive performance of the sow after lactation, in terms of the interval weaning-to-oestrus, pregnancy rate and litter size.
To reduce the interval weaning-to-oestrus it is important to keep the sows' body condition optimal. Earlier studies demonstrated a close relationship between backfat thickness and the reproductive performance in sows (Roongsitthichai et al., 2010). Gilts with a high backfat thickness are younger at first mating and have a shorter weaning-to-oestrus interval, a larger litter size and a higher farrowing rate compared with gilts with a low backfat thickness (Tummaruk et al., 2001a/b (via Roongsitthichai et al., 2010)).

A research of Tokach et al. (1992) showed that the average daily protein intake and energy intake affect the LH concentration on day 21 of lactation. Low intake of Metabolizable Energy (ME) and increasing lysine intake has effect on mean LH secretion.
The influence of lysine intake on LH secretion increased as energy intake decreased. As a result of this study, it can be concluded that the mean LH concentration at day 21 of lactation is reduced by a low intake of lysine or energy. This is confirmed by several studies: King and Martin (1989), Quesnel et al. (1998), Yang et al. (1989) and van den Brand et al. (2000).
The research of Yang et al. (1989) showed that insufficient feed intake during gestation (resulting in thin sows can not be compensated by increased voluntary feed intake during lactation in first litter sows, resulting in an increased weaning-to-oestrus interval.
On the other hand, too high feed intake also leads to decreased reproductive performance. Several studies have shown that excessive feed intake during the gestation period decreased the voluntary feed intake during lactation (e.g. Mullan and Williams, 1989; Yang et al., 1989; Dourmand, 1991). As a result of a decreased feed intake during lactation, sows will lose a lot of body weight.
Decreased energy and lysine intake will then result in a lower LH secretion, decreased follicle development and lower ovulation rates.
In contradiction with these studies, Eastham et al. (1988) found no relation between lactation and the weaning-to-oestrus interval.

Nutrition also seems to influence the follicle development during lactation, with a restricted feed intake resulting in lower ovulation rates. (Quesnel et al., 1998; Zak et al., 1997). In both studies sows fed ad libitum were compared with sows having a restricted feed intake. The study of Zak et al. (1997) concluded that a restricted feed intake at days 22-28 of lactation resulted in a smaller number of large follicles, compared with sows fed at libitum.
From these studies it can be concluded that low feed intake during lactation has a negative effect on the follicle development during and after lactation, resulting in a lower quality and number of recruited follicles for ovulation (Kemp et al., 2010). What levels of nutrients should be fed to optimize the follicle development and ovulation rate is not clear yet. In the following chapters the recommended nutrient levels according to literature are described in more detail.

2.2.4 Condition during the gestation period

An important aspect of successful swine reproduction is maintaining optimal condition of sows, so they do not gain or loose too much weight or body condition between parities. This will have a positive influence on the sow's reproductive performance, production efficiency, mortality rates and durability of the sow. Fertility problems are common in sows, with approximately one third of all sows being replaced as a result of fertility problems. (Karlberg, 1980 in Kauffold et al., 2004a; de Jong et al, 2009). Problems in body condition often play an important role in fertility problems. Inadequate control of sow body weight and condition can lead to farrowing difficulties, poor rebreeding performance and high culling rates (Coffey et al., 1999; van Engen en Scheepers, 2006). Too small or too fat sows have often more difficulties to become in heat and often have smaller litters. In addition, the body condition of the sow also influences the farrowing process, the number of stillborn piglets, the productivity of the sow, and pre-weaned mortality (GD, 2005).
Studies of Groppel (1999) and Hühn (1996, 2001, 2004) found a relation between the body weight of the sow and the reproductive performance in following parities. Thüringer Ministerium (2007) presented a summary for body weight at farrowing according to these studies. This summary is presented in Table 1.

Parity nr	Heinze et al., 1990 Kg	Hühn 1996 Kg	Groppel 1999 Kg	Hühn and Gericke 2000 kg	Close and Cole 2000 kg
1	125	125	125	130	140
2	160	160	160	160	175
3	191	185	185	185	200
4	191	205	205	205	220
5	191	.	215	215	235
≥6	221	.	225	220	245

Table 1 Recommendations for sow body weight at farrowing (Thüringer Ministerium, 2007).

Research of Wähner et al. (1995) found a direct relation between backfat thickness and reproduction, by means of activity of ova. The release of oestradiol was also higher in sows with high backfat reserves (Thüringer ministerium, 2007).
Yang et al. (1989) advice a target backfat thickness of 20 mm at first parturition, and Clowes et al. (2003) adviced a target backfat thickness of 17-20mm and a weight of 175-185 kg at first parturition. This study was executed on 77 Manor Hybrids x Large White and Manor Hybrids x Landrace.
Table 2 shows the recommended levels of backfat thickness stated by other studies.

Parity nr.	Hühn 1996 Mm	Groppel 1999 Mm	Hühn and Gericke, 2000 Mm	Close and Cole 2000 Mm
1	17	20	20	20
2	15	17	17	22
3	14	15	15	23
4	13	14	14	24
5	12	13	13	24
≥ 6	11	12	12	24

Table 2 Recommendations for backfat thickness at farrowing (P2-method), (Thüringer Ministerium, 2007).

A difference between German and English recommendations is seen. German studies report a decreased backfat thickness recommendation as parity number increases while the research of Close and Cole (2000) recommend an increase in backfat thickness in the first 4 parities. Hühn (2004) reported recommendations of 18mm backfat thickness and 130 kg body weight for gilts of 7.5 months old. Pig-Genetik recommends a backfat thickness of 14-16mm at the P2-method at weaning. By recommending 130-140 kg body weight and 18-20 mm of backfat thickness of gilts, Close and Cole (2000) report higher recommendations for backfat thickness and body weight.
It should be noted that information about used breeds is not available for all these studies and this may affect the outcomes of the studies.
Backfat thickness differs per breed, as not all breeds have the same genetic tendency to gain backfat reserves. B.E.V.A. ('Landsbond van de Belgische Varkensstamboeken') executed studies in 1999, 2000 and 2001, in which sows were assessed on body condition. Backfat and weight recommendations of most common breeds are presented in Table 3.
From this table it can be seen that sows of Piétrain have significant lower backfat levels. Finnish landrace and Large Whites are sow breeds selected for reproduction of piglets with a higher fat, while Piétrain mainly are breed for their lean quality. These sows show higher backfat levels, as they need to store enough energy to raise the piglets during the lactation period. Between these 3 types of breeds Large white sows showed the largest levels of backfat thickness.

Breed	1999			2000			2001		
	#	BF	BW	#	BF	BW	#	BF	BW
Finnish Landrace	63	9.2	115	76	8.9	109	66	8.7	106
Large White	78	12.3	116	57	12.1	116	141	12.7	114
Piétrain	1164	6.5	113	1194	6.2	112	765	6.2	113

Table 3 Average backfat thickness and body weight of sows of different breeds. (B.E.V.A., 1999-2000-2001, via van Gastel, 2003).

Although several surveys have been carried out still no clear recommendations for backfat thickness or body weight are given. What is the optimal body weight and backfat thickness of sows at moments of farrowing and weaning?
An important part of managing optimal condition is nutrition. Feeding the right levels of nutrients and total kg is very important for the overall success of pig production. Without appropriate feeding management, reproductive performance of sows can quickly reduce and optimal performance regarding weaned piglets is not reached.

2.2.5 Nutrition during the gestation period

During the gestation period, the nutrient requirements are relatively low (Hoste, 1993), which makes it possible for the sow to gain body condition.
During gestation, approximately 20-40% of the energy and amino acids consumed by the sows are used for growth of piglet and organs important for the gestation period, such as the placenta (NCR, 1998). The remaining 60-80% of the energy and amino acids consumed by the sow are used for maintenance of normal metabolism and normal body activities (Ball et al., 2008). In the first months of gestation maternal energy and nutrient levels mainly are required for body maintenance and development of energy reserves. Nutrient and energy requirements of sows increase during the gestation period as at day 60 of gestation foetuses weigh only 10% of their birth weight; in the last month of gestation foetal growth requires additional nutrients (van de Kerk, 1982).

Sow nutrition contributes to several factors influencing perinatal mortality. Birth weight is highly dependent on placental nutrient supply, which is determined by placental size and blood flow (van Rens, 2005). Placental insufficiency results in foetal loss, low birth weight, stillbirth, pre-weaning mortality and poor growth (Vallet et al., 2010). Besides the reseach of Vallet et al. (2010) many other studies (Everitt, 1986; Bell, 1992; Wu et al., 2006; Barker and Clark, 1997; Town et al., 2005; Foxcroft et al., 2006) suggested inadequate supply of nutrients and especially protein leads to decreased foetal growth, resulting in decreased postnatal growth and performance. In studies of Barker and Clark (1997), Bell (2006), and Wu et al. (2006) the reduced intrauterine growth was a result of decreased feed intake of the sow during gestation (Pond et al., 1969; Vonnahme et al., 2003; Fahey et al., 2005; Johnson et al., 2005). The number of muscle fibre is set during foetal development, and a decreased maternal feed intake influences this muscle fibre development negatively (Fahey et al., 2005).
Through research, the requirements for nutrients during the different stages in gestation, like calcium, phosphorus, protein and energy are determined quite precise.
Improper nutrition during gestation can have a negative effect on the average birth weight of piglets. Too high feed supply during pregnancy influences the feed intake of sows during lactation negative (Close and Cole, 1986). Sows that were fed ad libitum during pregnancy have a lower feed intake during lactation increasing weight losses of the sow. According to a study of Close and Cole (1986) a continued low feed intake during lactation, resulted into a longer interval from weaning to estrus.
Recommended nutrient levels according to the 'CVB Tabellenboek Veevoeding' are presented in Table 4. These nutrient levels are recommended based on weight estimations per parity at day 0 of gestation (CVB, 2010). Nutrient requirements for sows with a higher or lower body weight can be estimated by + or – 0.07 EW per day for each 10 kg.

Days in gestation	Parity 1 (140 kg)		Parity 2 (165 kg)		Parity 3 (185 kg)		Parity 4 (205 kg)		Parity 5+ (220 kg)	
	EW	digLys	EW	digLys	EW	digLys	EW	digLys	EW	digLys
0-14	2.15	9.89	2.30	10.58	2.40	11.04	2.50	11.50	2.60	11.96
15-28	2.25	10.35	2.40	11.04	2.45	11.27	2.55	11.73	2.60	11.96
29-56	2.35	10.81	2.50	11.50	2.55	11.73	2.65	12.19	2.70	12.42
57-84	2.60	11.96	2.75	12.65	2.80	12.88	2.90	13.34	2.95	13.57
85-98	2.85	13.11	3.00	13.80	3.05	14.03	3.10	14.26	3.15	14.49
99-115	3.00	19.20	3.15	20.16	3.20	21.08	3.30	21.12	3.30	21.12
Total	288.00		303.00		313.00		322.00		328.00	

Table 4 Recommended nutrient levels during gestation (CVB, 2010).

The NRC (1998) estimated the nutrient requirements for swine by means of summarizing 10 literature values. The mean daily maintenance energy requirements were estimated to be 444 kJ/kg $BW^{0.75}$ (Ball et al., 2008). However, reliability of this calculation can be discussed as it is based on old surveys, originating from more than 20 years ago. These surveys include studies of Böhme et al. (1980), Noblet and leDevich (1982), Campbell and Dunkin (1983), Close and Stanier (1984); McNutt and Ewan (1984), Gädeken et al. (1985), Whittemore (1976), Wenk et al. (1980) and Noblet et al. (1985). Heugten (2000)estimated nutrient requirements of gestating sows as well. These estimations were adapted from Everts (1994). Table 5 presents the required nutrient levels according to Heugten, 2000.

Parity nr.	Body weight	Weight gain (kg)	ME required (kcal/day)			Required intake total lysine g/day		
			Day 0 of gestation	Day 118 of gestation	Overall	Day 0 of gestation	Day 118 of gestation	Overall
1	118	54	5260	7650	6455	5.8	16.0	10.9
2	136	54	5500	7890	6695	5.4	16.0	10.7
3	152	50	5740	7890	6815	4.4	15.3	9.9
4	163	45	5740	7890	6815	4.4	15.3	9.9
5	172	45	5740	7890	6815	4.4	15.3	9.9

Table 5 Estimated nutrient requirements of gestating sows (Heugten, 2000).

In many swine producing farms the body condition score (BCS) is used to estimate feeding levels the sows. (Young et al., 2001). Typically a scale of 1 to 5 is used, with 1 being very thin, 3 being intermediate and 5 very fat. This system is very subjective and varies between assessors. A more objective method for measuring body condition is measuring the backfat thickness of sows. Backfat thickness in pigs is normally used to predict fat quantity and lean content. Most common area to measure backfat is the P2 position which measures the backfat level at about 5 cm from the dorsal midline at the same level as the last rib curve (Tummaruk et al., 2009). Research has shown that body condition score and backfat thickness are poorly correlated (Young et al., 2001).
More information should become available about optimal body condition of the sow during the different stages of the reproductive cycle, and a reliable and practical tool should be used.

2.2.6 Lactation period

Sows often loose large amounts of body mass during the lactation period as a result of their milk yield and relative small appetites (Aherne and Williams, 1992). Adequate milk production of the sow is critical for proper nutrition of the piglets. Lactation disturbances of the sow result in inadequate nutrition of the piglets, increasing pre-weaning mortality for the weakest piglets. Large litters require a much greater rate of milk production by the sow to ensure survival of the entire litter. Research has shown that increasing the dietary fat of the sow during late gestation and early lactation can increase the fat content of the colostrum and thus increase survival of low birth weight piglets. This is a result of the fact that increasing concentrations of colostral fat increases the piglets' energy intake and therefore fat deposition (Lay, 2001).

Another important factor in providing quality milk for the piglets is to keep sows in an environment that allows the sow to maximize feed intake. Environmental and disease stressors can both contribute to decreasing sow feed intake Heat stress is especially capable of depressing feed intake.
Low feed intake during lactation results in decreased milk production and excessive sow weight/backfat losses that can result in reduced reproductive performance in the following cycle. Most reproductive hormones are made from a base of fat molecules and, therefore backfat thickness at the end of gestation influences reproduction (Lay, 2001).
Reduced feed intake during lactation can be a result of overfeeding sows during gestation (Mullan and Williams, 1989; Yang et al., 1989; Dourmand, 1991), especially between day 75 and 100 (Young and Aherne, 2005). High energy intake between days 75-100, may result in an increase in fat deposition in the mammary gland, and reduced milk yield in the lactation period (Head and Williams, 1991; Weldon et al., 1994).

On the other hand, too little back fat reserves can reduce reproductive performance and increase sow mortality. Data from several studies have shown that low backfat reserves (<14mm) at farrowing result in subsequent reproductive performance (Young et al., 1991; Hughes, 1993 (of 2003); Tantasuparuk et al., 2001). Sows that are too thin as they enter the farrowing pen are unable to consume enough feed for both lactation and body maintenance. These sows often do not successfully return to oestrus. (Johnson et al., 2006). Most reproductive hormones are made from a base of fat molecules and, therefore, body condition score influences reproduction.

Sows in lactation need more energy, for both milk production and maintenance of the body (Whitney, 2007). Recommended nutrient levels for sows in lactation are presented in Table 6. These recommended nutrient levels are calculated for a sow of 200 kg when the litter grows 2.50 kg/day in a lactation period of 28 days (average weight gain in practise). For this calculation it was expected no mobilisation of fat will occur.

Days in lactation	Energy requirements/day (EW)	Requirements for dig. Lys (g/day)
1-7	5.9	37.76
8-14	7.5	48.00
15-21	8.3	53.12
22-28	8.5	54.40
1-28	7.6	48.64

Table 6 Recommended nutrient levels per day during lactation (CVB, 2010)

The energy, protein, lysine, and other nutrient requirements of a lactating sow depend on the sow's body condition, milk yield, and to a lesser extend environmental conditions (Aherne, 2005).
The energy requirements of a 150 kg lactating sow, having a litter of 10 piglets, are presented in Table 7. In this table the expected nutrient requirements are given in Mcal per day. According to this study this sow would require an average feed intake of 7 kg/day containing 3.34 Mcal DE/kg.

	Week 1	Week 2	Week 3	Week 4	Mean
Piglet weight (kg)	2.5	4.0	6.0	8.0	
Growth (g/day)	160	220	280	280	
Milk Yield (kg/day)	6.4	8.8	11.2	11.2	9.4
Required Mcal DE/day	17.5	22.3	27.1	27.1	23.5
Required feed intake/day (kg)	5.2	6.7	8.1	8.1	7.0
Actual feed intake (day)	4.4	5.5	6.0	5.9	5.5
Sow weight loss (kg/week)	2.6	4.1	7.5	7.8	Total 22 kg

Table 7 Expected nutrient requirements of a 150 kg sows with 10 piglets during a lactation period of 28 days (Aherne, 2005).

In Table 8 the estimated nutrient and energy requirements of lactating sows (175 kg) nursing 10 piglets are presented according to measurements NCR (1998). The diet of these sows contained 3.31 Mcal metabolizable energy (ME) per kg. This table shows an example of recommendations of intake during lactation according to the NCR. It should be noted that the average litter size these days is higher than the mentioned 10 piglets in Tables 7 and 8 and average body weight of sows is higher as well, meaning that the nutrient requirements of a recent sow are expected to be higher.

Piglet growth kg/day	0.15	0.20	0.25	0.15	0.20	0.25
Sow weight loss (kg)	0	0	0	10	10	10
Feed intake (kg/day)	4.30	5.35	6.35	5.54	4.58	5.67
ME intake (Mcal/day)	14.10	17.50	20.9	11.6	15.1	18.5
Protein (kg/day)	0.70	0.93	1.17	0.61	0.88	1.08
Lysine (g/day)	35.30	48.6	61.9	31.6	44.9	58.2

Table 8 Estimated nutrient and energy requirements of lactating sows of 175 kg nursing a litter of 10 piglets (NCR, 1998).

During lactation most sows loose protein and fat reserves, as a result of their high milk yield and relative small appetities (Aherne and Williams, 1992). This can result in problems like prolonged weaning to oestrus intervals, lower ovulation rates and higher embryonic mortality. An adequate feed intake during lactation, preventing high losses of body reserves is therefore important.
Research has been carried out in order to investigate the effects of protein and weight losses. King and Dunkin (1985) and Verstegen et al (1985) concluded that body weight loss of 10 to 15% in lactation period reduces milk production. Aherne and Kirkwood (1985); Yang et al. (1989), and Kemp et al. (2011) also found a negative effect on the reproductive performance of the sow, like extended weaning to oestrus interval, lower pregnancy rates after insemination and lower litter sizes.

Only little information on the influence of weight and backfat losses is available in literature. According to Groppel (1999), 20 to 35 kg loss in body weight during lactation, is related with 4-5 mm loss in backfat thickness. (Thüringer Ministerium, 2007). A study of Wähner et al. (2002) showed a decreased feed intake and increase in backfat losses when the backfat thickness was more than 26 mm. It is suggested that a loss of >16% of the sows body protein mass, results in a subsequent decline in reproductive performance. First parity sows, and in some extend second-parity sows take longer to return to oestrus than older sows (Hurtgen et al., 1980; Clark et al., 1986; Koketsu and Dial, 1997). First and second parity sows often consume less feed during lactation (Eisen et al., 2000) and exhibit a stronger relationship between lactation body weight loss and weaning to oestrus interval compared with older sows (Vesseur et al., 1994; Tantasuparuk et al.,2001). This may be attributed to a higher percentage of weight loss in young sows compared to older sows. Gilts are smaller in weight than older sows, but loose the same body weight. Decreased energy intake and increased energy demand for body growth and lactation result in a negative energy balance which inhibits LH secretion, maturation of follicles and post weaning return to oestrus (Belstra 2003).
Literature is clearly stating that backfat and weight losses for young and older sows is equal, but why are young sows not fed differently in lactation with more concentrated feed? Or how to control backfat and weight losses for young sows?

2.2.7 Sow body condition during lactation

During lactation sows are normally in anoestrus, and are restoring the pituitary's and hypothalamus' ability of pulsing LH to recruit follicles to grow out to ovulatory size. Follicle growth also has to restore during lactation, so antral follicles are of good quality at the end of lactation. A minimum lactation period of 3-4 weeks is therefore necessary. Feed intake during the lactation period influences the fertility of the sow in next parity. Low feed intake during lactation reduces the restoration of LH levels resulting in a longer weaning-oestrus interval. Low feed intake during lactation also impairs follicle growth, resulting in lower ovulation rates and lower embryo survival (Kemp et al., 2011).
Nutrient requirements of the sow during lactation are extremely difficult to determine because the requirements change daily due to changes in milk production and composition, voluntary feed intake, body weight loss and composition of that weight loss (Ball et al., 2008).
Sows in lactation should be full-fed in order to maximize milk production. The energy and nutrient requirements depend on the sow's weight, milk yield and composition, parity number, litter size and environmental influences. Especially milk-yield is important in determining the energy, amino acid and other nutrient requirements. This can be evaluated by the weight gain of piglets during the lactation period.
Extremely fat sows will have fat deposits that narrows the birth canal and therefore may increase the time spend for the birth process.
Dystocia (abnormal or difficult labour) and the resulting reduced oxygen supply (hypoxia) have long been associated with stillbirths (Jackson, 1975). Hypoxia during farrowing is an important factor, contributing to reduced vitality and 70-90% of all stillbirths (English and Morrison, 1984). Hypoxia is also related to an increased interval birth-first suckling, hypothermia, reduced growth and increased mortality (Herpin et al., 1996).
This highlights the importance of an optimal body condition and feed intake of the sow during both the gestation and lactation period.

2.2.8 Length of the lactation period

Besides parity number the total number of born piglets per sow per year is also influenced by the length of the lactation period and the number of loss days.
Soede et al. (2009) concluded that lactation lengths shorter than 3 weeks resulted in negative effects on follicle development. Between days 14-28 of lactation each extra day of lactation leads to 0.1 extra piglets in the next parity. After 28 days the increasing length of lactation does not influence size of the next litter.
Besides lactation length, nutrition has also been shown to affect the LH concentration in the blood and follicle development during lactation.

Research of van Wesel et al. (1996) concluded an increase of piglet weight gain as sow loose more backfat. They highlighted the importance of a high feed intake during gestation compared with losses of condition in order to raise piglets. Van Gils (2002) concluded that this is a result of the lower progesterone level in the blood of sows having a high feed intake. Progesteron has impact on the perinatal mortality and this level declines as a result of the high feed intake (van de Pavert, 2002).

3. Materials and Methods

3.1 Research design and data collection

Data of a total of 285 sows and litters was collected in April to August 2011, by means of a field study on 2 breeding farms; one in Germany and in one in the Netherlands. Farms were selected on having purebred line 20 sows and line 20 x Piétrain litters. The study consisted of measuring and assessing the condition of the sow and the vitality of the litter based on several chosen parameters: litter size, number of live born and stillborn piglets average birth weight and growth during the lactation period. Before the study and during the gestation period, all sows on both farms were kept in group-housed pens after artificial insemination until one week before farrowing.

Sows on the German farm were kept in straw-bedded pens and on the Dutch farm the sows were kept on slatted floors. At approximately day 108 of gestation, sows were placed in individual farrowing pens, with plastic flooring, where they remained until the end of lactation. All litters were weaned at an age of 25-29 days of age, and sows were returned immediately to the breeding stable.

Sows were individually fed, based on parity number and body condition score, and the feeding schedule was assessed based on the expected energy requirements, body condition score and backfat thickness.

The study was conducted from one week before farrowing until weaning. Condition of the sow was assessed 1 week before farrowing and one day after weaning, by means of the body weight, body condition score and backfat thickness.

Litter performance was assessed based on the total number of born piglets, number of piglets born alive, proportions of stillborn and mummified piglets, and pre-weaning mortality.

3.2 Study population

For this research only Topigs 20 sows were used to exclude the influence of type of breed as much as possible. The Topigs 20 sow is a F1 animal based on the Z-line (Large White type/ Great Yorkshire) and the N-line (Dutch Landrace type). Topigs 20 sows are used for this study as the Topigs 20 sows is the most popular sow in the Netherlands, representing 76.1% of the total market (TOPIGS jaarverslag, 2009. As a result of this study insight is gained in the main part of the Dutch breeding sow population in recent production levels.

Litters were bred from these Topigs 20 sows and Pietrain boars as also Pietrains are often used in the Netherlands.

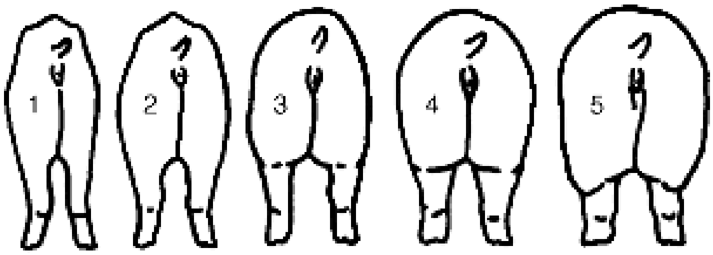
3.3 Sow Body Condition assessment

Condition of the sow was assessed on day 110, based on three parameters: body condition score (BCS), backfat thickness (BF), and weight (BW). Litters were weaned at 28 days and condition of the sows was assessed directly after weaning. Body condition score, BW, and BF were assessed on the same day to exclude changes as a result of the assessing date. Of each sow the parity number, date of artificial insemination and the expected farrowing date were registered.

Feeding schedules of all sows were documented and assessed based on energy requirements, body condition score and backfat thickness.

3.3.1 Sow body condition score

Body condition score was assessed using a subjective visual assessing method, with score 1 being very thin, 3 being intermediate and 5 being very fat (Figure 1). Sows were assessed in a standing position before body condition score was assessed, in order to decrease bias through the position of the sow, and before measurements of backfat thickness and body weight were carried out, in order to decrease bias through the measurements of more objective systems. The body condition score was assessed by one person to exclude different interpretation of the scoring system.



Score	Condition
1	Emaciated
2	Thin
3	Ideal
4	Fat
5	Overly fat

Figure 1 Sow body condition score (Coffey et al., 1999).

3.3.2 Sow backfat thickness

Sow backfat thickness was measured using an ultrasound scanner (Renco Lean Meater Series 11) shown in Figure 2. Backfat thickness was measured according to the Dutch "Stamboek" method, measuring BF at 6 points of the sow's back, 5 cm of the midline. These points are used for measuring BF, as fat tissue is the only tissue between the skin and bones in these areas. Points 5 and 6 were ultrasonically scanned at the last rib, and points 1-4 were measured at equally divided between the shoulder and the last rib, each 1/3rd of the total length, shown in Figure 3.

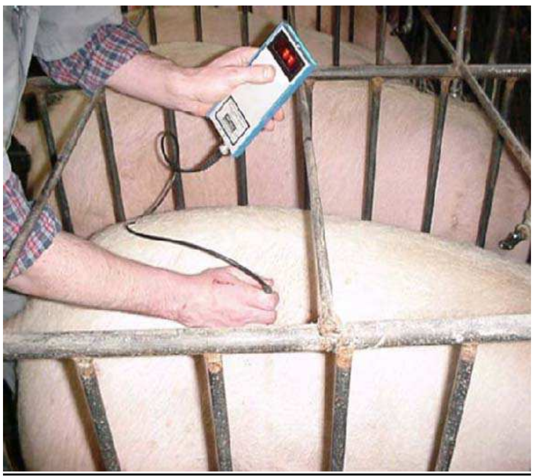


Figure 2 Measuring backfat thickness of a sow

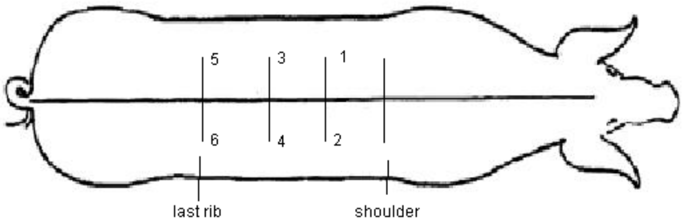


Figure 3 Measure points of BF according to the Dutch 'Stamboek'

3.3.3 Sow body weight

Sow body weight was measured at both day 108 of gestation and at moment of weaning. Sows were weighed as they entered and left the farrowing stable, by using a portable pig scale.

3.4 Feeding schedule

Sows on both farms were fed according to a different feeding schedule. On farm P only a distinction was made between sows and first parity sows, while on farm H sows were divided into 3 groups: gilts, 2-5 parity sows and sows in the sixth parity or higher. During the gestation period sows on farm P were fed according to the schedules presented in Table 9. Feeding schedules of farm H are presented in Table 10. Sows were fed according to different feeding schedules in lactation, presented in Tables 11, 12 and 13. On farm H a change in lactation feed occurred during this research, and 56 sows were fed according to this different feeding schedule mentioned in Tables 12 and 13.

Farm P	Days in gestation	Intake/day (kg)	EW/day	Dig Lysine/day
First Parity sows	0-40	3.00	3.18	14.63
	41-70	2.68	2.84	13,07
	71-115	3.15	3.34	15.36
	Total intake gestation	**342.15**	**1668.32**	**362.68**
Sows 2+	0-40	3.40	3.60	16.58
	41-70	3.05	3.23	14.87
	71-115	3.87	4.10	18.87
	Total intake gestation	**401.65**	**1958.45**	**425.75**

Table 9 Feeding schedules of gilts and sows on farm P during the gestation period.

Farm H	Days in gestation	Intake/day (kg)	EW/day	Dig Lysine/day
First Parity sows	0-25	2.5	2.58	12.45
	26-35	2.5	2.45	11.53
	36-76	2.3	2.25	10.60
	77-108	2.8	2.83	13.79
	109-115	2.5	2.58	12.75
	Total intake gestation	**288.9**	**1392.86**	**290.22**
Sows 2-5	0-25	3.0	3.09	14.94
	26-35	3.0	2.94	13.83
	36-76	2.5	2.45	11.53
	77-108	3.3	3.37	16.58
	109-115	2.8	2.88	14.28
	Total intake gestation	**332.7**	**1598.87**	**335.75**
Sows 6+	0-25	3	3.09	14.94
	26-35	3	2.94	13.83
	36-76	2.7	2.45	12.45
	77-108	3.4	3.37	17.05
	109-115	2.8	2.88	14.28
	Total intake gestation	**344.1**	**1668.02**	**346.53**

Table 10 Feeding schedules of breeding sows on farm H during the gestation period.

Days in lactation	Kg/day	EW/day	Dig. Lys/day
1- 6	2.7	3.00	13.79
7- 9	3.6	4.00	18.38
10- 12	4.5	5.00	22.98
13- 15	5.4	5.99	27.57
16- 18	6.3	6.99	32.17
19- 28	*ad lib*		

Table 11 Feeding schedules of gilts and sows on farm P during the lactation period.

		Feed type 1		Feed type 2	
Days in lactation	kg	EW/day	Dig. Lys/day	EW/day	Dig. Lys/day
1 and 2	2.8	3.05	20.72	3.00	20.75
3	3.4	3.70	26.52	3.64	25.19
4	3.8	4.14	29.64	4.07	28.12
5	4.2	4.58	32.76	4.49	31.12
6	4.6	5.01	35.88	4.92	34.04
7-9	5.0	5.45	39.00	5.35	35.57
10	5.4	5.89	42.12	5.99	41.50
11	5.8	6.32	45.24	6.21	42.92
12	6.2	6.76	48.36	6.63	45.88
13	6.6	7.19	51.48	7.06	48.84
14-15	7	7.63	54.60	6,42	51.80
16-28	*Ad lib*				

Table 12 Feeding schedule of older sows during the lactation period on farm H.

Days in lactation	Kg	Feed type 1		Feed type 2	
		EW/day	Dig. Lys/day	EW/day	Dig. Lys/day
1-2	2.8	3.05	20.72	3.00	20.75
3	3.4	3.70	26.52	3.64	25.19
4-6	4.2	4.58	32.76	4.49	31.12
7	4.8	5.23	37.44	5.14	35.57
8-13	5.6	6.10	43.68	5.99	41.50
14	6	6.54	46.80	6.42	44.46
15	7	7.63	54.6	7.49	51.87
16+	*Ad lib*				

Table 13 Feeding schedules of gilts on farm H during the lactation period.

3.5 Litter vitality and performance

Vitality of the litter was assessed based on several parameters. Within 24 hours after parturition, birth weight and gender of the individual piglets was measured and documented (both stillborn and live-born piglets), ratio live born: stillborn piglets, total litter size, number of piglets during the suckling period, number of pre-weaned deaths, and growth of piglets during the suckling period were calculated from the raw data. During the lactation period the reasons of pre-weaned deaths were documented. At weaning piglets were individually weighed and gender was determined. Data was documented.
Litter performance was assessed based on the raw data: weight gain during the 25-29 days of lactation: pre-weaning deaths during the lactation period, average weight at weaning and differences in weight at weaning within a litter.

3.6 Data processing

Gathered data was put into a spreadsheet (Microsoft Excel 2003) and reviewed for missing values and other errors. All analyses were carried out using Microsoft Excel 2003.
Analyses consisted of calculating correlations, means, variations and fitted models.

4. Results

Measurements were executed on two locations, a sow farm in Germany (P) and a Dutch sow farm (H). On farm P 62 litters and sows were assessed at birth and at weaning. 224 litters and sows of farm H were assessed at birth and weaning. Litters were weighed within 24 hours after birth, before possible cross-fostering occurred. Total litters were weighed, including live born and stillborn piglets; mummified piglets were not weighed.
Not all 286 litters could be used for the analyses because some litters were not weighed as a result of early weaning or birth before the expected day of birth.

Average birth weigh of piglets from farm P was 1.43 kg by an average litter size of 13.6 piglets. Data from last year indicated a total number of piglets of 13.6, of 0.8 were stillborn.
The average birth weight of piglets from farm H was 1.40 kg, and average total litter size (live born + stillborn) included 15.54 piglets, compared with an average total number of piglets per litter of 15.03 during the last year (1-8-2011 to 31-7-2011). Mean number of stillborn piglets per litter was 0.92 compared with 1.02 over the last year.

Average body condition score, backfat thickness and body weight were calculated per parity.
Body condition score, body weight, and backfat thickness can be used to indicate the sows' body condition during the different phases of the reproductive cycle. Backfat gain, as well as body weight gain and gain in body condition score was calculated by means of the difference of the average at weaning, and the average of sows of the next parity just before farrowing. Weight and backfat losses, and losses in body condition score were calculated by means of the difference between farrowing and weaning.

Mean backfat thickness was calculated from points 1 & 2, as well as average backfat thickness at 3&4, and 5&6. These means were calculated as backfat thickness on those points was identical. This resulted in 3 different means of backfat per sow, from which numerous tables and figures were calculated.
Sows on farm P were measured twice at day 108 of gestation, due to malfunctioning equipment during the first measurements. Sows were measured a second time at day 109 of gestation with a well-functioning lean meter. This was not expected to have influence on the results of this study.
Sows on farm H of parity 10 or older were categorized as one group (Parity 10+) as the number of sows within these parities did not exceed 5 and this was expected to have influence on the outcomes of the tests. On farm P no sows were measured having a parity number above 8.

Due to false measurements, sows on farm P were fed 20 percent above the expected feeding levels during the gestation period. Sows were expected to be fed 2.72 kg/day at days 1-40, 2.44 kg/day at days 41-70 and 3.10 kg/day at days 71-115, while the true feeding levels were 20 percent higher. This resulted in higher body weights, and backfat thicknesses than normally is advised.

Next chapters describe the sow indicators at day 108 of gestation and moment of weaning, followed by average birth weights, litter sizes and piglet vitality information. Finally relations between sow body condition and litter performance are described.

4.1 Sows

4.1.1 Body condition score

Body condition score (BCS) was assessed based on a subjective visual assessing method using a scale from 1-5, shown in Figure 1. Body condition score of 60 sows on farm P was assessed for at both moments and on farm H 127 sows were assessed for BCS at both day 108 of gestation and weaning.

The average BCS at day 108 of gestation of all sows of farm P was 4.0, ranging from 3.0 to 5.0. Body condition of sows on farm H was on average 3.5 ranging from 2.0 to 4.0. On this farm, sow BCS was normally distributed. Body condition score of sows at weaning were on average lower, compared with the mean BCS at day 108 of gestation. Mean BCS at weaning of sows on farm P was 2.8 (min 1.5, max 2.5); BCS of sows on farm H was on average 2.5, ranging from 1.0 to 3.5. Body condition score of sows at weaning was on both farms normally divided. Average BCS per parity at day 108 of gestation and at moment of weaning are shown in Table 14.

In general, BCS of sows at day 108 of gestation was higher on farm P compared to farm H. Body condition score at weaning was for first and second parity sows in general the same on both farms (BCS = 2.3). At weaning, the BCS of sows of farm P was generally also higher, except for sows of parity four.
Sows of farm P showed large variation in BCS at weaning. Body condition score seemed tending to increase as parity number increases. Sows of farm H showed an increasing score as parity number until the eighth parity. After the eighth parity sow body condition declined. Sows regained body condition in the gestation period. Gain and losses in body condition remained relative constant between parities. A clear overview of the changes in BCS over parities is shown in Figure 4.

Parity nr.	Farm P		Farm H	
	Day 108 of gestation	Weaning	Day 108 of gestation	Weaning
1	3.6	2.3	3.3	2.3
2	3.8	2.3	3.5	2.3
3	4.2	2.8	3.6	2.5
4	3.8	2.3	3.5	2.5
5	4.0	3.1	3.4	2.6
6	4.0	2.8	3.6	2.7
7	4.4	3.0	3.6	2.8
8	4.5	3.4	3.5	3.0
9	-	-	3.5	2.9
10+	-	-	3.5	2.3

Table 14 Average body condition score per parity at farrowing (d 108) and at moment of weaning.

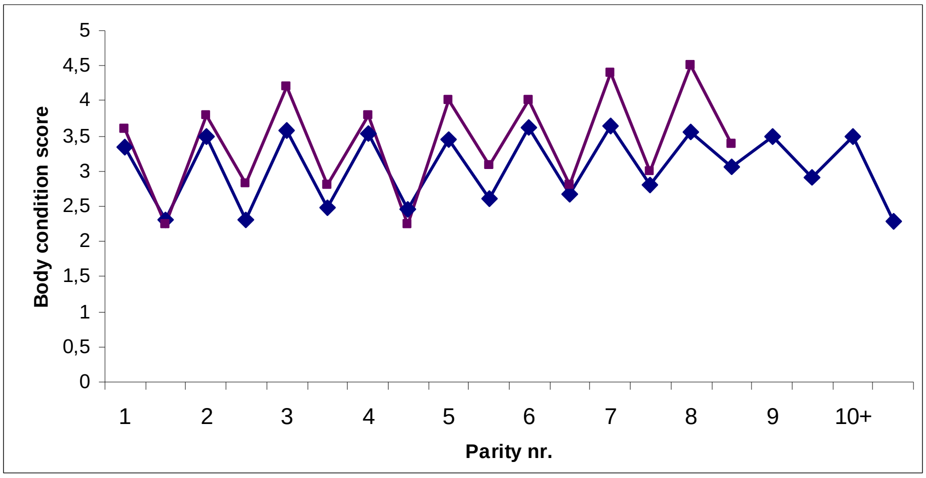


Figure 4 Gain and losses in body condition score between parities on tested farms.
Farm P; Farm H.

4.1.2 Body weight

59 sows of farm P were weighed at both day 108 of gestation and moment of weaning. As a result of a defect scale only 139 sows of farm H could be weighed. Results are shown per parity in Table 15. Sows of farm P had in general a higher body weight compared with sows of farm H. This can be addressed on the feeding schedule as sows were fed 20% above expected feeding levels.
On farm P sows had an average body weight of 295.8 at day 108 of gestation, ranging from 200 to 368. Body weight at weaning was on average 229.0 ranging from 147 to 297.
Average body weight of the 139 sows on farm H at day 108 of gestation and weaning were 278.4 ranging from 184 to 360, and 216.8 (min 138, max 298), respectively.

Parity nr.	Farm P		Farm H	
	Day 108 of gestation	Weaning	Day 108 of gestation	Weaning
1	215.6	157.3	223.3	169.6
2	233.0	179.3	252.8	191.7
3	271.0	212.4	275.2	212.7
4	305.0	230.3	281.2	216.8
5	319.6	252.8	291.0	227.3
6	313.5	242.6	301.2	244.6
7	318.8	257.5	298.5	253.8
8	334.3	269.5	318.7	257.5
9			323.7	272.0
10+			312.7	233.0

Table 15 Body weight of sows at day 108 of gestation and weaning on tested farms.

Sows lost body weight between parities and regained body weight during the gestation period. Average weight losses of sows ranged from 53.7 kg (parity 2) to 74.7 kg (parity 7) on farm P, and from 44.7 kg (parity 7) to 79.7 kg (parity 10+) on farm H. No relation with parity number was seen. From Table 8 an increase in body weight is seen as parity number increases. Figure 5 shows the average weight gain of sows during the gestation period.

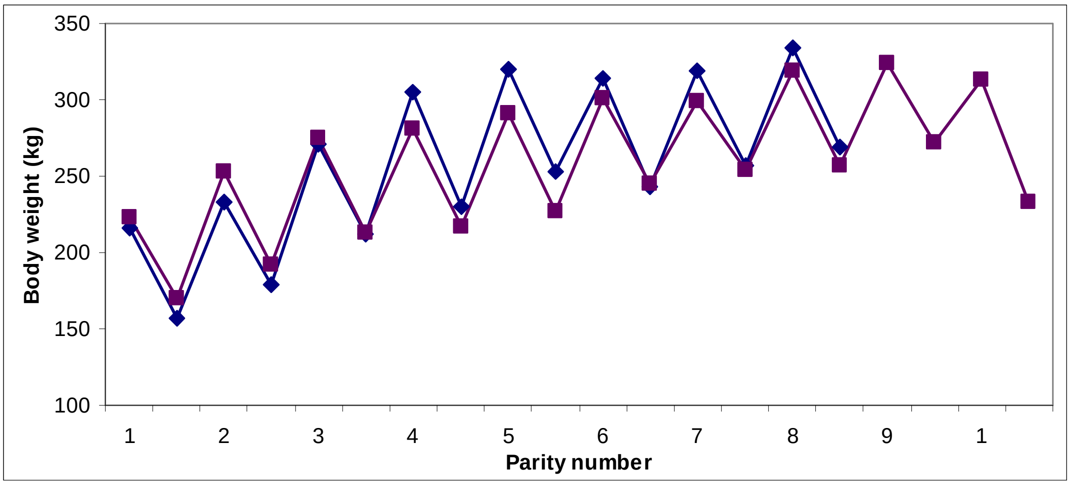


Figure 5 Weight gain and losses between parities on tested farms. Farm H; Farm P.

From figure 5 it can be concluded that body weight developed as parity number increased. Body weight of sows on both farms showed a linear increased development as parity number increased, until parity five. An overview is given in Figure 6. After the fifth parity sow body weight remained relative constant. Especially in parity 1-5 a strong linear increase in body weight was seen as parity number increased. For this reason an extra graph is presented, with only the weight gain during the first 5 parities. On farm P the increase in body weight is in line with the formula y= 28.0x + 148.81 and the increase in body weight of sows on farm H followed the curve y = 16.4x + 215.58.

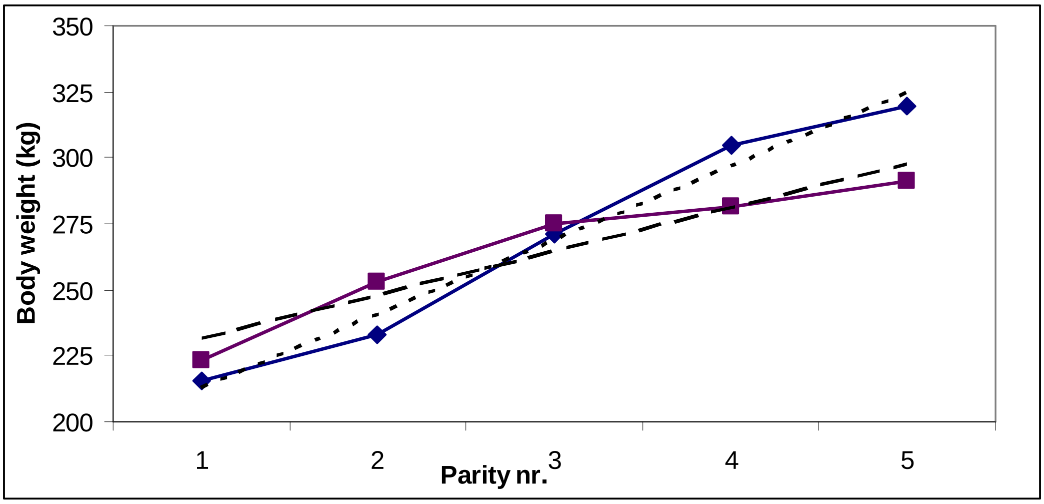


Figure 6 Increase in body weight at day 108 of gestation between parities 1-5 on farms P and H. Farm H: ; R^2 = 0.98, Farm P: ; R^2 = 0.92.

4.1.3 Backfat thickness

Backfat thicknesses of a total of 238 sows were measured according to the Dutch 'stamboek' method. Due to practical involvements a couple of sows were moved to the farrowing stable after day 108, were cripple or were removed from the farrowing stable before the expected weaning date. For this reason not all sows could be used for the complete analysis.

Large differences are seen between the average backfat thicknesses of both farms. The average difference between farm P and farm H at points 1&2 were on average 6.6 mm at farrowing and 6.7 at weaning. At points 3&4 the differences were 7.3 and 6 mm, while differences at points 5&6 between Farm P and Farm H at farrowing and weaning were 5.6 and 5.2 mm, respectively.
In general, backfat thickness at points 1 and 2 was higher in all sows, at both day 108 of gestation and at weaning compared to points 3-6. Backfat thickness was lowest on points 5 and 6, but differences between 3-4 and 5-6 (2.4 mm (P) and 0.7 mm (H) at day 108 of gestation and 1.8 mm (P) and 1.0 mm (H) at weaning) are smaller than differences between points 1-2 and 3-6. The differences in backfat thickness between points 1&2 and 3&4 were 5.2mm (Farm P) and 5.9mm (Farm H) at day 108 of gestation, and 6.1mm (Farm P) and 5.4mm (Farm H) at weaning (average 5.6 mm at day 108 of gestation and average 5.7 mm at weaning).

Loss in backfat thickness during the lactation period differed per farm and per measured point: Sows of P lost on average 7 mm backfat thickness, while sows of H lost on average 6.5 mm backfat during lactation. Summary of the average results per farm are shown in Table 16 and split out per parity in Table 17.

Points	Farm P		Farm H	
	Farrowing Mm	Weaning mm	Farrowing mm	Weaning Mm
1&2	33.5	26.9	26.9	20.2
3&4	28.3	20.8	21.0	14.8
5&6	25.9	19.0	20.3	13.8

Table 16 Average backfat thickness at 6 points measured on day 108 of gestation and at moment of weaning on tested farms.

		Farm P			Farm H		
parity nr.	Moment	1&2	3&4	5&6	1&2	3&4	5&6
1	farrowing	27.9	22.3	21.6	24.7	19.4	19.2
	weaning	21.0	16.3	15.4	19.3	14.2	13.2
2	farrowing	30.5	27.6	25.5	25.5	20.5	19.7
	weaning	24.8	21.7	18.7	19.4	14.3	12.9
3	farrowing	30.5	25.4	24.1	27.0	20.7	20.5
	weaning	26.0	20.9	18.7	20.2	15.1	14.2
4	farrowing	32.4	28.7	25.5	27.4	21.4	20.6
	weaning	24.6	18.6	16.5	19.6	14.4	13.4
5	farrowing	35.3	30.2	28.4	27.4	21.8	20.9
	weaning	28.1	22.1	20.7	21.3	15.0	13.8
6	farrowing	35.0	29.3	26.2	30.2	23.9	22.9
	weaning	27.5	20.9	19.2	22.7	17.4	16.5
7	farrowing	36.2	29.8	27.3	28.2	21.8	21.4
	weaning	28.3	22.6	23.6	19.5	14.7	13.2
8	farrowing	39.6	32.25	28.4	26.9	21.0	21.7
	weaning	29.5	23.25	21.5	22.0	15.3	15.7
9	farrowing				27.2	21.2	20.6
	weaning				23.0	17.0	17.3
10+	farrowing				26.7	23.4	21.8
	weaning				20.4	15.0	14.2

Table 17 Average backfat thickness per parity on tested farms.

Backfat thickness at points 1&2 was increasing as parity number increased. Parity eight sows of Farm P had the highest backfat thickness at points 1&2 (39.6) compared with Farm H and other parities. Biggest backfat losses were seen in eighth parity sow of P (10.0, 10.1, 6.9 for points 1&2, 3&4, and 5&6 respectively, while eighth parity sows of H had smaller backfat losses during the lactation period (4.9, 5.7 and 6.0). To have a clear overview of the development of backfat thickness over parities Figure 7 and 8 are shown.

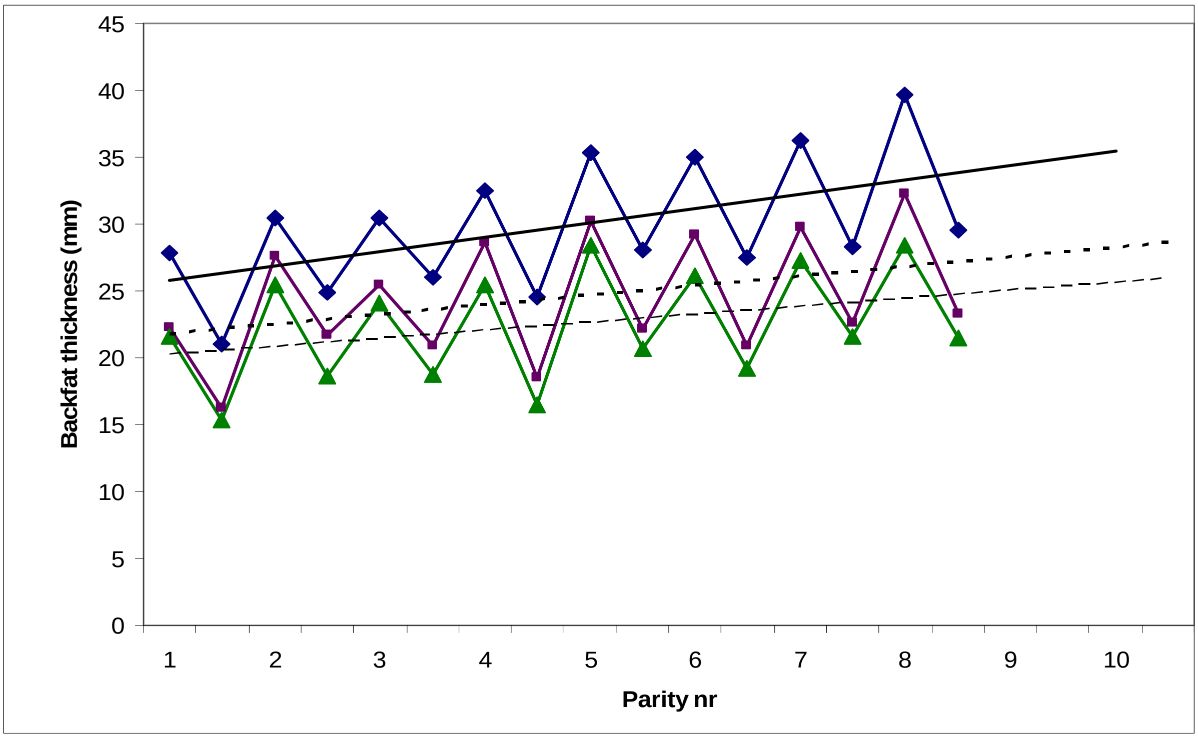


Figure 7 Development and losses of backfat during gestation and lactation of 59 sows on farm P. Points 1&2, Points 3&4, Points 5&6.

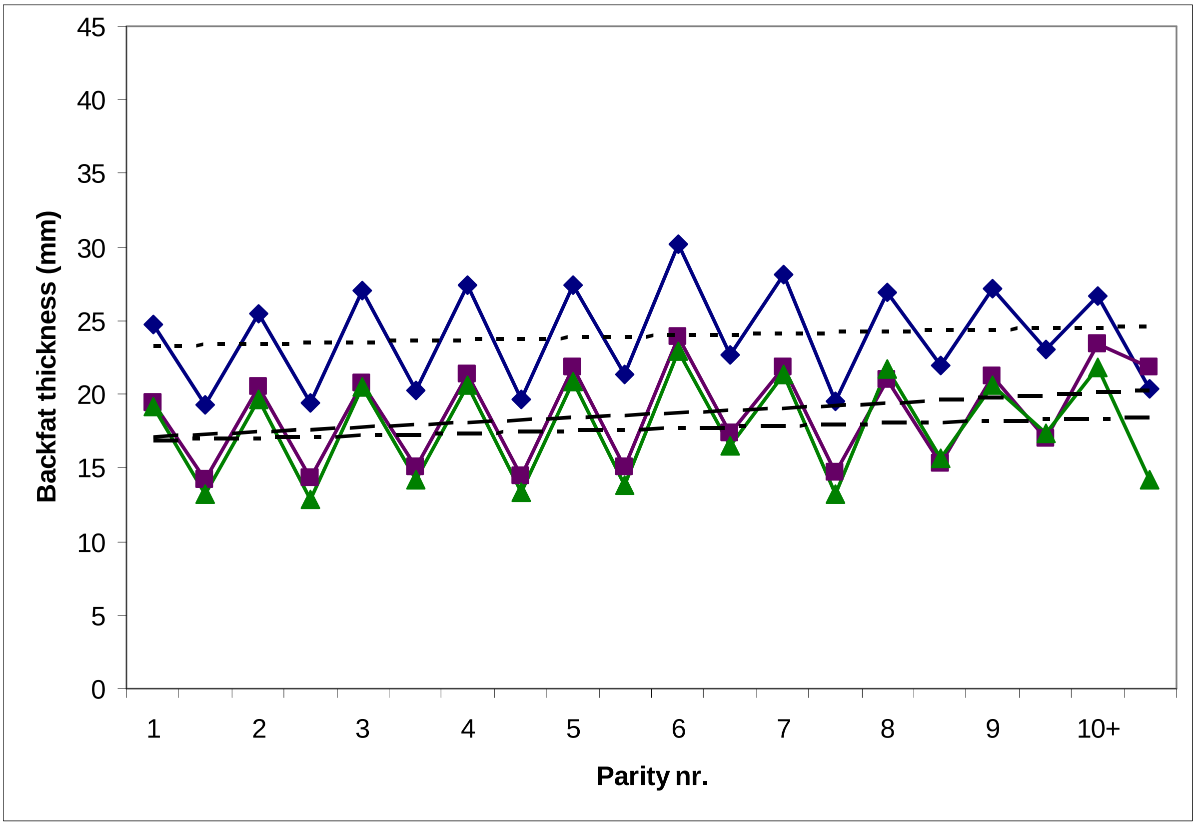


Figure 8 Development and losses of backfat during gestation and lactation of 179 sows on farm H. Points 1&2, Points 3&4, Points 5&6.

From these figures a clear change over parities can be seen in backfat development on farm P, and they give a clear overview of the differences between the two farms.
Sows of farm P show a linear increased development of backfat thickness at day 108 as parity number increases. Especially differences between backfat thickness at points 1&2 and 3-6 become larger, whereas backfat thickness at points 1&2 further increase. Differences in backfat thickness at points 3-6 remain relative constant. The development of backfat between parities is linear: y= 1.51x + 26.6 (R^2 = 0.95). This means that with each parity sows grow 1.51mm of backfat at points 1&2.
Figure 9 shows the development of backfat thickness of these sows. This positive linear effect was less persistent for points 3&4, (R^2= 0.77), and 5&6 (R^2=0.70).

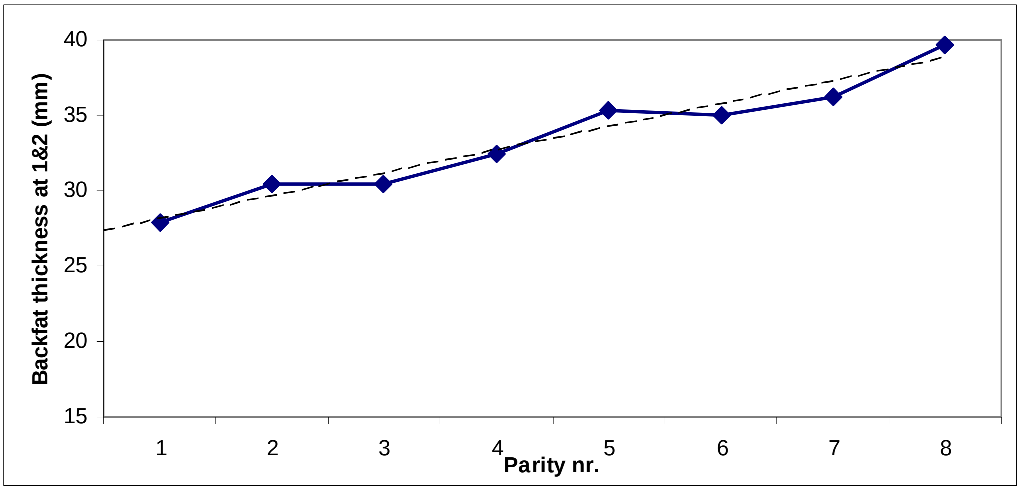


Figure 9 Increase in backfat thickness between parities on farm P.

Sows of farm H showed an increase of backfat thickness development during gestation until the sixth parity, after which less development of backfat thickness during gestation declined. For farm H also positive correlations were found for points 1-6, shown in Figure 10.
Levels of backfat showed a linear increase, reported in Table 18. This table does not show the formulas of the increase in backfat thickness of points 3&4, and 5&6, as these were less convincing.

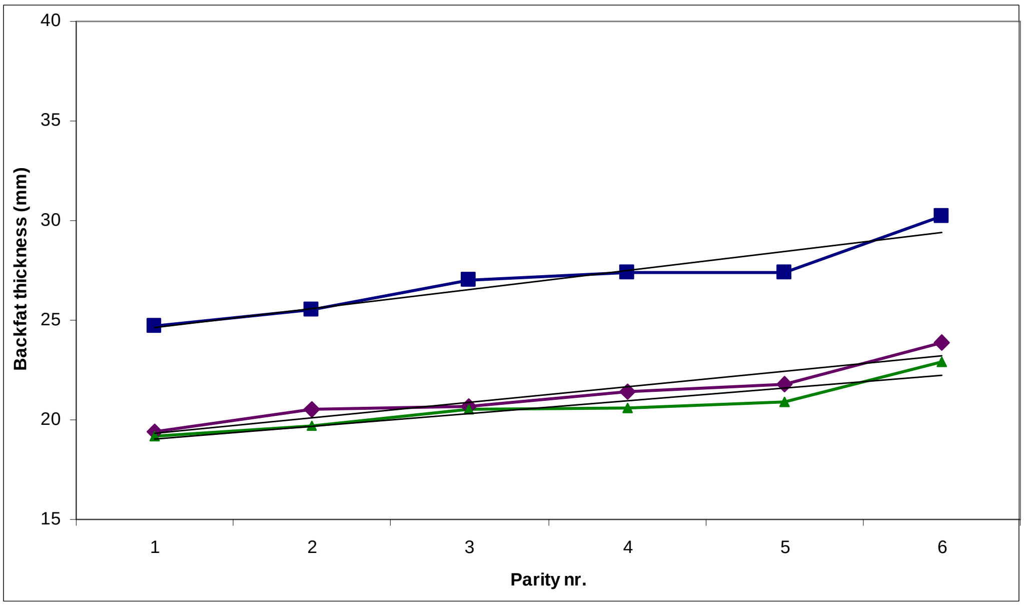


Figure 10 Increase in backfat thickness between parities on farm H, at points 1&2 (—◆—), point 3&4 (—■—), and points 5&6 (—▲—).

Farm	Points	Formula	R^2
P	1&2	y= 1.51x + 26.60	0.95
H	1&2	y = 0.96x + 23.67	0.90
	3&4	y = 0.77x + 18.57	0.90
	5&6	y = 0.63x + 18.41	0.86

Table 18 Formulas related to the linear increase in backfat thickness between parities.

4.2 Correlations of sow factors

4.2.1 Body condition score and backfat thickness

Figures 11 and 12 show the relation between backfat thickness and body condition score of sows on both farms. From these figures is seen that backfat thickness and body condition score show a slight tendency, however, R^2 was clearly stating a low correlation (0.39 for farm P, and 0.16 for farm H). This low correlation can be attributed to the large variation in backfat thickness per body condition score.

Backfat thickness of sows with a body condition score of 3.5 on farm P at day 108 of gestation ranged from 22 to 42.5; on farm H, backfat thickness of sows with a body condition score of 3.5 ranged from 16.5 to 40.0.

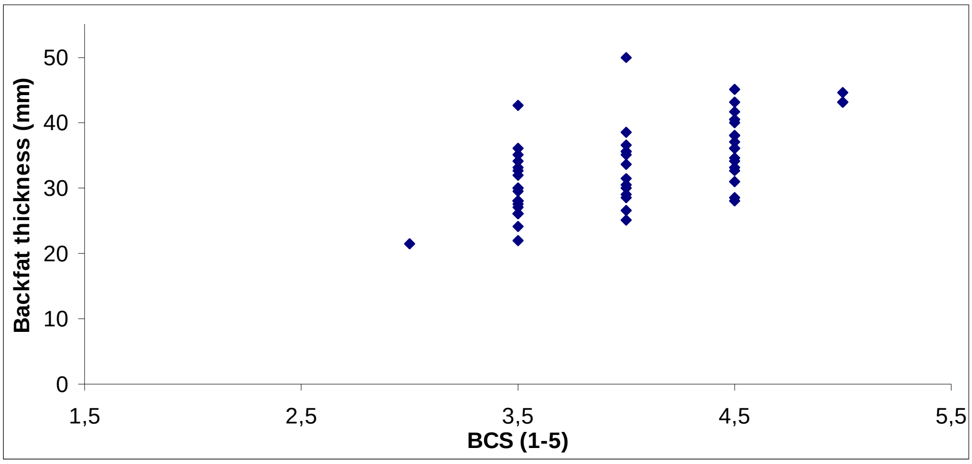


Figure 11 Backfat thickness at points 1&2 and body condition score at day 108 of gestation on farm P (n=58).

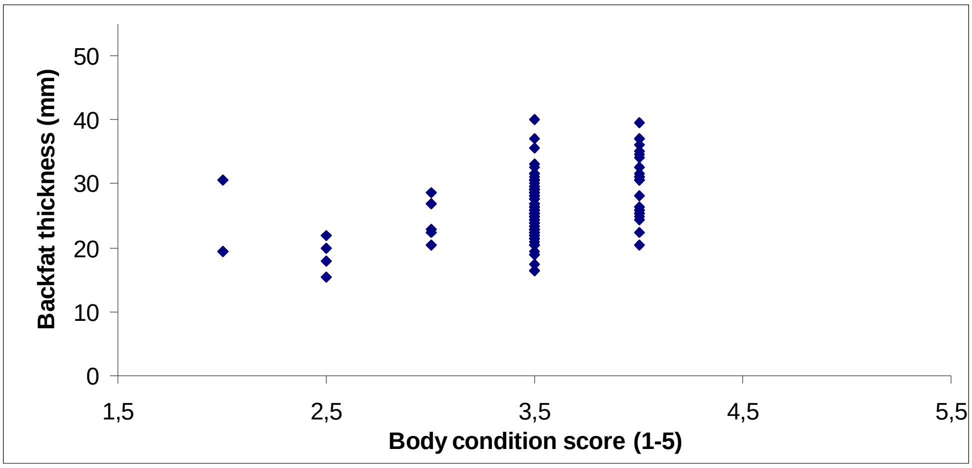


Figure 12 Backfat thickness at points 1&2 and body condition score of the sow at day 108 of gestation on farm H (n=127).

4.2.2 Body condition score and body weight

Body weight and body condition score were also compared with each other, to find possible correlations. An overview is given in Figures 13 and 14. Body weight seems to increase as body condition score increased, although R^2 remained low (R^2 = 0.05 farm H, R^2 = 0.20 farm P). This low correlation can be explained by the large variation in body weight per body condition score. E.g., sows of farm H with a body condition score of 3.5 ranged in body weight from a minimum of 193 to a maximum of 360, while sows on the same farm with a body condition score of 2 ranged in body weight from 184 to 312 kg.

Sows of farm P having a body condition score of 3.5 at day 108 of gestation showed a wide range of body weight; lightest sow weighed 200 kg, while the heaviest sow weighed 340 kg. Sows on the same farm having a body condition score of 4.5 ranged in body weight from 228 to 368 kg.

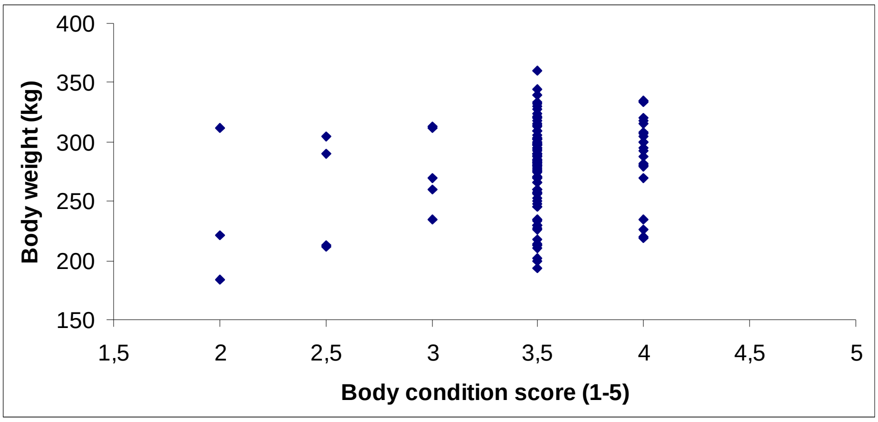


Figure 13 Relation between body condition score and body weight at day 108 of gestation on farm H (n=133).

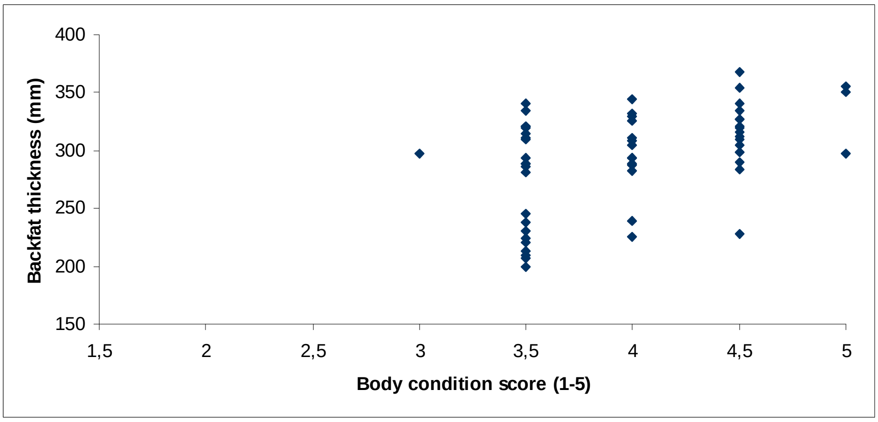


Figure 14 Relation between sow body condition score and body weight of sows at day 108 of gestation on farm P (n=58).

4.2.3 Backfat thickness and body weight

Body weight and backfat thickness were compared to find possible correlations.
Average body weight and backfat thickness were calculated per parity and are presented in Figures 15 and 16. An increase in backfat thickness is seen as body weight increases, but this can be related to the parity number. The sows with low body weight and backfat thickness were mainly first parity gilts, while sows with the highest level of backfat and body weight were mainly older sows. Figure 15 shows that the level of backfat thickness of sows on farm P remains constant during the first four parities, after which both backfat thickness and body weight increase. During these first four parities the sow gain weight, but backfat remains constant. Sows of farm H have a more constant backfat thickness, while body weight increases (Figure 16).
From these figures a clear difference can be seen between the two farms. Differences were clearer on points 1&2 compared to the traditional P2 method (points 5&6). This indicated that backfat level on points 1&2 give more detailed information about sow backfat development over parities.

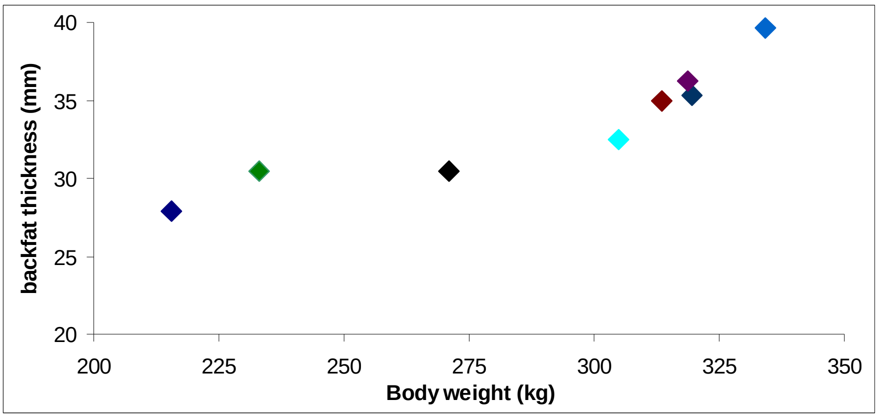


Figure 15 Relation between backfat thickness at points 1&2 and body weight on farm P at day 108 of gestation.

◆Parity 1 ◆Parity 2 ◆Parity 3 ◆Parity 4 ◆Parity 5 ◆Parity 6 ◆Parity 7 ◆Parity 8

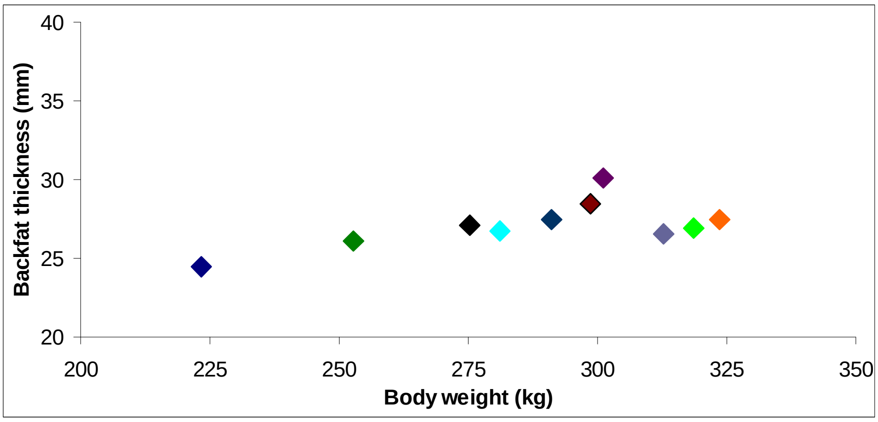


Figure 16 Relation between backfat thickness and body weight on farm H at day 108 of gestation .

◆Parity 1 ◆Parity 2 ◆Parity 3 ◆Pairty 4 ◆Parity 5
◆Parity 6 ◆Parity 7 ◆Parity 8 ◆Parity 9 ◆Parity 10+

4.3 Piglets

Sow reproductive performance and litter vitality can be assessed on several indicators. In this study the following indicators were used: litter size at birth, litter size at weaning, number of live born piglets per litter, and average weight at birth and weaning. These indicators are described in the following chapters.

4.3.1 Litter size at birth and birth weight

Litter sizes were in general higher on farm H compared to farm P, although the number of stillborn piglets was lower on this farm compared to farm H. However, the number of live born piglets was higher on farm H compared with P. On the farm of Farm P the average litter consisted of 13.6 piglets, of which 12.9 piglets were live born. Litters sizes on this farm were largest in parity four sows, while first parity sows delivered the smallest litters with on average 12.33 piglets. Litter size on farm H consisted on average of 15.54 piglets and were smallest in third-parity sows, while first parity sows had on average the smallest litters.
Average birth weight of piglets on farm P was 1.43 kg. Average birth weight of piglets was highest of parity 7 sows and lowest in parity 3. On farm H the average birth weight was 1.40 kg. Average birth weight and litter size are described per parity number in Table 19.

Parity nr.	Farm P				Farm H			
	Average litter size	Average nr. live born	Average nr. stillborn	Average birth weight (g)	Average litter size	Average nr. live born	Average nr. stillborn	Average birth weight (g)
1	12.83	12.33	0.50	1431.52	14.41	14.00	0.41	1334.67
2	13.67	13.67	0.00	1243.27	15.63	15.46	0.17	1403.29
3	14.25	14.00	0.25	1206.44	16.48	15.43	1.04	1406.03
4	14.78	13.44	1.33	1464.32	15.39	14.27	1.12	1431.47
5	14.46	14.31	0.15	1381.76	16.00	15.56	0.44	1453.33
6	12.46	11.46	1.00	1498.71	15.62	14.29	1.33	1373.79
7	12.60	12.00	0.60	1571.41	15.88	15.13	0.75	1328.06
8	14.25	12.75	1.50	1358.61	15.69	13.77	1.92	1380.02
9					16.14	13.43	2.71	1344.70
10+					14.56	12.89	1.67	1542.63
total	**13,64**	**12.95**	**0.69**	**1433.15**	**15.54**	**14.63**	**0.92**	**1397.78**

Table 19 Average litter sizes, and birth weights per parity on farm P and H.

Figure 17 and 18 show the division of birth weight of all piglets on both farms. Average birth weight was lower on farm H compared to farm P. On farm P 12.1% of the total number of weighed piglets had a birth weight below 1000 gram, compared to 14.9% of the piglets on farm H. 7.1% of the total weighed piglets on farm H exceeded a birth weight of 1900 gram, while the goal is minimum of 4%. On farm P this figure was 9.8%.

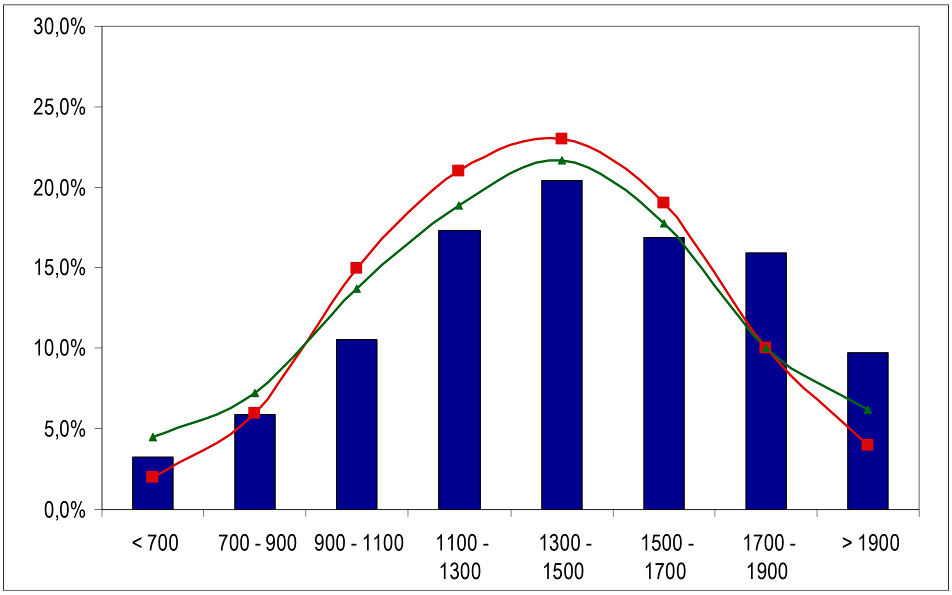


Figure 17 Distribution of birth weight of all piglets on farm P compared with Dutch standards.

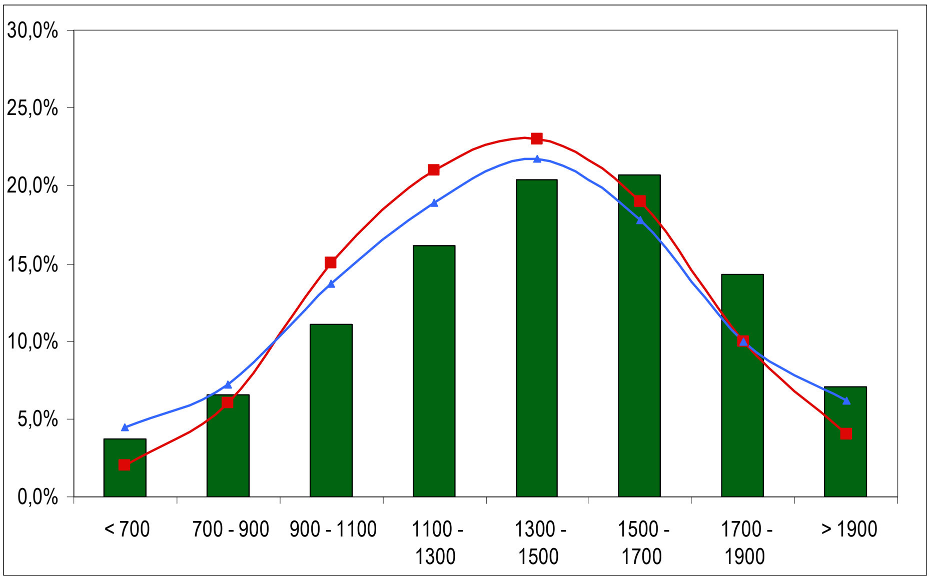


Figure 18 Distribution of birth weight of all piglets on farm H compared with Dutch standards.

Figures 19 and 20 present the relation between the number of piglets and the average weight of piglets per litter. A slight tendency is seen between total number of piglets and average birth weight, with a higher number of piglets resulting in a lower birth weight. However, the R^2 remained low for both farms (Farm P 0.11; Farm H 0.24). A wide variation was seen in the birth weight of piglets.

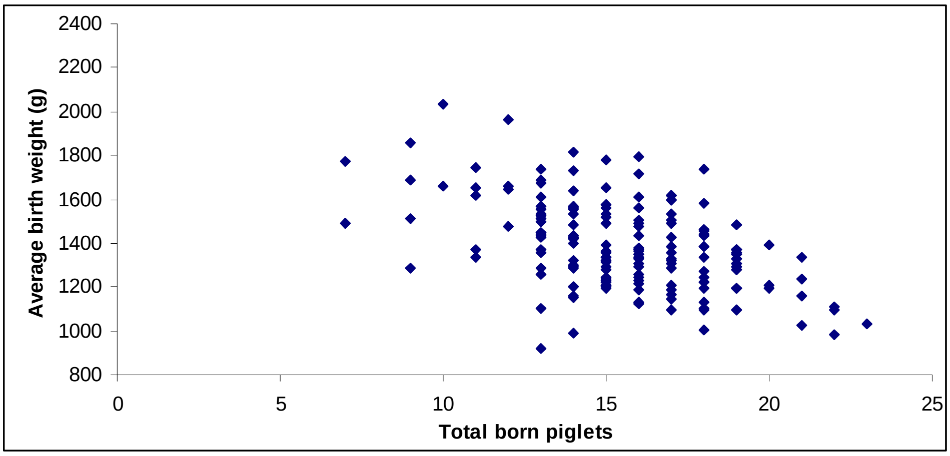


Figure 19 Litter size and average birth weight piglets per litter on farm H.

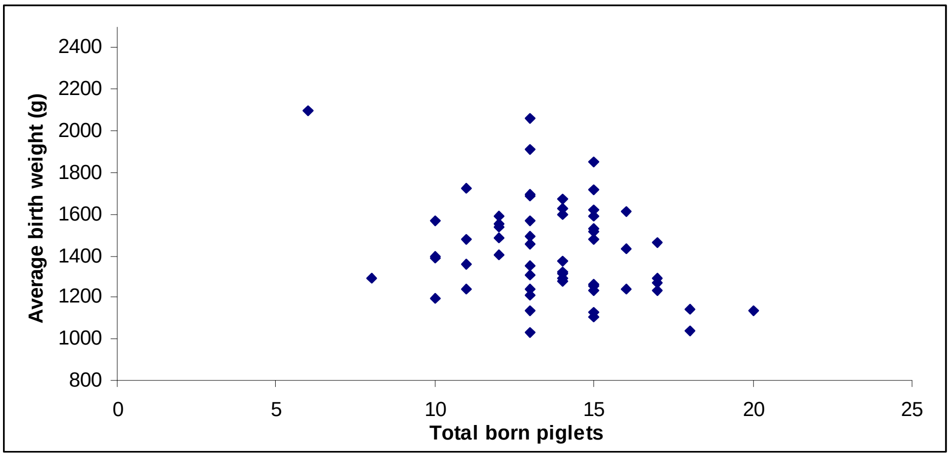


Figure 20 Litter size and average birth weight piglets per litter on farm P.

4.3.2 Parity number and total litter size at birth

Total litter size at birth was calculated by means of the number of stillborn and live born piglets. A large variation was seen in total litter size at birth. An increase in the total number of piglets was seen in parity 1-4 in sows of farm P, while an increase in litter size was seen in 1-3rd parity sows of farm H. Largest variations were seen in sows of parity 5 and 6 on farm P, with a litter size ranging from 10-20, and 8-16, respectively. Variations in litter size on farm H were largest in first and fourth parity sows: litter size of first parity sows ranged from 7 to 21 piglets, and litter size of fourth parity sows ranged from 7 to 23 piglets.
In Figure 21 the average number of piglets per sow per parity number is presented, including the variation within each parity.

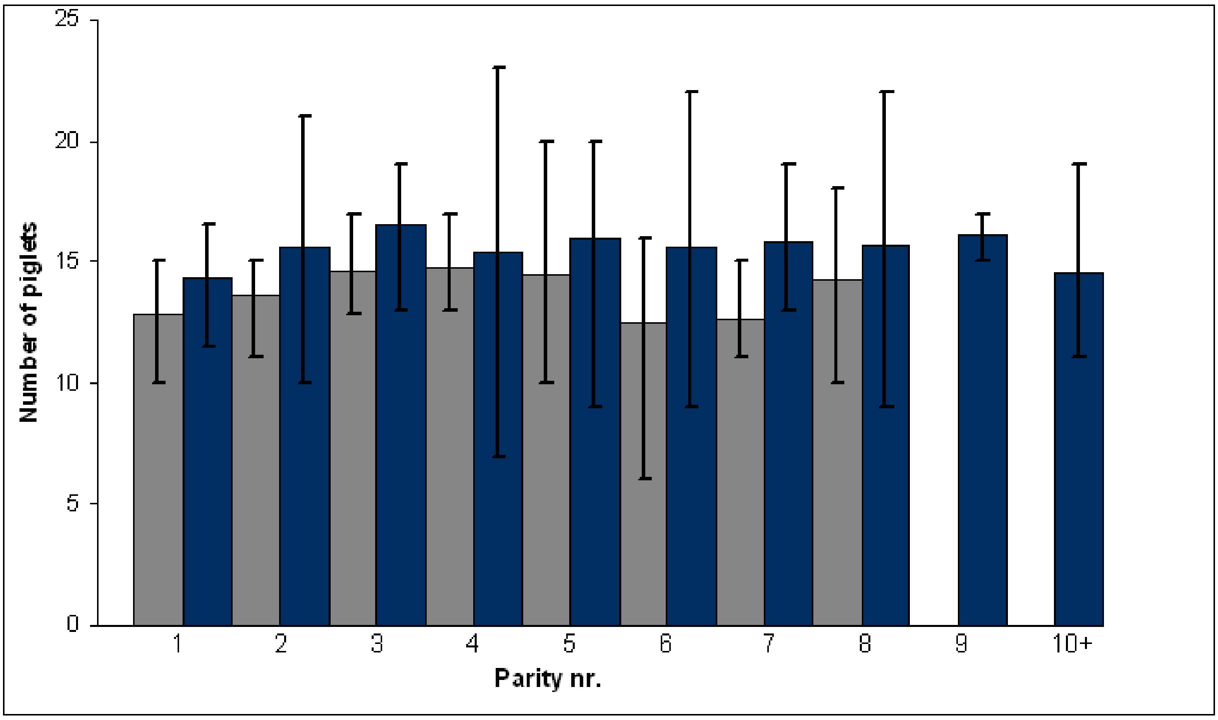


Figure 21 Average number of total born piglets per litter per parity number on farm P Farm H ■. and farm H ■, including lowest and highest number of total born piglets per parity number.

4.3.3. Parity number and average birth weight

Birth weight of piglets showed large variations within parities. Average birth weight of piglets on both farms was on average within a range from 1000-1750 gram.
Figure 22 shows the average birth weight of all piglets of sows within the same parity number. Per parity number also highest and lowest birth weight are reported.

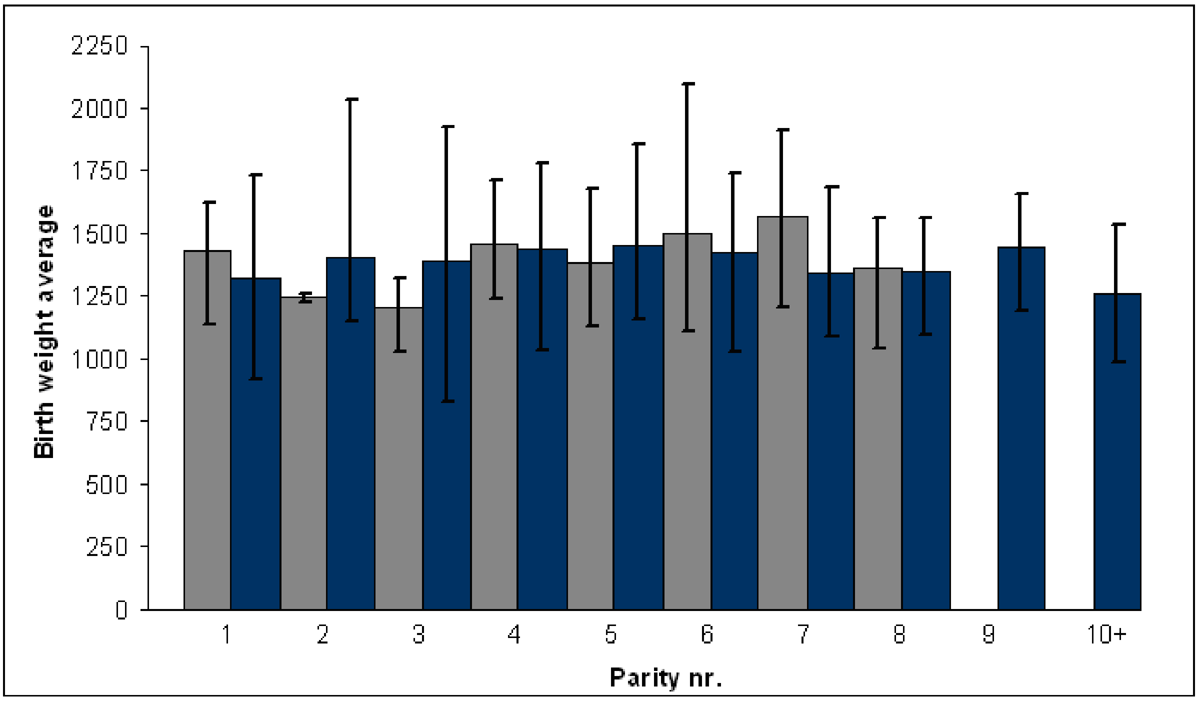


Figure 22 Average birth weight per parity number on farm H and farm P, with lowest and highest birth weight of piglets. Farm H ; Farm P .

The figure shows that variations among litters are high and the average birth weight does not show a direct relation with parity number. Though, average birth weight is important as birth weight is expected to be important for piglet growth during the lactation period.

4.3.4 Litter size at weaning

On farm H the average litter size at weaning was 12.2 piglets. The average number of piglet per litters was lower on farm P, with on average 10.59 piglets per litter. The average weight of the piglets on farm H at weaning was 7.20 kg. Weight at weaning was lowest in gilts, and was highest in seventh parity sows. In general, piglets of farm P were heavier (7.93 kg) at moment of weaning compared with piglets of farm H. Piglets of litters of parity 7 sows on farm H, and parity 8 sow of farm P were heaviest. Table 20 shows average piglet weight and litter size at weaning.

Farm P			Farm H	
Parity nr.	Average weight at weaning	Average litter size at weaning	Average litter size at weaning	Average weight at weaning
1	7387.32	11.24	6257.28	12.67
2	6396.61	11.67	7092.20	12.05
3	8267.50	10.25	7302.69	12.57
4	7790.10	11.22	7675.04	12.33
5	8196.56	10.77	7374.76	12.26
6	7968.36	10.08	7445.00	12.05
7	8356.90	9.40	8240.43	11.31
8	8543.81	10.00	7038.54	12.00
9			7079.24	11.57
10+			6534.16	12.11
	7931.96	10.59	7196.36	12.21

Table 20 Average litter size and piglet birth weight per parity number.

193 litters of farm H were weighed at both moments, together with 55 litters of farm P. Average weight per piglet was calculated per litter at birth and moment of weaning. Average weight gain was reported, by means of calculating the weight gain of this average piglet per litter. These figures are shown in Figure 25. In general piglets of farm H showed a larger weight gain during the lactation period compared with piglets on farm P (6.54 versus 7.12kg). Weight gain of piglets on farm H seemed to increase as parity number increases, with a small drop in fifth and sixth parity sows. Piglets of first parity sows on farm P showed a large weight gain during the lactation period compared to piglets of farm H (Figure 23).

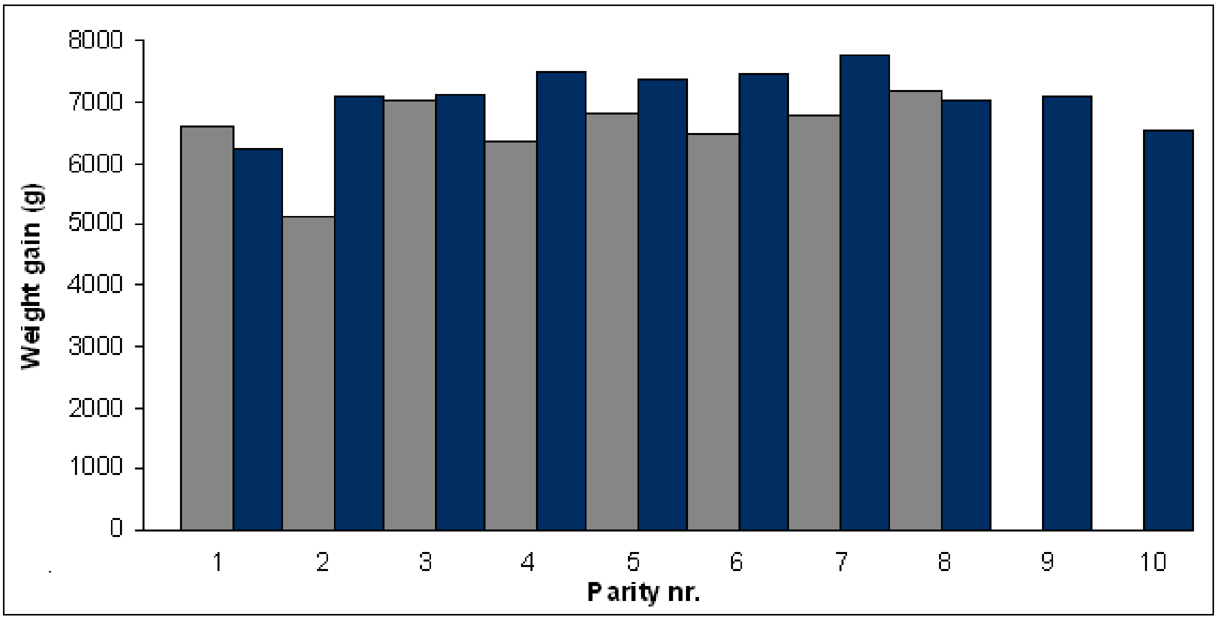


Figure 23 Average weight gain during lactation of piglets within the same litter on farm H and P. Farm H ■ ; Farm P ■.

4.4 Relations between sow condition and litter performance

4.4.1 Relations between piglets and sow backfat thickness

Relations between the condition of the sow and litter vitality and performance were assessed on the earlier mentioned indicators. Figure 24 and 25 show the relation between the sow's backfat thickness at points 1 and 2 at day 108 of gestation, and the average birth weight of piglets on both farms. No relation is seen between backfat thickness of the sow and average birth weight of the piglets as a wide variation was observed.

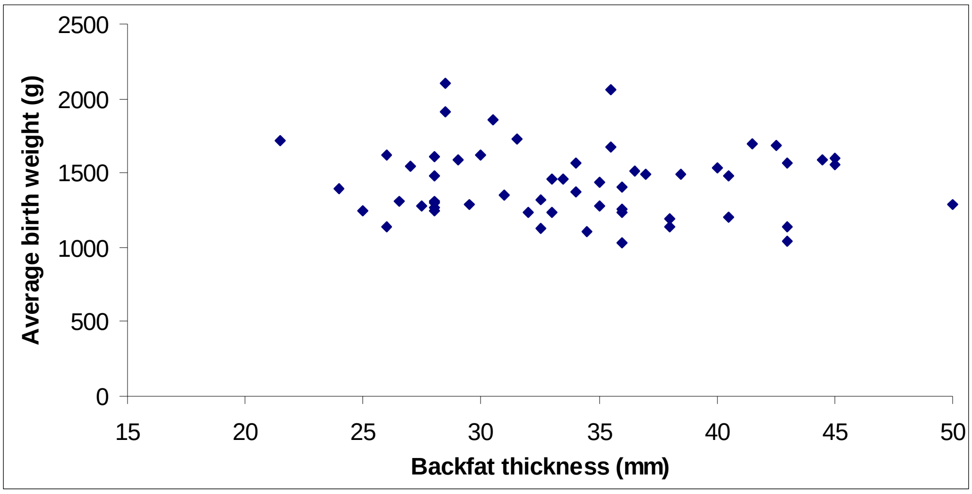


Figure 24 Sow backfat thickness at points 1&2 and average birth weight on farm P.

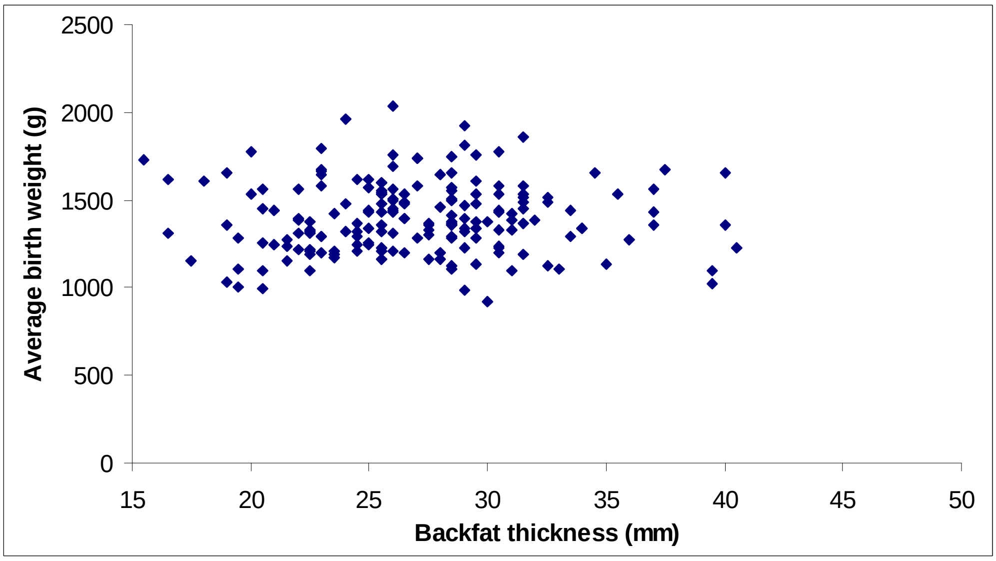


Figure 25 Sow backfat thickness at points 1&2 and average birth weight on farm H.

It was also investigated if the number of stillborn piglets was dependent on the backfat thickness and parity number of the sow. These findings are presented in the following figures (Figures 26 and 27). Large variations were seen in stillbirth and no relation was found between the numbers of stillborn piglets and sow backfat thickness and parity number.

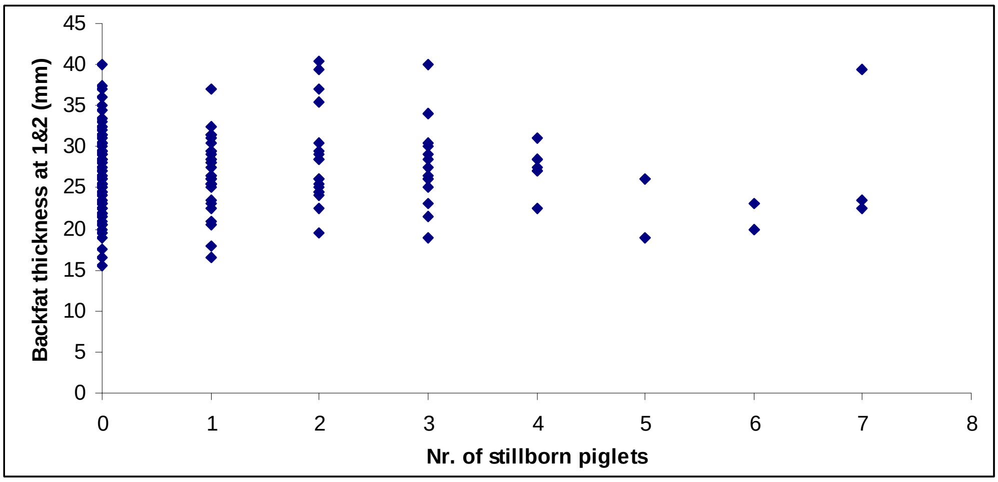


Figure 26 Relation between the number of stillborn piglets and the backfat thickness of the sow at points 1&2 on day 108 of gestation: Farm H.

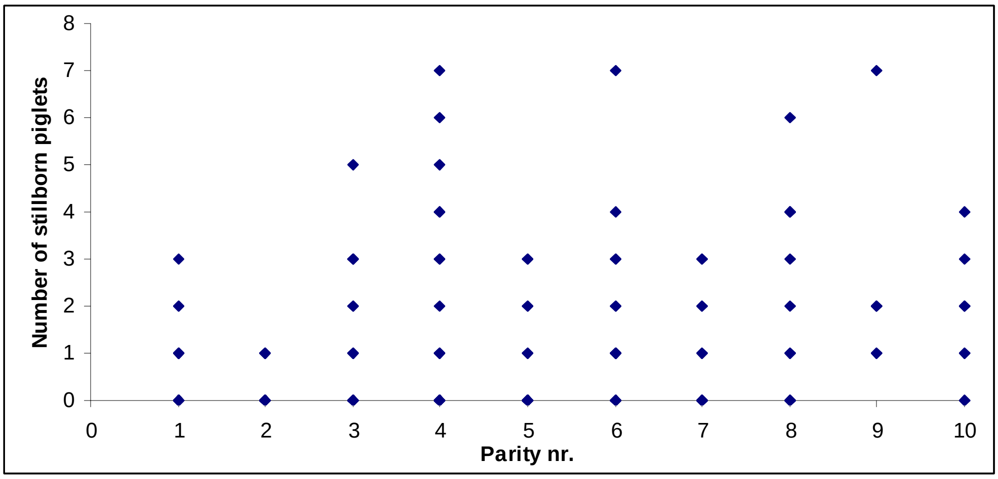


Figure 27 Relation between parity number and the number of stillborn piglets on farm H.

4.4.2 *Sow backfat thickness and piglet weight gain during lactation*

It was investigated whether the weight gain of piglets was influenced by the backfat loss of sows. An overview of farm P is shown in Figure 28 and in Figure 29 for farm H. A wide variation was seen on both farms, and no relation was found. These figures show a negative loss of backfat during the lactation period, for a small number of sows. In fact, this is an increase in backfat thickness of the sow during the lactation period.

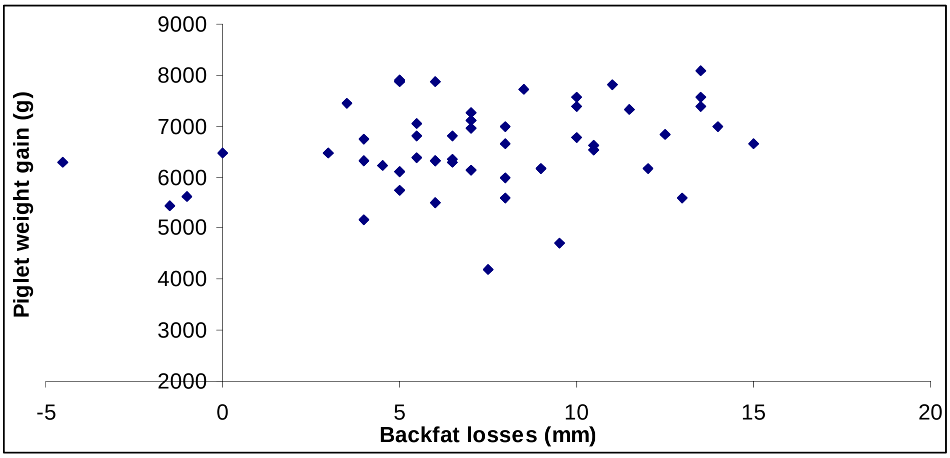


Figure 28 Relation between sow backfat losses and piglet weight gain during the lactation period on farm P.

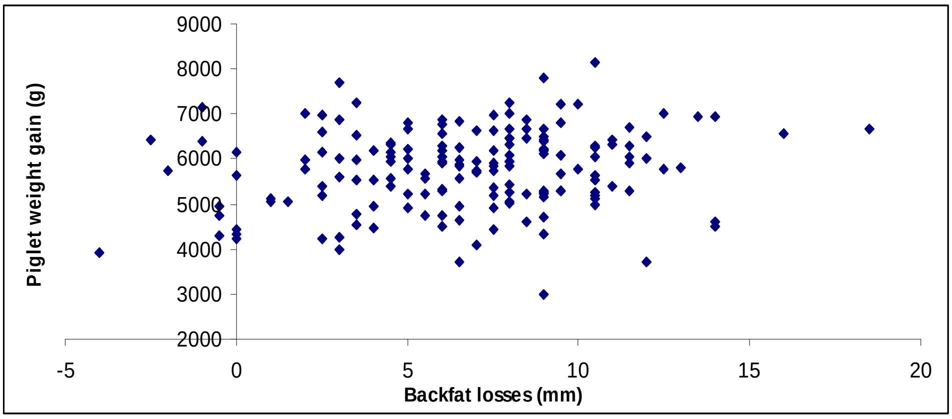


Figure 29 Relation between sow backfat losses and piglet weight gain during the lactation period on farm H.

4.4.3 Sow weight loss and piglet weight gain

The relation between sow weight loss and piglet weight gain is investigated. Per sow the average weight loss was calculated by means of the difference in weight at day 108 of gestation and the weight at moment of weaning. Weight losses of all weighed sows were used for the analysis.
In Figures 30 and 31 the relation between sow body weight loss and piglet weight gain during the lactation period are shown. No relation was seen between sow weight loss and piglet weight gain as a result of large variations. It should be noted that the weight losses of the sow include the weight of the litter, and products resulting of gestation, such as the placenta.

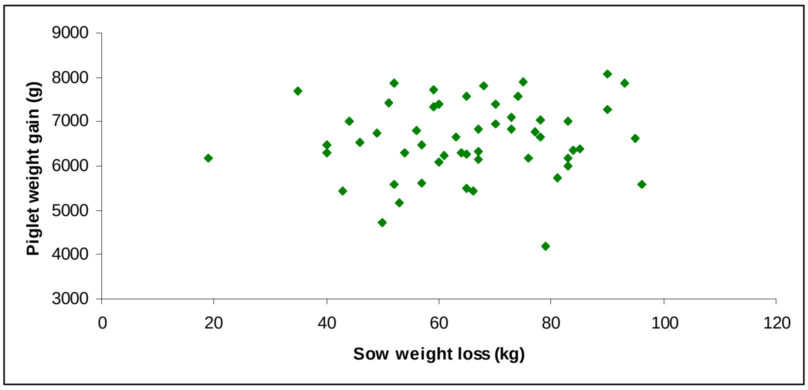


Figure 30 Relation between weight loss of the sow and piglet weight gain during lactation; Farm P

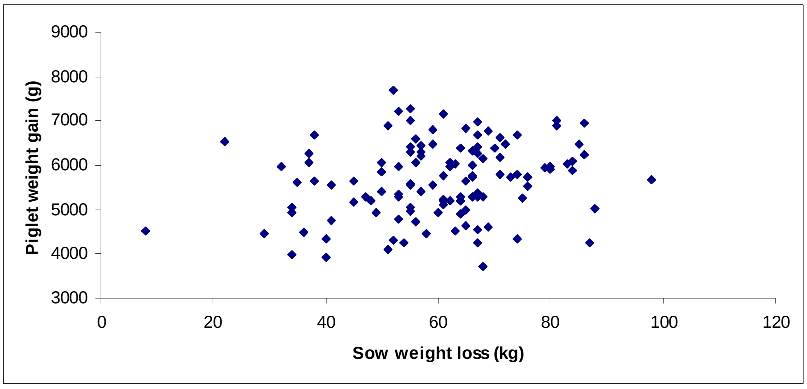


Figure 31 Relation between sow weight loss and piglet weight gain during lactation; Farm H.

Finally, the relation between the feed intake during lactation of the sow on farm H, and the average weight gain is investigated. 56 sows of farm H were fed a ration with lower levels of energy and digestible energy. It was expected that a high feed intake of the sows would have a positive influence on the weight gain of piglets, and the weight gain of the piglets of the second group was lower as a result of lower energy and nutrient intake. The results are shown in Figure 32.

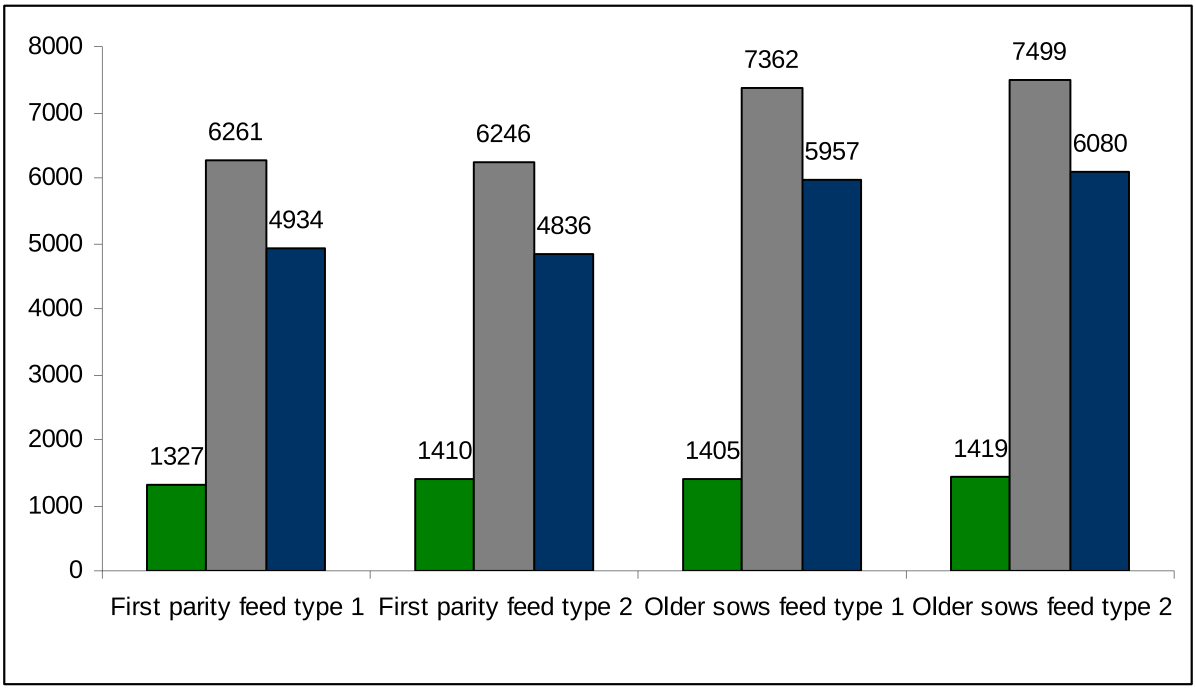


Figure 32 Influence of maternal feed intake during the lactation period on piglet weight gain and weight at weaning on farm H. : Average birth weight of piglets , : Average weight at weaning, : Average weight gain during the lactation.

5. Discussion

5.1 Practical situations

This study was executed to evaluate the influence of the sow's body condition on piglet vitality. To meet this objective 286 sows were used on 2 farms. Data of these 2 farms was compared and was checked for differences and similarities. Large differences were seen between these farms and within farm data, although the sows had the same genetics. Sow on farm P were fed 20% above the expected feeding levels in the gestation period because of computer control failure. These sows showed excessive levels of backfat thickness and body weight gain. This had influence on the outcomes of this research, though; many outcomes of the survey were still in line with the outcomes of farm H.

When writing a research proposal it is difficult to determine all possible problems in a practical setting. One of these unforeseen problems was cross-fostering. At both farms cross-fostering occurs. Sows having too many piglets, compared to the number of functional teats can be spared by means of fostering a number of piglets by other sows, having fewer piglets. During this survey it was not noted which and how many piglets were cross-fostered. This makes it difficult to determine the weight gain of the individual piglet and the litter. In next surveys cross-fostering should be noted. It should also be noted that not all sows and litters can be used for the analyses as a result of failures during the measurements.
Outcomes of this line show that doing a research in practical settings results compared with studies in build-up settings. The variation is in practise is larger than in setting in which small groups of selected animals are used. This highlights the importance of verifying the outcomes of a research with practical results. A good example is the backfat thickness of the sows. On both farms, the backfat level of the sows, was higher compared to recommendations according to literature. This indicates that information about previous studies may be dated or not suitable for all genetics.

5.2 Sow condition

5.2.1 Body condition score

Body condition score is used in many swine producing farms to estimate the feeding levels of the sows mainly during gestation. Body condition score is a subjective method to assess the sow's body condition score, and differs per assessor. Correlation coefficients in recent research between body condition score and the two other condition scores (backfat and weight) were low.
For instance, the relation between sow body condition score and backfat thickness are poorly correlated (0.39 for farm P, and 0.16 for farm H). Whether this was expected, data showed a lot of variation. This poor correlation is in line with findings of Young et al., 2001. Several studies reported a low correlation between body condition parameters as well (Ebenschade et al., 1986; Whittemore et al., 1980).

Results from this research and from mentioned literature are indicating that doing a subjective condition score of sows is only giving an overall condition level of the herd, e.g. on these two farms it could be concluded that body condition scores of sows on farm P were higher compared to farm H. However, because of its subjectivity it is not related at all with measured factors like backfat thickness. Risk of feeding sows according to their body condition score is that sows are becoming too fat and/or are fed more on muscle development.
Current practise is asking more and more for an optimised feeding schedule towards sows, to optimise the efficiency and production goals. To reach this, more objective measurements should be executed on farm level to be more precise towards sow feeding.

5.2.2 Backfat thickness

Backfat thickness is an objective method to assess sow body condition. It gives insight on the energy reserves on different locations of the sow. Backfat thickness was measured at 6 points to gather more accurate information about the development and losses of backfat. It was found that backfat thickness was highest at points 1&2, and lowest at points 5&6. Backfat thickness can be divided into two types (Quirijnen, 1996). Target fat is genetically determined and needed for metabolic function. This layer should not be metabolized as this fat plays an important role in reproductive processes. Depot fat is fat that can be used for energy reserves. It was expected that sows have mainly depot fat at points 1&2 while at points 5&6 backfat consists mainly of target fat. This means it was expected that sows would lose and gain more backfat at points 1&2 compared with 5&6. However, sows did not lose more backfat at 1&2 compared to other points on the sow's back.
Measuring backfat thickness at points 1&2 gives a clearer overview of the changes in backfat thickness in time. This is in line with the differences between farm P and H. On farm P a clear increase in backfat thickness was observed with increasing parity, which was easier to observe at points 1 and 2 compared with 5&6. Small changes in body condition score at 5&6 are in line with larger changes at points 1&2, as the sow gains easier backfat at this point.

It can be concluded that sows on farm H were fed more accurate according to their nutrient requirements as no increase in fat storage occurred on points 1&2 with increasing parity. On farm P the nutrient intake was higher than the expected nutrient requirements and as a result excessive fat storage occurred. This can probably be addressed to the different approach on feeding sows on farm P and H. Sows on farm P were fed based on the body condition score, while sows on farm H were assessed based on backfat measurements. Backfat thickness is an objective method to assess body condition of a sow, and a more accurate method to steer feeding in gestation. By measuring backfat thickness and feeding sows more on individual basis, the variation in body condition can be decreased or stabilized, having a positive influence on the reproductive performance overall. Literature states a optimal backfat loss of about 4mm. This is not in line with this study, as the backfat losses on both farms is on average much higher. Advice according to literature may be dated, not in line with recent genetics or production levels.

Literature focuses mainly on the P2 method when measuring backfat thickness of the sow. This makes it is difficult to compare recommendations or findings according to literature and findings of this study. Research of Close and Cole (2000) showed the same line of development in backfat thickness as the findings of this study. Both showed an increase in backfat as parity number increased. However, backfat recommendations of Close and Cole (2000) were higher compared with farm H but lower compared with farm P.
In contradiction with these studies Hühn (1996), Groppel (1999) and Hühn and Gericke (2000) showed a decline in backfat recommendations as parity increased. It should be noted that evaluated breeds are not known.
More precise and up-to-date knowledge is necessary in order to improve recommendations towards sow backfat thickness during the different stages of the reproductive cycle. It would be interesting to gain more information on the backfat thickness of sows per parity in order to create recommendations towards backfat thickness per parity number. Also more research is necessary in order to create more insight in the optimal backfat level of sows per breed. A follow-up study therefore is necessary.

5.2.3 Body weight

Large differences were seen between and among the two farms. The difference between the 2 farms can mainly be addressed by the 20% overfeeding on farm P during the gestation period. However, weight development is already starting at moment gilts are introduced to the herd, and therefore influenced for the rest of the sow's life. Important, therefore, is to weight gilts and sows each cycle to control the development and uniform the herd.

Body weight showed no relation with the other 2 parameters of sow condition. It was expected that sows with a high body weight also had a high level of backfat and a high body condition score. Especially the correlation between backfat thickness and body weight was low (R^2 farm H =0.05, R^2 farm P = 0.20). This can be addressed to the development of sows during the first 5 parities. During these parities sow body weight increased linear, with a gain of 28 kg (P) and 16 kg (H) each parity. During these parity backfat thicknesses of the sows remained relative constant, which means that sows mainly grow in body mass, without becoming fat. From this, it can be concluded that sows are not fully developed until parity number 5. A research of Hoving (2011) concluded that sows develop until parity number 4 towards a weight of 250 kg.

Body weight of the sow should be measured in order to evaluate the sow's development during the different gestations, especially the first 5 five parities, where backfat does not develop. Especially the first 5 parities it is important to weigh the sows, as the backfat level of these sow remain relative constant, and body weight is during these parities more accurate. When controlling both sow body weight and backfat thickness by using objective methods, feeding schedules can be adapted more precise to the need of the sow. This results in a more uniform sow herd and more focus on the development of the young sows. This focus will result in improved reproductive performance of the total herd and more durable sows.

5.3 Feed intake of the sow during gestation

Feed intake during the gestation period was higher on farm P compared to farm H. Total feed intake of first parity sows was 342 kg. The total energy and digestible lysine intake was 1668 EW, and 363 g, respectively. Older sows were fed in total 402 kg containing 1958 EW and 426 g digestible lysine.
On farm H the total intake during the gestation period of first parity sows was 289 kg (1393 EW, 290 g digestible Lysine). Sows in the second to fifth parity were fed 333 kg (1599 EW and 336 g digestible Lysine) and parity-six sows or older were fed 344 kg (1168 EW/ 347 g digestible Lysine).

Although sows of parity 2 and older did not increased in feed intake on farm P, their backfat level showed an increase as parity number increased, while sows on farm H remained relative constant in backfat, and their feed intake increased from parity 6 and older. This difference may be explained by the lower energy requirements of sows on farm P, as their litters were smaller. These sows probably were fed a too high level from the day they were as gilt introduced to the herd, resulting in depositing more and more backfat, and backfat losses during lactation were lower than the gains.
From these findings, it can be concluded that on farm P the feeding levels are not in line with the sow needs over the different parities.

Sows on farm P were expected to have a smaller litter size as the high feed intake would have a negative effect on embryonic survival rates and it will influence the performance in the lactation stage. This is in line with studies of den Hartog and van Kempen (1980) who concluded that a higher feed intake during the early-gestation period resulted in a higher embryonic mortality rate. Van Gils (2002) concluded that this was a result of the hormonal regulation as perinatal mortality is influenced by the progesterone level in the blood. An extremely high feed intake is affecting the progesterone level negatively.
These studies were in agreement with the outcomes of this study, in which litter size was smaller on farm P compared to farm H. It can be concluded that feeding sows a too high level of nutrients and energy around the oestrus cycle and early gestation period has negative effect on litter size at birth.

It should be noted that a too low feed intake also has a negative effect on the reproductive performance. Research of Zak et al. (1997) concluded that a restricted feed intake during the last week (days 22-28) of lactation had a negative effect on follicle development. In this study sows were fed ad libitum until day 21 of lactation, after which at days 22 to 28 the sows were fed 50% of the average feed intake in the previous 5 days. These sows had a decreased follicle maturation. Almeida et al. (2000) found a relation between a restricted feed intake during days 8-15 of gestation and an increased embryonic mortality rate. These sows were fed 2.1 times the nutrient requirement for maintenance, calculated from the sow's body weight at day 7 of gestation. Embryonic mortality was significant higher in restricted sows.
It can be concluded that the feed intake of the sow during the oestrus cycle and early gestation period should both not be too low or too high. It should meet energy requirements for body maintenance and reproductive performance. Van de Pavert (2002) advices a restricted feed intake of 1.1 to 1.5 times the required feeding levels for body maintenance at the beginning of gestation during the first 10-14 days of gestation in order to optimize reproductive performance.

Overall results from this study and from literature are clearly indicating that improving the number of weaned pigs is starting already short after mating by feeding the sow the correct amounts of feed and nutrients. However, it is still not clear what energy or lysine levels are needed, while literature used and available is old and current figures are very scarce.

5.4 Feed intake of the sow during lactation

It is important to increase the milk yield of the sow, to increase piglet weight gain during the lactation period. Therefore, the condition of the sow should be kept optimal: not too high, not too low. This can be influenced by the feed intake of the sow's during the gestation period.
As mentioned earlier, the feed intake of sows on farm H was lower compared with sows on farm P, and was more in line with the nutrient requirements compared to the high feed intake of sows on farm P. This high feeding level during gestation on farm P has resulted in lower feed intakes during the lactation period. In addition, the feeding levels on farm P were lower during lactation compared to H. These findings are in agreement with conclusions of previous studies (Hoste, 1993; Prunier et al., 2001; Yang et al., 1989; Thacker, 2000; Van Gastel, 2007), who expected that a sow with excessive backfat levels had a decreased feed intake during the lactation period, resulting in a decreased milk production, thus smaller weight gains.
lactation. This part again confirms also how important feed intake and regulation is. Even this is in the lactation period, which is often not seen as influence.
More research should be done to investigate the optimal backfat level during the different stages of the reproductive cycle.
The small differences can be addressed to the litter sizes on both farms. Sows on farm P had smaller litters compared to farm H, so relative more milk was available per piglet on farm P compared to H.

It was expected that a high feed intake during lactation has a positive influence on the weight of piglets at moment of weaning. Feed intake of sows on farm P was lower compared with sows on farm H, so more weight gain was expected in piglets of farm H compared to farm P. The average weight gain of piglets on farm H was slightly higher than on farm P, though differences were relative small. However, the fact that farm P had smaller litters compared to farm H, gave in contradiction expectations that relative more milk was available per piglet on farm P and should give better weight gains.

5.5 Relations between sow factors and litter vitality

5.5.1 Influences on litter size

An increase in litter size was seen on both farms during the first 3 parities. After parity 3 the litter size remained relative constant. This is in line with a study of Tummaruk et al. (2000) and Kemp (2010) who also concluded an increase in litter size during the first 3 parities, after which litter size in parities 3-6 remained relative constant. Litter sizes were expected to increase as parity number increases with a small drop in the second parity. Latter is a known problem in pig production. Indications are that the impact during the first cycle of the sow is too much to be high productive again in second parity. Currently several studies are focussing on this subject (Hoving….). Could it be too low levels of nutrients in lactation or is the development of the gilt undermined during the gestation period?

5.5.2 Influences on the average birth weight

Average birth weight on farm P was higher compared to farm H. Litter size did not seem to influence the average birth weight when correlations were calculated. Though, a slight relation could be observed by eye in the graphs. However, the R2 remained low (P: 0.11, H: 0.24). Literature states that the average birth weight of piglets declined as litter size increases, but in this research variations between litter sizes did not gave this effect. It is important to keep the average birth weight of the piglets high, as this increases the survivability of the piglets. It should be evaluated per parity if a relation can be found between the average birth weight of piglets and the litter size, as it is known that the litter size is influenced by parity number.

Backfat thickness did not seem to influence the average birth weight of piglets, as variations were large in both factors backfat thickness and average birth weight. That no relation was found between backfat thickness of the sow and average birth weight of the piglets may be addressed to the fact that energy is less required for foetal growth compared with protein.
Literature states that sows should be fed high levels of feed in order to provide the sow enough nutrients and energy for both body maintenance and gestation, including foetal weight gain. On the other hand, sows not should be fed too high levels of feed to develop excessive fat levels. This will have negative influence on the sow's reproduction in the next cycle.
It can be concluded that a high backfat thickness at the end of gestation does not automatically lead to a higher birth weight of the piglets. Therefore, question is whether backfat is of influence on piglet weight? This research is not indicating any influence.

More knowledge should become available to find out if the sow's backfat level can be or should be steered to improve piglet birth weight, as the variation in backfat thickness in the recent study was very large. Sows should be evaluated individually on body condition, and steered individually on feed intake in order to minimize variation in sow body condition. When a follow-up-study is executed, enough data should be collected per parity number, as parity number has influence on the average birth weight of piglets. To evaluate the effect within parity of feed two different approaches should be taken to influence piglet weight. Besides energy also amino acids should be a variable.

5.5.3 Influences on stillbirth

The number of stillborn piglets showed large variations, and no relation was found between stillbirth and parity number. Parity number was expected to influence the number of stillbirths, with older sows having a higher number of stillborn piglets.
It can be concluded that the number of stillborn piglets is not influenced by parity number, which is in contradiction with several studies which concluded that old sows had a higher number of stillborn piglets. Though it was expected that high backfat levels, especially on farm P would result in many stillbirths, no relation was found.

The same results accounted for backfat thickness in relation to the number of stillborn piglets. It was expected to see an increase in the number if stillbirths as the level of backfat increased. Extremely fat sows are expected to have fat deposits that narrow the birth canal and therefore may increase the time spend for the birth process, with more stillbirth as consequence. This may be explained by the small litter sizes: As obstruction in the birth canal would lead to increased farrowing time, this mainly would have impact on large litters. It is possible that litter sizes on farm P were too small to really have impact on farrowing duration.

An increase in time spend for the birth process, or dystocia, results in a reduced oxygen supply towards the piglets, which have already long been associated with stillbirths (Jackson, 1975) or reduced vitality of the piglets (English and Morrison, 1984; Herpin et al., 1996).
Outcomes of this research were not in line with the mentioned previous surveys. Large variations were seen in the number of stillbirths, and the number of stillbirths was not higher in sows with a high level of backfat compared to sows with a low backfat thickness. Nevertheless, also the sows, which were fat, were more observed on farm P, and this farm had lower live born piglets. Will stillbirth increase on farm P if production figures increase towards figures of farm H? This subject should be investigated more deeply if condition of the sow has influence. More factors are involved, like health and management to influence still births.

5.5.4 Influences on growth of the piglets during lactation/ weight at weaning

No direct correlation was found between the backfat and weight losses of the sow, and growth of the piglets during the lactation period. It is difficult to draw conclusions from these findings, as the variation in weight gain of piglets may be addressed to cross-fostering. It is possible that the born litter of a sow was partly or completely replaced by piglets with a higher or lower birth weight, influencing the outcomes of this calculation. In follow-up-studies the number and weight of cross-fostered piglets should be noted, in order to calculate the exact weight gain of the litter.
Due to cross fostering and lactation management not recorded it was not possible to give hard conclusions on the growth of piglets during lactation. However, it clear from this study that sow condition is highly influencing the performance of the sow during lactation and indirect also piglet performance. Combination studies should be carried out to observe the total effect on piglet growth, with the attention of individual sow feeding.

According to literature, a high level of backfat at the beginning of lactation leads to a lower feed intake during the lactation period, resulting in a lower milk yield. A lower milk yield will result in a lower growth of the piglets. On farm P the growth of piglets during the lactation period was slightly lower compared to the piglets on farm H. This may be addressed on the higher levels of backfat on this farm. This is in agreement with literature. According to literature also a relation is found between litter size and milk yield of the piglets. Larger litters would result in a higher milk yield of the sow. This is also in agreement with the findings on farm P and H, as litter sizes on farm H were larger.

Outcomes of this study illustrate that the sow’s ability to nurse piglets greatly varies between individual sows. More research is necessary to find out if steering sows individually has a positive effect on the reproduction of the sow.

5.6 Other points of discussion

It should be noted that no statistical analyses are executed during this study. This may influence the outcome of the study. In a follow-up study several outcomes can be tested for significance, e.g. the linear increase in backfat thickness and body weight of sows. In this study no linear formulas are mentioned for points 3-6 as the R2 remained relative low for these formulas. By using statistics, it is possible, that these formulas are in fact reliable.

In this research the influence of body condition during the oestrus period and early gestation is not assessed. This makes it impossible to investigate the exact influence of sow condition on litter size and piglet vitality measures, as litter size mainly is a result of ovulation rate and embryonic losses. During this study it also was also not investigated what the exact influence of weight and backfat losses was on the reproductive performance in the next parity.
Also the impact of farming management on the outcomes of the study is not investigated. Environmental conditions or other farm-related influences were not evaluated, but probably have influence on the reproductive performance of the sow.

6. Highlighted conclusions and recommendations

Sow condition can be assessed best by both body weight and backfat thickness. This study clearly showed that body condition score is not accurate enough to base a feeding schedule on.
Backfat thickness and body weight both showed a linear increase as parity number increased, meaning this was parity-number dependent. More, detailed studies should be executed in order to find out what is the optimal growth of sows per parity. When this information is available, sows can be steered more precisely, by correct feeding levels, to improve or optimize reproductive performance.
It was seen that changes in backfat thickness were clearer at points 1&2 compared with the points 3-6, thus including the often used P2-method. Measuring backfat thickness at points 1&2 is more accurate, and can be measured by dividing and marking the length between the shoulder of the sow and the last rib in three equal parts. The points in neighbourhood of the shoulder (1&2, Figure 3) are the points that should be measured. Dependent on the size of the sow, this is about 10 cm from the shoulder.

Though, this research clearly shows the importance of using body weight and backfat thickness as parameter for sow body condition, still a follow-up study is necessary. In a follow-up study the exact level of nutrient requirements of sows of this breed, and in how far the feeding levels of these farms differ from these requirements should be investigated.
A good example of this is the results of the 2 different rations on farm H. It was expected that the change in ration would influence the weight gain of piglets, while in fact no changes were seen. Questions remain if both feeding levels are not in line with the sow's nutrient requirements, and therefore no differences in reproductive performance were seen.

This study revealed that too high levels of feed do not have a positive influence on the sow's reproductive performance. On the other hand, it is known that too low feed intakes also are negatively influencing the reproductive performance. Exact energy and nutrient requirements depend on a lot of factors, and a lot of different recommendations are given by literature. The optimal feeding levels of sows, and for this study Topigs 20 sows, should be investigated.

Feed intake during the lactation period should be high to have a high milk yield, thus piglet weight gain. Feed intake of sows with a high backfat thickness was lower than sows with a lower feed intake. This again shows the negative impact of high backfat levels.

It also should be investigated whether sows during the first three parities need more energy during gestation, than is fed on both trial farms. It is not known if the increase in litter size in the first three parities is a result of higher nutrient requirements than actual feeding levels, or if this growth in litter size is not related to feed intake.
In a follow-up study, sows of the same breed, in a practical situation, should be feed different feeding and nutrient levels to determine the optimal levels, and related body weights and backfat thickness during the different stages of gestation and lactation.

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