**Effects of within-litter birth weight variation of piglets on performance at three weeks of age and at weaning**

by

**Titus Jairus Zindove**

**A dissertation submitted in fulfilment of the requirements for the degree of**

**Master of Science in Agriculture (Animal Science)**

**in the**

**Discipline of Animal and Poultry Science**

**Faculty of Science and Agriculture**

**University of KwaZulu-Natal**

**2011**

**Pietermaritzburg, South Africa**

**Supervisors:**

**Prof M. Chimonyo** **Mr E.F Dzomba**

**Declaration**

I, **Titus Jairus Zindove**, vow that this dissertation has not been submitted to any other University other than the University of Kwazulu-Natal and that it is my original work conducted under the supervision of Prof. M. Chimonyo and Mr E.F Dzomba. All assistance towards the production of this work and all the references contained herein have been duly accredited.

**Titus Jairus Zindove………………** **Date………………….**

**Approved as to style and content by:**

**Prof M. Chimonyo…………………..** **Date……………………….**

**Mr E.F. Dzomba……………………..** **Date………………………**

**Abstract**

The impact of within-litter weight variation on the productivity of pig enterprises is poorly understood. The objective of the study was to determine the effect of within-litter birth weight variation on litter performance at three weeks of age and at weaning. The study was conducted using records from 1 788 litters, collected between January 1998 and September 2010, from a pig herd at the Agricultural Research Council (ARC), Irene. The records consisted of piglet identity, breed of sow, breed of boar, parity number, date of farrowing, number of piglets born alive (NBA), individual piglet weight at birth, three weeks and at weaning. From these records, mean birth weight (MBWT), litter weight at birth (TBWT), within-litter birth weight coefficient of variation (CVB), minimum birth weight (MinB) and maximum birth weight (MaxB) were calculated. Mean weight at three weeks (MWTT), litter weight at three weeks (LWTT), within-litter weight coefficient of variation at three weeks (CVT), percent survival to three weeks (SURVT), mean litter weaning weight (MWWT), litter weight at weaning (LWWT), within-litter weaning weight coefficient of variation (CVW) and percent survival at weaning (SURVW) were computed as derivatives. The factors affecting CVB were analysed using the General Linear Model procedures (SAS, 2008). For the relationships between CVB and litter performance at three weeks and weaning, PROC STEPWISE was used. The PROC REG (SAS, 2008) was then used to test whether the relationships between CVB and CVT, SURVT, MWTT, LWTT, CVW, SURVW, MWWT, LWWT and LWWT.

Multiparous sows farrowed litters with higher ($P<0.05$) CVB than gilts. The litter weight (TBWT) and NBA, fitted as covariates, also affected ($P<0.05$) CVB. The correlation between CVB and NBA was 0.30. The CVB had a linear relationship ($P<0.05$) with SURVT (SURVT = 83.21 - 0.20 CVB), CVT (CVT = 16.71 + 0.50 CVB), SURV (SURW = 87.9 – 0.04CVB) and CVW (CVW= 15.8 + 0.5CVB). An increase of CVT with CVB depended on parity (P<0.05). The rate of increase of CVT with CVB was highest in Parity 1 (b=0.41) followed by Parity 2 (b=0.36) then middle aged (Parity 3-5) sows (b=0.32). The CVB had no effect on MWTT, LWTT, MWWT and LWWT (P>0.05). The CVB was shown to be an important determinant of SURVT and SURVW. A uniform litter at birth is likely to lead to a homogenous litter at three weeks and weaning, thereby reducing costs of production. Pig producers should, therefore aim at producing homogenous litters at birth.

**Key words:** Pigs, within-litter weight variation, litter traits.

**Acknowledgements**

I thank my supervisors Prof M. Chimonyo and Mr. E.F Dzomba for their patience, guidance and mentorship. If I have seen further, it is by standing on your giant shoulders. Records were collected from the Agricultural Research Council (ARC) with the help of Dr A. Kanengoni. I gratefully acknowledge Dr A. Kanengoni for his continuous support, input and assistance in editing and producing this document. Dr M.C. Marufu and Mr. N. Chikumba's tireless assistance with statistical analysis is greatly appreciated. I also thank my friends Saymore Petros Ndou, Archibold Bakare and Thando Mpendulo for their input, support and encouragement.

I acknowledge financial support from the National Research Foundation.

Thanks to one and all.

## Dedication

To: God who has brought me this far, my family and friends who have been great sources of motivation and inspiration, my mentors for developing me to my fullest potential and all those who believe in the richness of learning.

**Table of Contents**

**List of Tables**

**List of Figures**

# Chapter 1: General Introduction

Profitability of pig enterprises largely depends on the number of pigs weaned per sow per annum (Wolf *et al*., 2007). Pigs with poor growth performance require extra facilities, consume more feed, produce less meat and complicate management (Milligan *et al*., 2001). Most pig producers record litter size, litter weight at birth, three weeks and weaning weight in addition to body weights and carcass traits. One of the most common causes of piglet mortality and poor growth performance is low birth weight. Weak piglets are highly susceptible to diseases and crushing and are also less competitive during feeding than their stronger counterparts. Performance of piglets at three weeks is, thus, crucial for subsequent growth, vitality and survival of the piglets at weaning and beyond (Chimonyo *et al*., 2011). Body condition and energy intake pre- and post-farrowing are critical aspects of maintaining high herd fertility, hence improved birth weight. Sows should have a condition score of between 3 and 3.5 at mating. Sows whose body condition deteriorates markedly during lactation subsequently show low levels of fertility and low weight of piglets at birth. For example, Foxcroft *et al.* (2006) observed that nutritional restriction in gestating sows had runting effects on piglets, subsequently, post-natal growth. Post-natal nutritional intervention cannot do much to reduce the effects of low birth weight. Besides low birth weight, Kyriazakis and Whittemore (2006) indicated that, apart from low birth weights, focus should be placed on birth weight variation.

Most commercial farmers record litter weight at birth instead of individual birth weights. This could mainly be due to additional labour, time and costs involved in recording individual piglet weights (Chimonyo *et al*., 2006). A number of studies have shown that piglet birth weight has a huge impact on weight gain or survival of piglets (Milligan *et al*., 2001; 2002; Quinion *et al*., 2002; Knol *et al*., 2002). The impact of within-litter birth weight variation is, however, still poorly understood. Within-litter birth weight variation refers to the spread of individual piglet weights within the litter (Wolf *et al*., 2007) and is usually measured using within litter birth weight coefficient of variation (CVB). Numerous factors have been established to influence the variability in birth weights. Parity, nutrition, body condition of the sow at farrowing and breed are some of the factors that affect piglet birth weight. It is not clear whether these factors also influence variation in birth weight.

Large litters at birth are the aim for every pig farmer for it is an important contributor to maximising the number of pigs weaned per sow per year. Wolf *et al*. (2007), however, demonstrated that piglet losses are greater in larger litters. The bulk of these high piglet losses in larger litters are attributed to a high proportion of small piglets in the litter (Marchant *et al*., 2000; Lay *et al*., 2002). Litters with high birth weight variation are likely to have low survival because light litter-mates will be directly excluded from more productive teats (Milligan *et al*., 2002). In the first few hours after birth, there is always aggressive competition for teats where most piglets establish ownership of particular teats and the weaker piglets either die or struggle to survive. Light litter-mates may also be outcompeted indirectly, with heavier litter-mates suckling the teats more effectively, directing a larger fraction of hormones and nutrients involved in milk production to the respective teats (Grandinson *et al*., 2005). As a result, larger piglets gain weight faster than their smaller littermates. Due to the direct and indirect competition among littermates, within-litter birth weight variation is either maintained or increased until weaning (Milligan *et al*., 2001). Measures should, therefore, be taken to reduce variation of piglet weight at birth. Two possible options are appropriate feeding of pregnant sows and selection for mothering ability (Damgaard *et al*., 2003).

Generally, all reproductive traits in pigs such as number of piglets born alive (NBA) and farrowing interval have low heritability but that of individual birth weight is fairly high (close to 20%) (Roehe, 1999; Chimonyo *et al*., 2006). The heritability of CVB is generally unknown but is expected to be low, making its response to selection slow. Large data sets are required to estimate these genetic parameters, yet few farmers record individual piglet weights at birth. To promote the recording of individual piglets at birth, farmers need to appreciate the intended benefits and value to offset the additional labour and time resources required. Although response to selection is slow, there is need to focus on characterizing CVB, with the aim of increasing uniformity of piglets at birth. Pig producers can make significant improvement in CVB through management. Minimising within-litter birth weight CV is likely to increase piglet survival, litter weight and within-litter weight CV at three weeks and weaning. To increase uniformity of litters, piglet variation should be considered as a trait of economic importance.

### 1.1 Justification

Pig breeders routinely select for reproductive traits such as litter size and litter birth weight. Less effort has, however, been dedicated to increasing the uniformity of piglets at birth (Kyriazakis and Whittemore, 2006). Although small piglets are likely to take more days to reach market weight, large variation in weight at birth has been shown to have a bigger impact on pig enterprises (Milligan *et al*., 2001; Wolf *et al*., 2007)). Sows that produce uniform piglets at birth reduce costs of production significantly (Foxcroft and Town, 2004). If the relationship between within-litter birth weight variation and within-litter weight variation at weaning and at marketing is determined, the farmer will be able to accurately predict the weight of pigs from a litter at marketing. The revenue to be generated can also be predicted with precision, thereby making planning easier. In addition, production of uniform piglets at birth reduces the incidences of foster-mothering, which is done to reduce variation among littermates. Foster-mothering introduces serious practical inconveniences in the management of pigs. It has also been established that large variation, usually a consequence of selecting for increased litter size, requires the construction of more pens, thereby increasing the cost of housing, cleaning and general management. Impact of pig variation at birth has not received much attention. The lack of understanding of the role of piglet weight variation at birth largely explains why most commercial farmers are reluctant to record individual piglet weights at birth. The cost-benefit implications of recording individual birth weights needs to be determined. Understanding within-litter birth weight variation and its impact on future performance will help improve litter homogeneity at birth. This will help commercial farmers to reduce production costs and, hence, increase the efficiency of pig production.

## 1.2 Objectives

The broad objective of the study was to determine the effect of within-litter birth weight variation on litter performance to weaning. The specific objectives were to:

1. Determine factors that influence within-litter birth weight variation in pigs;
2. Determine the relationship between CVB and within-litter weight variation, percent survival and litter weight at three weeks; and
3. Determine the relationship between CVB and within-litter weaning weight variation, percent survival and weight at weaning.

## 1.3 Hypotheses

The hypotheses tested were that:

1. Non-genetic factors influence within-litter birth weight variation;

2. There is a relationship between CVB and within-litter weight variation, percent survival and litter weight at three weeks; and
3. There is a relationship between CVB and within-litter weaning weight variation, percent survival and weight at weaning.

### 1.3 References


Chimonyo, M. and Dzama, K., 2006. Estimation of genetic parameters for growth performance and carcass traits in Mukota pigs. Animal, 1: 317-323.

Chimonyo, M., Dzama, K. and Bhebhe, E., 2006. Genetic determination of individual birth weight, litter weight and litter size in Mukota pigs. Livestock Science, 105: 67-69.

Damgaard, L.H., Rydhmer, L., Lovendahl, P. and Grandinson, K., 2003. Genetic parameters for within-litter variation in piglet birth weight and change in within-litter variation during suckling. Journal of Animal Science, 81: 604–610.

Da Gloria Taela, M., Gaughan, J.B., Bryden, W.L. and Bauer, M., 2006. Genetic parameters of production traits in large white and duroc pigs. Australian Society of Animal Production 26th Biennial Conference paper. School of Animal Studies, University of Queensland, Australia.

Grandinson, K., Rydhmer, L., Strandberg, E. and Solanes, F.X., 2005. Genetic analysis of body condition in the sow during lactation, and its relation to piglet survival and growth. Animal Science, 80: 33–40.

Foxcroft, G. R., Dixon, W. T., Novak, S., Putman, C. T., Town, S. C. and Vinsky, M. D. A., 2006. The biological basis for prenatal programming of postnatal performance in pigs. Journal of Animal Science, 84: 105-112.

Kaufmann, D., Hofer, A., Bidanel, J.P. and Kunzi, N., 2000. Genetic parameters for individual birth and weaning weight and for litter size of Large White pigs. Journal of Animal Breeding Genetics, 117: 121–128.

Knol, E.F., 2001. Genetic aspects of piglet survival. Ph.D. Thesis, Institute for Pig Genetics and Animal Breeding and Genetics Group, Wageningen University, The Netherlands.

Knol, E.F., Ducro, B.J., van Arendonk, J.A.M. and van der Lende, T., 2002. Direct, maternal and nurse sow genetic effects on farrowing, pre-weaning- and total piglet survival. Livestock Production Science, 73: 153–164.

Kyriazakis, I. and Whittemore C.T., 2006. Whittemore's Science and Practice of Pig Production. Third edition. Blackwell publishing.

Lay Jr., D.C., Matteri, R.L., Carroll, J.A., Fangman, T.J. and Safranski, T.J., 2002. Preweaning survival in swine. Journal of Animal Science, 80: 74–86.

Marchant, J.N., Rudd, A.R., Mendl, M.T., Broom, D.M., Meridith,M.J., Corning, S. and Simmons, P.H., 2000. Timing and causes of piglet mortality in alternative and conventional farrowing systems. Veterinary Records, 147: 209–214.

Milligan, B.N., Fraser, D. and Kramer, D.L., 2001. Birth weight variation in the domestic pig: effects on offspring survival, weight gain and suckling behaviour. Applied Animal Behaviour Science, 73: 179–191.

Roehe, R. 1999. Genetic determination of individual birth weight and its association with sow productivity traits using Bayesian analyses. Journal of Animal Science, 77: 330-343.

Town, S., Patterson, J., Pereira, C., Gourly, G. and Foxcroft, G.R., 2004. Embryonic and fetal development in a commercial damline genotype. Animal Reproduction Science, 85: 301–316.

Wolf J., Zakova E. and Groeneveld, E., 2007. Within-litter variation of birth weight in hyper prolific Czech Large White sows and its relation to litter size traits, stillborn piglets and losses until weaning. Livestock Science, 115: 195–205.

# Chapter 2: Review of Literature

## 2.1 Introduction

The primary goal of pig producers is to maximize profit. The number of pigs produced per sow per year is a key factor in maximizing profit. Breeding programmes have been focusing on NBA to maximize pigs weaned per sow per year. The economic feasibility of continuing to increase NBA has been questioned due to its detrimental effects on litter performance. There continues to be the quest to maximize performance of the large litters produced. Increasing NBA has been found to increase within-litter birth weight variation (Damgaard *et al*., 2003; Wolf *et al*., 2008). This literature review discusses the effects of within-litter birth weight variation on litter performance to weaning and its interaction with other traits of economic importance.

## 2.2 Pig statistics and production systems in South Africa

Global livestock production is growing more dynamically than any other agricultural sector (Faustin *et al*., 2003). Pig production is one of the livestock activities which have been rapidly increasing worldwide in recent years. The South African pig industry is comprised of different pig production systems, with intensive production more pronounced as compared to free-range and large-scale outdoor production systems. The predominant commercial pig breeds are the South African Landrace, the Large White, the Duroc and the Pietrain (Visser, 2004).

### *2.2.1 Pig production statistics*

In South Africa pig producers are distributed across all nine provinces (Visser, 2004). Commercial pig production in South Africa largely involves the use of exotic pig breeds.

There are approximately 100 000 sows, with 71 067 sows being possessed by 210 pork producers who are members of South African Pork Producers Organisation. The South African Pork Producers Organisation (SAPPO) represents about 65% of all pig producers in South Africa (Visser, 2004). About 1.8 million pigs are slaughtered per annum.

South Africa accounts for less than 0.2 per cent of world pork production (Oyewumi and Jooste, 2006). The competitive disadvantage of South Africa on pork production can be attributed to a lack of an advanced genetic improvement programme as compared to competing countries, such as Brazil. The commercial breeds in South Africa have been selected for traits such as high lean growth potential, reduced back fat thickness and increased litter size (Webb *et al*., 2006) and reared under different production systems with the intention of meeting global consumer demands in terms of quantity and quality of pork and pig products.

### *2.2.2 Production systems*

Various production systems for pigs are found worldwide. In South Africa, two different production systems may be defined according to scale of production: small scale and large scale production systems. Small scale system is mainly comprised of scavenging, semi-intensive and intensive systems. The small scale system is commonly practised by communal farmers in South Africa. The most common system for large-scale pig production is generally capital intensive and may involve sow herds from 40 to 1000 (Visser, 2004). High-performance exotic pig breeds and/or hybrids are used. There is intense selection of better performing individuals such as large litters, based on records. Housing is designed specifically for the different classes of stock and environmental conditions. Breeding facilities are excellent, with fully slatted floors in breeding compartments. Increased litter size is noticed under these systems, which are as a result of improved genetics, better sow nutrition, feeding practices and health management.

Large scale pig production in South Africa usually has all age groups placed either in outside pens or within buildings in close proximity to one another (Honeyman, 2005). Recently, South African commercial farms have been noted to practice mainly multi-site rearing systems. Multi-site rearing system refers to the rearing of various age groups of pigs at different isolated locations or farmsteads. Groups such as breeding sows, weaners and grow-out pigs can be kept on sites sufficiently distant from one another to prevent aerosol infections and spread of diseases by birds and pests (Kyriazakis and Whittemore, 2006).

Commercial outdoor pig production has been introduced in parts of South Africa and there is potential for further expansion (Honeyman, 2005). Outdoor pig production systems use recent advances such as electric fence, all-terrain vehicles, plastic ear tags, low-cost plastic water pipes, and improved farrowing huts for easy management (Honeyman *et al.,* 2001). Sows are kept in paddocks and provided with individual pens for shelter. Type of production system employed is highly dependent of the characteristics of the breed to be used. Commercial outdoor pig production is mostly suitable for highly productive hybrid sows with a greater ability to withstand erratic climatic changes.

## 2.3 Traits of economic importance in pigs

One of the first steps in developing a breeding programme is to consider which phenotypic traits are of importance. Traits with recognisable economic value are generally to be given the most emphasis. A trait has economic value if a change of that trait results in economic benefit such as lower production costs or a higher price for the product (Kanis *et al.,* 2005). Pig improvement programs have focused mainly on reproductive, growth, carcass and meat quality traits. The economic importance of functional traits is influenced by management and production systems.

Economically important growth performance traits in pigs are feed conversion efficiency (FCE) and growth rate (Prevolnik *et al.*, 2011). Growth rate is measured using average daily gain (ADG). Producers need pigs with high growth rates. Fast growing pigs result in reduced feed costs and this has a positive effect on the pig enterprise. Fast growth is a function of feed conversion efficiency. Fast growth has, however, been reported to have undesirable correlation with other economically important traits such as meat quality (Latorre *et al.*, 2008). Holm *et al.* (2004) found unfavourable genetic correlations between litter size and growth traits. It is, therefore, important to take into account the undesirable correlation between growth traits and other traits when selecting breeding stock. The heritabilities of growth performance traits have been found by Hoque *et al.* (2009) to be moderate, with heritability estimates of 0.45 and 0.49 for FCE and ADG, respectively, in Duroc pigs.

Backfat thickness, drip loss, eye muscle area, intramuscular fat content and lean weight are the main traits measured on carcasses. Correlations between these traits and other traits should be considered when selecting breeding stock. For example, genetically, very lean pigs may have problems when they enter the breeding herd because they will farrow with little fat reserves, have lower feed intake and poor reproductive performance (Chen *et al*., 2002). Oh *et al*. (2005) reported a genetic correlation of -0.1 between average daily gain and eye muscle area. Moderate and high heritabilities have been reported for carcass traits (Hermesch *et al*., 2000). A heritability of 0.25 was reported for fat content in Iberian pigs (Fernandez *et al.,* 2003) and 0.72 for back fat thickness in Duroc pigs **(**Hoque *et al*., 2009).

For years, pig-breeding programmes have focused mainly on the reduction of costs of pork production. Selection has been aimed at increased litter size and lean meat percentage, in addition to weight gain and improved feed conversion. Consumer expectations have caused broadening of breeding goals due to the inclusion of meat quality traits. Selection for meat quality is based on drip loss, pH, intramuscular fat (IMF) and colour. Differences in pork quality among pig breeds have been shown in several studies (Cameron *et al*., 1990; Gjerlaug-Enge *et al*., 2010). Meat quality traits have low to medium heritabilities (Gjerlaug-Enge *et al*., 2010).

Profitability of a pig enterprise primarily depends on the sow's reproductive efficiency. The performance of sows is reflected by reproductive traits such as NBA, number born dead (NBD) and litter weight at birth (TBWT) (Kanis *et al*., 2005). The NBA is strongly correlated to ovulation rate, with a relatively high heritability of 0.3 (Cassady *et al*., 2000). These traits are important contributors to maximizing number of piglets weaned per sow per year. Mean birth weight (MBWT) and individual birth weight are also of economic importance in pig production. The reason why farmers ignore individual piglet weights could be that its value in a pig enterprise is considered irrelevant. Individual piglet birth weight can, however, be used to compute within-litter birth weight variation, whose impact on pig enterprises has been recognised (Milligan *et al.,* 2002; Wolf *et al*., 2007). Within-litter birth weight variation refers to the spread of individual weights within a litter. Although numerous studies have been conducted on reproductive traits such as NBA, TBWT and MBWT, less have been done on within-litter birth weight variation, despite its importance.

Reproductive traits of pigs generally, have been found to be lowly heritable (Norris *et al.*, 2010). It might be because of the low heritability of these traits that little effort has been put to try to improve them through selection. Interestingly, traits of low heritability have been improved through a combination of crossbreeding and manipulation of the environmental factors. Within-litter birth weight variation has recently been prominent due to its huge implications on pig production but less has been done to determine its genetic parameters and its relationships with various production parameters. Therefore, part of this review will focus on aspects of within-litter birth weight variation and its relationships with other economically important traits.

### 2.4 Within-litter birth weight variation

Variation can be defined in a variety of ways; the most common terms are standard deviation (SD) and coefficient of variation (CV), although range (minimum and maximum within a litter) weights may also be useful. The minimum and maximum refer to the lightest and heaviest weights within the group. The difference between the minimum and maximum is called the range. The larger the range, the less uniform the litter. Typically, the range in weights declines as a percentage of the mean as the pigs get heavier. The standard deviation shows how much dispersion there is from the mean. The greater the variation in weight of a group of pigs, the larger will be the standard deviation. The CV is an estimate of the relative range in weights compared in proportion to the average weight of the litter, thus the greater the CV the more variable the birth weight. Various authors suggested CV as the best measure of variability of birth weight among littermates (Milligan *et al.*, 2002; Quiniou *et al.*, 2002) and Damgaard *et al.*, 2003). On-farm variation measurement is a real challenge (Patience *et* *al*., 2004) especially at birth when farmers tend to record total litter weight instead of individual birth weight of piglets, due to the additional labour and time required.

On-farm optimal levels of within-litter birth weight variation aimed to maximize production have not been specified (Milligan *et al.*, 2002; Quiniou *et al*., 2002; Damgaard *et al.*, 2003). The heritability of CVB ranges from 0.08 to 0.11 (Hogberg and Rydhmer, 2000; Huby *et al*., 2003; Wolf *et al*., 2008). In the Netherlands, CVB in farrowing groups is reported to typically range from 0.18 to 0.25with within-litter birth weight variation contributing two thirds of this variation in birth weights (Dewey *et al*., 2001). Coefficient of variation values of between 0.22and 0.26have been reported for birth weight of piglets within a litter in the USA (Patience *et al.,* 2004). There are no reported estimates of within-litter birth weight on South African pig herds.

While the relationships among reproductive traits such as NBA, MBWT and TBWT is fairly well understood, less has been reported on the relationship between within-litter birth weight variation with NBA, MBWT, TBWT and other birth traits, despite the fact that the impact of this variation on production is of great economic importance to commercial pig producers.

### 2.5 Impact of within-litter birth weight variation on litter performance

On-farm sow performance testing is usually done at three weeks and weaning age of five weeks for selection purposes. Weaning is also a crucial time in the management of litters as it significantly affects performance to marketing. Taylor and Roese (2006) and Chimonyo *et al.* (2011) emphasised on the importance of three week performance to subsequent growth, vitality and survival. The effect of within-litter birth weight variation on litter performance to three weeks, five weeks and piglet survival will be reviewed in this section.

### *2.5.1 Effect of within-litter birth weight variation on performance at three weeks*

While a few studies on the effect of birth traits such as NBA and MBWT on performance to three weeks have been conducted (Mungate *et al.,* 1999; Wolf *et al*., 2008), the impact of within-litter birth weight variation on performance to three weeks is not clearly understood. There is little information on the relationship between within-litter birth weight variation on mean litter weight, total litter weight and within-litter weight variation at three weeks. Damgaard *et al.* (2003) found that uniformity in birth weight was genetically correlated (0.22) to uniformity in weight at three weeks. They also found a positive genetic correlation (0.16) between within-litter birth weight variation and mean litter weight at three weeks.

### *2.5.2 Effect of within-litter birth weight variation on performance at weaning*

The effect of within-litter birth weight variation on mean litter weaning weight and total litter weaning weight is not well documented. A few studies have reported the effect of within-litter birth weight variation on growth rate to weaning hence litter weight at weaning. English and Bilkei (2004) found an increase in pre-weaning gain when low birth weight piglets were grouped with high birth weight litter mates compared to homogeneous groups. This was attributed to a decrease in competition for milk between light and heavy piglets. In other studies, variation in litter birth weights has been reported to have no effect on pre-weaning weight gain (Milligan *et al.,* 2001; Milligan *et al.,* 2002; Fix *et al.,* 2010). To our knowledge, no studies have estimated the genetic correlations between within-litter birth weight and litter weight at any age beyond three weeks.

Now that large NBA are being produced and much has been done to increase survival, the next big challenge of pig producers is to wean the piglets at the same period at an acceptable weight and deliver uniform groups to the nursery. Due to the introduction of all-in, all out systems in pig production, weaning weight variation and consequently market weight variation have become one of the crucial elements of successful pig production. Weaning weight variation reflects post weaning weight and growth variation, with about 73% of market weight variation reported to be accounted for by weaning weight variation (Patience *et al.,* 2004).

A few studies have been conducted on the impact of within-litter birth weight variation on within-litter weaning weight variation (Milligan *et al*., 2001). Milligan *et al.* (2002) found an increase in weaning weight at four weeks of age when litters had lower birth weight variation. Despite its importance, no studies have been conducted on prediction of levels of weight variability of pig groups at weaning. Exactly how much within-litter birth weight variation affects within-litter weaning weight variation is not known. Information on genetic correlations between within-litter birth weight variation and within-litter weight variation beyond three weeks of age is also not available. Early prediction of within-litter weaning weight variation on a farm can be quite useful, allowing farmers to make management decisions to manage or minimize the variation to maximize economic takings and accurately predict profits. Since some studies have proved that within-litter birth weight variation is a major contributor to within-litter weaning weight variation, it may be used to predict weight variation at weaning among littermates.

*2.5.3 Effect of within-litter birth weight variation on piglet survival*

There have been contradicting reports on the effect of within-litter birth weight variation on piglet mortality. Various studies showed that variation in birth weight is a major factor affection pre-weaning mortality in pigs (Milligan *et al*., 2001; English and Bilkei, 2004;

Roehe *et al.,* 2009). English and Bampton (1982) found that litters with the same mean birth weight and NBA but different within-litter birth weight variation had different pre-weaning mortalities. Contrary to these reports Milligan *et al.* (2001) and Fix *et al.* (2010) found no effect of variation within litters on pre-weaning mortality.

There have been conflicting results on which one is of greater importance to piglet survival, within-litter birth weight variation or individual birth weight. Recent studies suggest that variation in birth weight within the litter seems to be more important than individual birth weight of the animals (Milligan *et al*., 2002; Kapell *et al.,* 2010). Beymon (1997) reported that smaller piglets that are within 0·2 of the mean birth weight of their litter have a greater chances of survival than those piglets with a higher deviation from the average birth weight of the same litter. According to Le Dividich (1999) there is no threshold for individual birth weight below which piglets have an increased probability of dying thus within-litter birth weight variation appears more pertinent than individual piglet weight. Estimated genetic correlations suggest that selection for uniformity in birth weight may improve piglet survival (Damgaard *et al*., 2003; Huby *et al*., 2003). Knol *et al.* (2001) also predicted that selection for the piglet's own ability to survive will lead to more uniform litters.

The effect of within-litter birth weight variation on survival to weaning is attributed to the fact that light litter-mates are outcompeted indirectly after farrowing, with heavier littermates suckling their teats more effectively directing a larger fraction of hormones and nutrients involved in milk production to their respective teats (Grandson *et al.,* 2005). The larger piglets have more vigour than their smaller littermates due to this indirect competition. These findings contrast with a recent study by Fix *et al*. (2010) who found that the impact of within-litter birth weight variation on survivability rate was not significant. Although the majority of the studies reported a significant effect of within-litter birth weight variation on piglet survival to weaning, there is no general consensus yet. None of the studies did prediction of survival estimates using within-litter birth weight variation.

Numerous studies have shown cross-fostering during the first few days of life to be an effective method of reducing weight variation to improve survival (Neal and Irvin, 1991). This leads to a proposition on whether reduction in weight variation through fostering would reduce survival just like reducing within-litter birth weight variation. In their study, Deen and Bilkei (2004) found that piglets which were fostered to reduce weight variation had half the mortality rate of piglets fostered without regard to weight. However, cross-fostering introduces practical inconveniences in the management of pigs, such as matching the number of piglets in each litter to fit sow capacity, grouping and adjusting the size of fostered piglets in the litter to minimize variations in piglet weights. Furthermore, cross-fostering is a significant factor influencing piglet growth rate (Hermesch *et al.,* 2000). Fostering is stressful and can contribute to the susceptibility of the piglets to diseases and parasites; consequently reducing within-litter birth weight variation remains the appropriate option to maximise survival to weaning.

*2.5.4 Effects of within-litter birth weight variation on post-weaning performance*

Uniformity at marketing enables easy prediction of revenue and eliminates 'tail-end pigs' (Taylor and Roese, 2006), thus favourable throughput and reducing extra feed costs. Tail-end pigs reduce barn utilization. In modern pig grow out barns, feeder pigs are placed in the barn at once, but selected for marketing over a period of up to 5 weeks because they reach market weight at different times (Dewey *et al*., 2001). Marketing all pigs at the same time, and thus saving about 5 weeks per barn and reducing transport costs will have a great economic impact. Fostering, split weaning, feeding additional feeds among other methods have been tried as tools by commercial farmers to create uniformity at marketing but all these seem not to pay off (Deen and Bilkei, 2004; Walker, 2002). Attempts to reduce weight variability in the nursery were reported as a failure by Taylor and Roese (2006) who also found that efforts to reduce variability in weights by sorting prior to entering weaner facilities has an unfavourable impact on performance in general.

Earlier work suggests that in homogenous groups formed through regrouping at weaning social factors will result in some pigs growing faster than others (O'Connell and Beattie, 1999), thus eliminating the effect of forming uniform groups. Furthermore, prolonged aggression associated with unresolved dominance relationships within the uniform weight groups (Anderson *et al*., 2000) may have a negative effect on growth performance to finishing (Stookey and Gonyou, 1994) hence litter weight at marketing. Reduction of variation in piglet weight in the nursery without regrouping needs critical consideration. It may be possible to reduce within-group variation post weaning without regrouping through production of homogeneous litters at weaning. Foxcroft and Town (2004) suggested that the best way to increase uniformity at marketing is by minimizing within-litter birth weight variation. Patience *et al*. (2004) suggested that high within-litter birth weight variation causes variation in carcass size and shape at marketing and this affects the packing and processing industry, both in terms of handling of the carcass and its products, and in the uniformity of the pig products. To date, no studies have been published on the effects of within-litter birth weight variation on post weaning litter performance.

## 2.6 Factors affecting within-litter birth weight variation

Consequences of increased birth weight variation among litters have been described by various authors (Milligan *et al*., 2002; Wolf *et al*., 2008; Fix *et al*., 2010), but less investigation has been done on the sources of variation of this trait. The large variability in birth weights of littermates suggests that many factors or conditions may be responsible for these differences. Possible determinants of within-litter birth weight variation are genotype, season of farrowing, Parity of sow, sex ratio in a litter and litter size.

### *2.6.1 Litter size*

In recent years, increased emphasis on sow prolificacy, both from a genetic and management standpoint, has resulted in an increase in litter size in pigs (Foxcroft, 2008). Various studies have shown that litter size affects birth weight variation among litter mates (Damgaard *et al*., 2003; Milligan *et al*., 2001). In two different studies, Wolf *et al*. (2008) and Quesnel *et al.* (2008) reported that genetic improvement by selection for prolificacy over a long period of time resulted in a significant increase in within-litter birth weight variation. This shows that large litters have more variation in piglet birth weight. Quesnel *et al.* (2008) found that for a population with litter size ranging from 2 to 21, within-litter birth weight CV had a ranged from 0 to 51%, with larger litters having more variable individual birth weights. Given the fact that South African pork commercial industry is mainly comprised of exotic pig breeds producing large litters and the association between litter size and within-litter birth weight variation, it can be concluded that there is greater variation in birth weight of litter mates within production systems.

The effect of litter size on within-litter birth weight variation can be attributed to crowding in the uterine as litter size increases. The area of placenta available for each foetus in large litters is less than that available in smaller litters. The degree of placental growth is primarily influenced by the availability of space and vascular supply. Piglets near the uterine walls where blood is higher receive more nutrients than littermates positioned centrally, and, this results in different growth rates hence weight variation (Canario *et al*., 2010).

### *2.6.2 Genotype*

There is considerable variation between pig breeds in terms of growth and reproductive performance. There are several pig breeds used in South African commercial pig production which include Large White, Yorkshire, Landrace, Duroc and crosses of the four breeds. While breed effects on various production traits in pig herds has been established, less has been published on variation in within-litter birth weight variation among breeds. Damgaard *et al.* (2003) found no significant difference in within-litter birth weight variation in litters sired by Yorkshire and Landrace pure breeds. No studies have been reported on the effect of breed of sow on within-litter birth weight variation. There is a need to investigate more on the effect of breed on within-litter birth weight variation in order to draw precise conclusions.

### *2.6.3 Season of farrowing*

The detrimental effects of high ambient temperature and heat stress on sow performance are well known. Although, modern pig facilities have been developed to cushion seasonal effects on reproductive traits by housing sows indoors and in individual crates with artificial lighting and controlled temperatures, differences in sow performance across seasons were reported by various authors (Mungate *et al*., 1999; YinHua *et al*., 2000). The impact may be direct as a result of increased body temperature or compensatory changes in blood flow or it may be indirect through the hypothalamus involving changes in the sow's appetite and body metabolism. No studies have been published on the effect of season of farrowing on variation in piglet weight at birth. However, Love *et al.* (1993) reported that in sows, during the first week of pregnancy, heat stress results in higher embryo mortality and consequently a reduction in litter size (Xue *et al*., 1994). Consequently, within-litter birth weight variation will be affected since litter size is negatively correlated to within-litter birth weight variation (Milligan *et al.,* 2002).

### *2.6.4 Parity*

Parity structure of the breeding herd can have a significant effect on efficiency (Tantasuparuk *et al.,* 2000). Older sow herds are reported to have positive effects on productivity. Smits and Collins (2009) reported that litters from parity 3 or higher sows generally perform better than litters from gilts in terms of number born alive and mean birth weight. While such detailed information is available on the effect of parity of sow on NBA and MBWT, less has been done on the effect of parity of sow on within-litter birth weight variation.

Miller *et al.* (2006) showed variation in birth weight differences in litters from sows and gilts. Wahner and Fischer (2005) reported that there are differences in uterine environment such as rate of blood flow to the foetus and nutrient delivery and distribution to foetuses between gilts and sows. This could be a source of differences in within-litter birth weight variation across parities. As the parity of a sow increases litters become more heterogeneous in terms of birth weight (Quesnel *et al*., 2008). Milligan *et al*. (2002) reported that first parity sows farrowed more uniform piglets than multiparous. This can also be due to increase in litter size as parity increases.

### *2.6.5 Sex ratio*

The sex of the animal is a feature, which affects the performance of many traits (Peaker and Taylor, 1996). The sex of the piglet plays an important role in the growth rate of the developing foetus. Alfonso (2005) reported that at birth, male piglets were significantly heavier than female piglets. The difference was attributed to hormonal differences between sexes and their resultant effects on foetal growth. Although no studies have been conducted on the effect of sex ratio on within-litter birth weight variation, the reported effect on individual birth weight implies that the proportion of piglets from one sex (sex ratio) might have effects on within litter birth weight variation. The conditions that influence sex ratio are known but not well understood (James, 2001) hence manipulating them to improve on within-litter birth weight variation is a real challenge.

### *2.6.6 Nutrition*

One of the causes of low birth weight is nutrition, specifically inadequate energy intake during the gestation period. Body condition and energy intake pre- and post-farrowing are critical aspects of foetal growth and development and thereby affect within-litter birth weight variation (Campos *et al*., 2011). As the litter size increases the nutritional requirements to support the metabolic needs of the foetuses increase. Inadequate feeding of highly prolific sows results in intense competition for the nutrients hence an increase in within-litter birth weight variation. Kim *et al.* (2009) found that sows which could not provide sufficient nutrients to the foetus during gestation had high within-litter birth weight variation. Sows whose body condition deteriorates during lactation usually farrow piglets with low birth weights and can farrow runts (Foxcroft *et al.*, 2006).

## 2.7 Summary

The South African pig industry is predominated by the South African Landrace, the Large white, Duroc and Pietrain breeds. These pig breeds are kept are two main production systems, the large scale production system and the small scale production system. The large scale production system is mainly defined by commercial pig production which further divides into the multi- site rearing system and the outdoor production system. The traits of economic importance considered under commercial pig production in South Africa include Feed conversion efficiency, growth rate, backfat thickness, lean weight, number born alive and mean birth weight. These traits are affected by genetic factors such as breed and non-genetic factors such as parity of sow, month of farrowing and sex ratio in a litter. One trait which is becoming prominent in commercial pig production is within-litter birth weight variation, though less have been done in South Africa.

Commercial pig farmers prefer to measure and record total litter weight than individual piglets weights and this makes on-farm within-litter birth weight variation measurement a challenge. Within-litter birth weight variation poses great implications on pig production, although not much has been done on characterising it and determining its relationship with subsequent litter performance traits. A few studies done on the within-litter birth weight variation, in Canada and Czech Republic, show that it has considerable effect on subsequent litter performance traits such as growth rate, mean weaning weight and percent survival to weaning. The objective of the study was, therefore, to determine the effect of within-litter birth weight variation on litter performance at three weeks and weaning.

## 2.8 References

Alfonso, L., 2005. Sex ratio of offspring in pigs: farm variability and relationship with litter size and piglet birth weight. Spanish Journal of Agricultural Research, 3(3): 287-295.

Andersen, I.L., Andenes, H., Boe, K.E., Jensen, P. and Bakken, M., 2000. The effects of weight asymmetry and resource distribution on aggression in groups of unacquainted pigs. Applied Animal Behaviour Science, 68: 107-120.

Beymon, N., 1997. Ten ways to foster pigs. Pig International Magazine, 20-23.

Cameron, N.D., Warriss, P.D., Porter, S.J. and Enser, M.B., 1990. Comparison of Duroc and British Landrace pigs for meat and eating quality. Meat Science, 27: 227–247.

Campos, P. H. R. F., Silva, B. A. N, Donzele, J. L., Oliveira, M. R. F. and Knol, E. F.,2011. Effects of sow nutrition during gestation on within-litter birth weight variation: a review. Animal, 1-10.

Canario, L., Lundgren, H., Haandlykken, M. and Rydhmer, L., 2010. Genetics of growth in piglets and the association with homogeneity of body weight within litters. Journal of animal science, 88(4): 1240-1247.

Cassady, J.P., Johnson, R.K. and Ford, J.J., 2000. Comparison of plasma FSH concentration in boars and gilts from lines selected for ovulation rate and embryonal survival and litter size and estimation of (co)variance components for FSH and ovulation rate. Journal of animal science, 78 (6): 1430-1435.

Chen, P., Bass, T. J., Mabry, J. W., Dekkers, J. C. M. and Koehler K. J., 2002. Genetic parameters and trends for lean growth rate and its components in U. S. Yorkshire, Duroc, Hampshire and Landrace pigs. Journal of animal science, 80: 2062-2070.

Chimonyo, M., Dzama, K., Bhebhe, E. and Mapiye, C., 2011. Pre-weaning performance of the Zimbabwean Mukota and Large White × Mukota pigs under low-input production systems. Research opinions in animal & veterinary sciences, 1(6): 352-359.

Damgaard, L.H., Rydhmer, L., Lovendah, P. and Grandinson, K., 2003. Genetic parameters for within-litter variation in piglet birth weight and change in within-litter variation during suckling. Journal of Animal Science, 81: 604–610.

Deen, M. G. H. and Bilkei, G., 2004. Cross fostering of low-birth weight piglets. Livestock production science, 90: 279-284.

Dewey, C., de Grau, A., and Friendship, B., 2001. Grow/finish variation: cost and control strategies. In: Proceedings of the 1st London Swine Conference. London, Ontario. pp 115-122.

English, J. G. H. and Bilkei, G., 2004. The effect of litter size and littermate weight on pre-weaning performance of low-birth-weight piglets that have been cross fostered. Animal science, 79: 439-443.

English, P. R. and Bampton, P. R., 1982. Importance of within litter variation in piglet birth weight in relation to piglet survival and the influence of cross fostering simultaneously farrowed litters so as to achieve more uniform birth weights within litters. Proceedings of the international pig veterinary society congress, Mexico.

Faustin, P., Lekule, A., Niels, C. and Kyvsgaard, B., 2003. Improving pig husbandry in tropical resource-poor communities and its potential to reduce risk of porcine cysticercosis. Acta Tropica, 87: 111-117.

Fernandez, A., Rodriganez, J., Zuzuarregui, J., Rodriguez, M. C. and Silio, L., 2003. Genetic parameters for litter size and weight at different parities in Iberian pigs. Spanish journal of agricultural research, 6:98-106.

Fix, J.S., Cassady, J.P., Holl, J.W., Herring, W.O., Culbertson, M.S. and See, M.T., 2010. Effect of piglet birth weight on survival and quality of commercial market swine. Livestock Science, 123 (1-3): 98-106.

Foxcroft, G. R., and Town, S., 2004. Prenatal programming of postnatal performance -The unseen cause of variance. Advanced pork production, 15: 269-279.

Foxcroft, G., 2008. Hyper Prolificacy and acceptable post-natal development- a possible contradiction. Advances in pork production, 19: 205.

Gjerlaug-Enger, E., Aass, L., Odega, J. and Vangen O., 2010. Genetic parameters of meat quality traits in two pig breeds measured by rapid methods. Animal, 4(11):1832–1843.

Grandinson, K., Rydhmer, L., Strandberg, E. and Solanes, F.X., 2005. Genetic analysis of body condition in the sow during lactation, and its relation to piglet survival and growth. Animal science, 80: 33–40.

Hermesch, S., Luxford, B.G. and Graser, H.U., 2000. Estimation of variance components for individual piglet weights at birth and 14 days of age. Advanced Animal Breeding and Genetics, 14: 207-210.

Holm, B., Bakken, M., Klemetsdal, G. and Vangen, O., 2004. Genetic correlations between reproduction and production traits in swine. Journal of animal science, 82:3458-3464.

Hogberg, A. and Rydhmer, L., 2000. A Genetic study of piglet growth and survival. Animal science, 50: 300–303.

Honeyman, M.S., 2005. Extensive bedded indoor and outdoor pig production systems in USA: current trends and effects on animal care and product quality. Livestock Production Science 94, 15-24.

Honeyman, M.S. and Roush, W.B., 2001. The effects of outdoor farrowing hut type on prewean piglet mortality in Iowa. American Journal of Alternative Agriculture, 17:92-95.

Hoque, M.A., Kadowaki, H., Shibata, T., Oikawa, T. and Suzuki, K., 2009. Genetic parameters for measures of residual feed intake and growth traits in seven generations of Duroc pigs. Livestock science, 121(1): 45-49.

Huby, M., Canario, L., Tribout, T., Caritez, J. C., Billon, Y., Gogue, J. and Bidanel, J. P., 2003. Genetic correlations between litter size and weights, piglet weight variability and piglet survival from birth to weaning in Large White pigs. Proceedings 54th annual meeting. European association of animal production. Wageningen, Italy. pp. 362.

James, W. H., 2001. A prediction on the sex ratios of piglets. Journal of Theoretical Biology, 209: 1-2.

Kanis, E., De Greef, K. H., Hiemstra, A. and van Arendonk, J. A. M., 2005. Breeding for societally important traits in pigs. Journal of Animal Science, 83:948-957.

Kapell, D.N.R.G, Ashworth, C.J, Knap, P.W. and Roehe, R., 2010. Genetic parameters for piglet survival, litter size and birth weight or its variation within litter in sire and dam lines using Bayesian analysis. Livestock science, 135: 215-224.

Kim, S.W., Hurley, W.L., Wu, G. and Ji, F., 2009. Ideal amino acid balance for sows during gestation and lactation. Journal of Animal Science, 87: 123–132.

Knol, E.F., 2002. Genetic aspects of piglet survival. Ph.D. thesis, institute for pig genetics and animal breeding and genetics group, Wageningen University, The Netherlands.

Kyriazakis, I. and Whittemore, C.T., 2006. Whittemore's Science and Practice of Pig Production. Third edition. Blackwell publishing.

Latorre, M.A., Pomar, C., Faucitano, L., Gariepy, C. and Methot, S., 2008. The relationship within and between production performance and meat quality characteristics in pigs from three different genetic lines. Livestock science, 115:258–267.

Le Dividich, J., 1999. Review: management to reduce variation in pre- and post-weaned pigs. In: Cranwell, P.D. (Ed.), Manipulating Pig Production VII. Australasian pig science association, 135-155.

Love, R.J., Evans, G. and Klupiec, C., 1993. Seasonal effects on fertility in gilts and sows. Journal of Reproduction and Fertility, 48: 191-206.

Milligan, B.N., Fraser, D. and Kramer, D.L., 2001. Birth weight variation in the domestic pig: effects on offspring survival, weight gain and suckling behaviour. Applied animal behaviour science, 73: 179-191.

Milligan, B.N., Fraser, D. and Kramer, D.L., 2002. Within-litter birth weight variation in the domestic pig and its relation to pre-weaning survival, weight gain, and variation in weaning weights. Livestock production science, 76: 181–191.

Miller, Y.J, Collins, A.M, Smits, R.J. and Holyoake, P.K., 2006. Improving the performance of gilt progeny. Proceedings of the Australian Pig Veterinarians Conference. Melbourne.

Mungate, F., Dzama, K., Mandisodza, K. and Shoniwa, A., 1999. Some non-genetic factors affecting commercial pig production in Zimbabwe. South African journal of animal science, 29: 164-173.

Neal, S. M., and Irvin, K. M., 1991. The effects of cross fostering pigs on survival and growth. Journal of animal science, 69: 41-46.

Norris, D., Varona, L., Ngambi, J.W., Visser, D.P., Mbajiorgu, C.A. and Voordewind, S.F., 2010. Estimation of the additive and dominance variances in SA Duroc pigs. Livestock Science, 131: 144-147.

Oh, S. H., Lee, D. H. and See, M. T., 2005. Genetic correlations between growth and carcass traits. Animal science departmental report, North Carolina State University.

Oyewumi, O.A. and Jooste, A., 2006. Measuring the determinants of pork consumption in Bloemfontein, Central South Africa. Agrekon, 45(2):185.

O'Connell, N.E. and Beattie, V.E., 1999. Influence of environmental enrichment on aggressive behaviour and dominance relationships in growing pigs. Animal welfare, 8: 269-279.

Patience, J.F., Engele, K., Beaulieu, A.D, Gonyou, H.W. and Zijlstra R.T., 2004. Variation: costs and consequences. Advances in pork production, 15: 257.

Peaker, M. and Taylor, E., 1996. Sex ratio and litter size in the guinea-pig. Journal of Reproduction Fertility, 108: 63-67.

Prevolnik, M., Ocepek, M., Candek-Potokar, M., Bavec, M. and Skorjanc, D., 2011.Growth, carcass and meat quality traits of pigs raised under organic or conventional rearing systems using commercially available feed mixtures. Slovenian veterinary research, 48 (1): 15-26.

Quesnel, H., Brossard, L., Valancogne, A. and Quiniou, N., 2008. Influence of some sow characteristics on within-litter variation of piglet birth weight. Animal, 2: 1842-1849.

Quiniou, N., Dagorn, J. and Gaudre, D., 2002. Variation of piglet's birth weight and consequences on subsequent performance. Livestock production science, 78: 63–70.

Roehe, R., Shrestha, N.P., Mekkawy, W., Baxter, E.M., Knap, P.W., Smurthwaite, K.M., Jarvis, S., Lawrence, A.B. and Edwards, S.A., 2009. Genetic analyses of piglet survival and individual birth weight on first generation data of a selection experiment for piglet survival under outdoor conditions. Livestock science, 121: 173–181.

Taylor, G. and Roese, G., 2006. Basic pig husbandry-the litter. PRIMEFACT 71.

Smits, R. and Collins, C., 2009. Measurement and comparison of feed intake and growth performance during lactation and wean-finish of gilt progeny pigs cross-fostered onto multiparous sows. QAF Meat Industries.

Stookey, J.M. and Gonyou, H.W., 1994. The effects of regrouping on behavioural and production parameters in finishing swine. Journal of Animal Science, 72: 2804-2811.

Tantasuparuk, W., Lundeheim, N., Dalin, A. M., Kunavongkrit, A. and Einarsson, S., 2000. Reproductive performance of purebred Landrace and Yorkshire sows in Thailand with special reference to seasonal influence and parity number. Theriogenology, 54**:** 481–496.

Visser, D.P., 2004. The components of the pork supply chain in South Africa. PhD thesis. University of Pretoria, South Africa.

Wahner, M. and Fischer, K., 2005. Current physiological aspects of foetal growth and parturition in the pig. Biotechnology in Animal Husbandry, 21 (5-6): 135 -148.

Walker, N., 2002. Carcass quality of Northern Ireland pigs compared with those originating in the Republic of Ireland and Great Britain. A report commissioned by the Department of Agriculture and Rural Development for Northern Ireland.

Webb, E.C., Phiri, L.M. and Pieterse, E., 2006. Gonadal development of commercial pig genotypes in South Africa. South African Journal of Animal Science, 36 (5):26-29.

Wolf, J., Zakova, E. and Groeneveld, E., 2008. Within-litter variation of birth weight in hyper prolific Czech Large White sows and its relation to litter size traits, stillborn piglets and losses until weaning. Livestock Science, 115: 195–205.

Xue, J.L., Dial, G.D., Marsh, W.E and Davies, P.R., 1994. Multiple manifestations of season on reproductive performance of commercial swine. Journal of the American veterinary medical association, 204: 1486–1489.

YinHua, H., Han, S., DengQun, S., 2000. The effect of litter number and mating season on litter size of different breed pigs. Acta of Sichuan Agricultural University, 22: 106-109.

# Chapter 3: Partitioning of within-litter birth weight variation and its distribution in piglets

**Abstract**

Increasing within-litter birth weight variation in pigs affects litter performance. The objective of the study was to characterise within-litter birth weight variation in piglets. The study was conducted using records from 1 788 litters collected between January 1998 and September 2010 from a pig herd at the Agricultural Research Council (ARC) farm in Irene, South Africa. The farm is located at 25°34’0’’ S and 28°22’0’’ E and lies 1523 m above sea level. An approximate mean annual rainfall of 715 mm is received with mean annual temperature of 17.3°C. The number of piglets born alive (NBA) ranged from 3 to 18. The mean within-litter birth weight coefficient of variation (CVB) was 17.64 % and ranged from 0.47 to 50.65 %. The distribution of CVB in the herd was positively skewed. Multiparous sows farrowed litters with higher ($P<0.05$) CVB than gilts. The litter weight (TBWT) and NBA, fitted as covariates, also affected ($P<0.05$) CVB. The correlation between CVB and NBA was 0.299. Estimated phenotypic correlation between MBWT and CVB was moderate (-0.309). The phenotypic correlation between TBWT and CVB was low (0.058), but significantly different from zero ($P<0.05$). To enhance profitability of pig enterprises, the selection for NBA should, therefore, be accompanied by selection for CVB.

**Key Words:** Number of piglets born alive, Correlations, Parity, Coefficient of variation, Skewness, Litter weight at birth.

## 3.1 Introduction

Sow farrowing performance is among the most important determinants of profitability of pig enterprises (Fix *et al.*, 2010). The NBA has been a major component of sow productivity and genetic improvement programmes linked to it have been given priority (Zhu *et al.*, 2008). The number of teats a sow possesses limits the number of piglets it can nurture to weaning. When a sow farrows more piglets in a litter than the number of teats it has, the excess number of piglets have to be fostered (Canario *et al*., 2010). To date, sows from most breeds exhibit NBA of over 11 (Huang *et al.,* 2003; Zhu *et al*., 2008; Umesiobi, 2009). Kim *et al*. (2005) reported average teat numbers of 14 in Large White and Landrace sows. The continued selection for litter size is, therefore, likely to be limited by the number of teats. Although lowly heritable, litter size at birth is still incorporated in breeding programmes for pigs.

Profitability of pig enterprises primarily depends on the reproductive efficiency of sows in the herd. Traditionally, greater emphasis from pig producers and breeders has been on litter size at birth and at weaning. Litter weight is used as an indicator of sow productivity. It, however, does not indicate the variation within each litter, which has been shown to be important in predicting survival of each piglet to weaning. Recent reports have indicated that increasing NBA is associated with an increase in the variability in birth weights (Damgaard *et al*., 2003; Wolf *et al*., 2008; Fix *et al*., 2010). Light piglets have a reduced likelihood of surviving to weaning age and have reduced growth rates and weights at slaughter (Opschoor *et al*., 2009). Factors affecting the variability in piglet birth weights are complex, and poorly understood. These factors include nutrition and age of the sow, breed of boar and genetic selection of gilts (Chimonyo *et al*., 2006). To improve the homogeneity of litters at birth, the relative importance of these factors needs to be explored.

Besides NBA, virtually all commercial pig enterprises record cumulative traits such as NBD and litter weight at birth. Understandably, recording of litter traits saves time, is cheaper and easier when compared to individual piglet traits (Mungate *et al.*, 1999; Chimonyo *et al.*, 2006). Individual birth weights of piglets at birth are largely ignored because the value of individual piglet weights is considered irrelevant. The heritability of individual piglet birth weights has, however, been reported to be higher than for litter traits (Roehe, 1999; Chimonyo *et al*., 2006). The general practice among pig producers is to record the individual pig performance from three weeks of age until marketing. Within-litter birth weight variation, defined as the distribution of individual weight within a litter, has not been given much attention despite its recognised huge impact on pig enterprises (Wolf *et al*., 2007). Variation in the weights of piglets needs to be quantified and recorded as a sow trait that should be reflected in selection indices for gilts and sows. Similar to MBWT, either the coefficient of variation (CV) and/or the standard deviation (SD) can easily be computed (Milligan *et al*., 2001; 2002; Quiniou *et al*., 2002; Wolf *et al*., 2008).

Considering that the impact of stress due to fostering on the susceptibility of the piglets to diseases and parasites, as well as on growth performance, is well documented (Straw *et al.*, 1998; McCaw, 2000), there is need to consider selecting sows that produce uniform piglets at birth to reduce incidences of fostering. Uniform piglets at birth are likely to produce uniform pigs at weaning and also at marketing (Fix *et al*., 2010). Farmers are, therefore, able to accurately predict the productivity and performance of pigs up to marketing. Revenue to be generated can also be predicted with precision, thereby making financial planning easier. In addition, production of uniform piglets at birth reduces the incidences of foster-mothering which is commonly practised to reduce variation among litter mates. Large weight variations at birth also require the construction of more pens, thereby increasing the cost of housing, cleaning needs and general management. The additional labour, time and costs involved are among the main factors making pig producers not to record individual piglet weights (Hogberg and Rydhmer, 2000; Kaufmann *et al*., 2000; Chimonyo *et al*., 2006). The benefits of producing homogenous litters, therefore, outweigh the extra costs incurred to record individual weights of piglets at birth.

Considering its importance to pig production, CVB should be included in plans for genetic improvement and there is need to determine its heritability. As expected, CVB has low heritability (Hermesch *et al.*, 2001; Damgaard *et al.,* 2003), thus little improvement through selection is expected. Management is expected to have a substantial impact on CVB. Various studies have been conducted on non-genetic factors such as genotype, herd-year-season and parity of sow affecting litter traits in pigs (Mungate *et al.*, 1999; Tantasuparuk *et al.*, 2000; Prasamna *et al.*, 2009). The extent to which these factors influence within-litter birth weight variation has not been established. It is not clear whether the factors that influence litter traits at birth are also important in determining differences among variations in birth weight. In genetic analysis of traits, estimates for these fixed factors are required for adjusting the random genetic influences that are inherited across generations. The objective of the study was to identify factors that influence within-litter birth weight variation in pigs. It was hypothesized that non-genetic factors influence within-litter birth weight variation.

## 3.2 Materials and methods

### *3.2.1 Study site*

Data were collected from a pig herd at the Agricultural Research Council (ARC) farm in Irene, South Africa. The farm is located at latitude 25°34’0’’ S and altitude 28°22’0’’ E and lies 1523 m above sea level. An approximate mean annual rainfall of 715 mm is received with mean annual temperature of 17.3°C and mean annual humidity of 75 %. The warm humid season (November to January) and the cool dry season (May to July) average 23ºC and 15ºC, respectively.

### 3.2.2 Herd management

The study was conducted on a mixed pig herd with Landrace, Large White, Duroc, Pietrain and crosses between these breeds. The herd was kept on all-in-all-out systems in the farrowing, weaner and grower houses. Dry sows with body condition scores of more than 2 (on a scale of 1-5) were given 2 kg a day of sow and boar meal (13.5 MJ digestible energy (DE) and 160 g/kg crude protein (CP)/ kg as fed). Those with body condition score less than 2 received 2.5 or 3 kg per day until their body condition improved. In preparation for farrowing, sows were moved to the farrowing house and fed their daily ration of 2 kg sow and boar meal till they farrowed. After farrowing, lactating sows were fed a lactation meal (13.8 MJ DE and 160g CP/ kg as fed) with each sow receiving a daily allowance of 2 kg. An additional feed allowance was given gradually for an adaptation period of 1 week such that each sow would get an additional 0.5 kg for every piglet suckling. Piglets were given supplemental nutrients in the form of high energy crumbs (15.2MJ/kg DE and 180g CP/kg as fed) from 10 to 14 days old in small feed troughs with daily feed allowance increasing gradually.

### 3.2.3 Data structure and preparation

Data used in the study included 20 741 piglets from 1 836 litter records obtained from January 1998 until September 2010. The records consisted of piglet identity, breed of sow, breed of boar, parity number, farrowing date, farrowing month, farrowing year, NBA and individual piglet birth weight. From these records, MBWT, TBWT, within-litter birth weight standard deviation (SDB), CVB, minimum birth weight (MinB) and maximum birth weight (MaxB) were calculated. Records of litters with piglets fostered in or out were excluded in the analyses. Litters less than 3 piglets were assumed to have piglets fostered out and were excluded from the analyses. Data from 48 litters were deleted, leaving a total of 1 788 litters available for analysis. Parities greater than 6 were categorised as more than or equal to seven.

### *3.2.4 Descriptive statistics for birth weight variation*

Distribution of birth weights within the litter was described by several quantities. The arithmetic mean represented the average birth weight. The PROC UNIVARIATE (SAS, 2008) was used to examine the distribution of CVB, SDB and MBWT and frequency distributions. Skewness was calculated to describe the deviation of the distribution of CVB, SDB and MBWT between litters from the (symmetric) normal distribution. A negative skewness value indicated that the majority of the litters' CVB, SDB or MBWT were above the herd mean while a minority number of litters had CVB, SDB or MBWT substantially below herd mean. A positive skewness value indicated that the majority of the litters' CVB, SDB or MBW were below the herd mean while a minority of the litters had CVB, SDB or MBWT substantially above herd mean (Milligan *et al*., 2002).

### *3.2.5 Model development and analyses*

The effects of breed of sow and boar, parity, month of farrowing and relevant covariates on NBA, TBWT, MBWT, MinB , MaxB , SDB and CVB were analysed using the General Linear Model procedures (SAS, 2008). The models used were:

*Model 1: Number born alive (NBA)*

$Y_{ijk} = \mu + S_i + P_j + M_k + \beta_1 TBWT + \beta_2 MBWT + E_{ijkl}$

*Model 2: Mean birth weight (MBWT)*

$Y_{ijkl} = \mu + S_i + P_j + M_k + (P \times M)_{jk} + \beta_3 NBA + E_{ijkl}$

*Model 3: Maximum birth weight*

$Y_{ijkl} = \mu + S_i + P_j + M_k + (P \times M)_{jk} + \beta_1 TBWT + \beta_3 NBA + E_{ijkl}$

*Model 4: Minimum birth weight*

$Y_{ijkl} = \mu + S_i + P_j + M_k + \beta_3 NBA + E_{ijkl}$

*Model 5: Litter weight*

$Y_{ijkl} = \mu + S_i + P_j + M_k + (P \times M)_{jk} + \beta_3 NBA + \beta_2 MBWT + E_{ijkl}$

*Model 6: Birth weight standard deviation*

$Y_{ijklmn} = \mu + S_i + P_j + M_k + (PxM)_{jk} + (SxP)_{ij} + \beta_3 NBA + E_{ijkl}$

*Model 7: Birth weight CV*

$Y_{ijklmn} = \mu + S_i + P_j + M_k + B_l + (P \times M)_{jk} + (S \times P)_{ij} + \beta_3 NBA + E_{ijkl}$

where:

$Y_{ijkl(mn)}$ = the dependant variable ( NBA, MBWT, MaxB, MinB, TBWT, SDB or CVB);

$\mu$ = arithmetic mean common to all observations;

$S_i$ = effect of $i^{th}$ breed of sow;

$P_j$ = effect of $j^{th}$ parity of sow;

$M_k$ = effect of $k^{th}$ month of birth;

$B_l$ = effect of $k^{th}$ breed of boar;

$P \times M_{jk}$ = effect of interaction between parity and month;

$S \times P_{ij}$ = effect of interaction between parity and breed of sow;

$\beta_1$ = partial linear regression coefficient of the dependent variable on TBWT;

$\beta_2$ = partial linear regression coefficient of the dependent variable on MBWT;

$\beta_3$ = partial linear regression coefficient of the dependent variable on NBA; and

$E_{ijkl}$ = residual error.

Simple Pearson correlations were calculated among measures of variability (SDB, CVB) and other dependant variables TBWT, NBA, MBWT, MinB and MaxB. Relationships between CVB and parity and CVB and NBA were plotted using Proc Gplot (SAS, 2008).

## 3.3 Results

### *3.3.1 Summary statistics*

Table 3.1 shows the number of observations, raw means, standard deviations, skewness of distribution, minimum and maximum values for the traits studied. A wide range of CVB from 0.47 to 50.65 % reflected considerable differences among litters in the distribution of the CVB over the 10-year period. Table 3.2 summarises the levels of significance of breed of sow, breed of boar, parity, month, TBWT, MBWT, NBA and the interactions in the models on studied traits.

### *3.3.2 Number born alive*

Parity of sow had a significant effect ($P<0.05$) on NBA (Table 3.2). The NBA increased then decreased with parity (Table 3.3). The maximum NBA was observed in Parity 4. The NBA then decreased significantly for litters beyond parity 6 (Table 3.3). The NBA for gilts was significantly different from multiparous sows, except those greater than Parity 6.

**Table 3.1: Summary statistics of number born alive, litter weight at birth, mean birth weight, within-litter birth weight standard deviation, within-litter birth weight coefficient of variation, minimum birth weight within a litter and maximum birth weight within a litter**

| Trait | N | Mean | Standard deviation | minimum | maximum | Skewness |
|---|---|---|---|---|---|---|
| NBA | 1768 | 10.21 | 2.74 | 3.00 | 18.0 | -0.21 |
| TBWT | 1763 | 15.60 | 4.63 | 6.70 | 36.70 | 0.20 |
| MBWT | 1777 | 1.55 | 0.33 | 0.54 | 2.88 | 0.58 |
| SDB | 1774 | 0.27 | 0.10 | 0.04 | 0.79 | 0.78 |
| CVB | 1774 | 17.64 | 6.89 | 0.47 | 50.65 | 0.54 |
| MinB | 1779 | 1.10 | 0.36 | 0.20 | 2.90 | 0.48 |
| MaxB | 1778 | 1.92 | 0.37 | 0.80 | 3.30 | 0.73 |

NB: CVB = Within-litter birth weight coefficient of variation;

MaxB = Maximum birth weight within a litter;

MBWT = Mean birth weight;

MinB = Minimum birth weight within a litter;

NBA = Number born alive;

SDB = Within-litter birth weight standard deviation;

TBWT = Litter weight at birth.

**Table 3.2: Levels of significance for non-genetic factors on number born alive, litter weight at birth, mean birth weight, minimum birth weight within a litter, maximum birth weight within a litter, within-litter birth weight standard deviation and within-litter birth weight coefficient of variance**

| Source | Significance level | | | | | | |
|---|---|---|---|---|---|---|---|
| | NBA | TBWT | MBWT | MinB | MaxB | SDB | CVB |
| Breed of sow | NS | NS | NS | * | * | NS | NS |
| Parity | * | ** | * | NS | ** | ** | ** |
| Month | NS | * | NS | ** | * | NS | NS |
| Parity x sow breed | NS | NS | NS | NS | NS | ** | * |
| TBWT | ** | _ | ** | _ | _ | ** | ** |
| MBWT | ** | ** | _ | _ | _ | - | _ |
| NBA | - | ** | ** | ** | ** | ** | ** |

**P<0.05; **P< 0.01;   NS- not significant (P>0.)*

NB: CVB = Within-litter birth weight coefficient of variation; MaxB = Maximum birth weight within a litter; MBWT = Mean birth weight; MinB = Minimum birth weight within a litter; NBA = Number born alive; SDB = Within-litter birth weight standard deviation; TBWT = Litter weight at birth.

**Table 3.3: Least square means for the effects of sow parity on number born alive (NBA), litter weight at birth, mean birth weight, minimum birth weight within a litter, maximum birth weight within a litter, , within-litter birth weight standard deviation, , and within-litter birth weight coefficient of variation**

| Parity | n | NBA | TBWT | MBWT | SDB |
|---|---|---|---|---|---|
| 1 | 684 | $9.8 \pm 0.58^{a}$ | $15.7 \pm 0.95^{a}$ | $1.61 \pm 0.064^{a}$ | $0.26 \pm 0.022^{a}$ |
| 2 | 367 | $10.6 \pm 0.59^{bc}$ | $17.4 \pm 0.97^{bc}$ | $1.66 \pm 0.066^{b}$ | $0.27 \pm 0.023^{ab}$ |
| 3 | 232 | $10.8 \pm 0.60^{bcd}$ | $17.9 \pm 0.98^{c}$ | $1.68 \pm 0.067^{b}$ | $0.29 \pm 0.023^{c}$ |
| 4 | 158 | $11.3 \pm 0.62^{d}$ | $18.3 \pm 1.01^{c}$ | $1.65 \pm 0.069^{ab}$ | $0.30 \pm 0.024^{c}$ |
| 5 | 102 | $11.1 \pm 0.64^{cd}$ | $18.2 \pm 1.05^{c}$ | $1.66 \pm 0.072^{ab}$ | $0.31 \pm 0.024^{c}$ |
| 6 | 61 | $11.0 \pm 0.67^{bcd}$ | $17.3 \pm 1.10^{bc}$ | $1.62 \pm 0.075^{ab}$ | $0.29 \pm 0.026^{bc}$ |
| 7≤ | 66 | $10.1 \pm 0.66^{ab}$ | $16.3 \pm 1.08^{ab}$ | $1.63 \pm 0.074^{ab}$ | $0.31 \pm 0.025^{c}$ |

*Values in the same column with different superscripts differ (P<0.05)*

NB: CVB = Within-litter birth weight coefficient of variation;

MaxB = Maximum birth weight within a litter;

MBWT = Mean birth weight;

MinB = Minimum birth weight within a litter;

NBA = Number born alive;

SDB = Within-litter birth weight standard deviation;

TBWT = Litter weight at birth.

The TBWT and MBWT, fitted in as covariates, also affected NBA ($P<0.01$). The month of farrowing and breed of sow did not affect NBA.

### *3.3.3 Litter weight*

Both parity of sow and month of farrowing had significant effects ($P<0.05$) on TBWT. The TBWT increased with parity up to Parity 4 and decreased beyond the fifth parity. As shown in Table 3.4, the heaviest litters were born in September and October ($P<0.05$), whilst the lightest litters were recorded during the cool-dry months (May to August) ($P<0.05$). There was no significant difference in TBWT between Landrace, Large White, Duroc, Pietrain and crosses between the breeds.

### *3.3.4 Maximum and minimum birth weights*

Both breed of sow and month of farrowing affected ($P<0.05$) both MaxB and MinB. Parity had a highly significant effect ($P<0.01$) on MaxB but not on MinB. There was a general increase in MaxB from Parity 1 to 5 followed by a decrease from Parity 5 to parities greater than 6 (Figure 3.1). The MaxB was high during the hot-wet season (November to March) and the dry-hot season (August to October), reaching its peak value in October. Low MaxB were observed during the cold-dry season (May to July) reaching its lowest value in May (Table 3.4). Likewise, MinB values were high during the hot-wet season (November to March) and the dry-hot season (August to October) reaching their peak value in March. Low values of MinB were observed during the cold-dry season (May to July) reaching their lowest value in May. The NBA, fitted as

**Table 3.4: Least square means for the effects of farrowing month on litter weight at birth, minimum birth weight within a litter, and maximum birth weight within a litter**

| Month | N | TBWT | MinB | MaxB |
|---|---|---|---|---|
| Jan | 118 | $17.6 \pm 1.03^{bc}$ | $1.17 \pm 0.081^{b}$ | $2.05 \pm 0.080^{bc}$ |
| Feb | 161 | $17.5 \pm 1.01^{bc}$ | $1.16 \pm 0.079^{b}$ | $2.09 \pm 0.078^{cd}$ |
| Mar | 136 | $17.6 \pm 1.04^{bc}$ | $1.18 \pm 0.081^{b}$ | $2.07 \pm 0.080^{bcd}$ |
| Apr | 143 | $17.4 \pm 1.03^{ab}$ | $1.12 \pm 0.081^{ab}$ | $2.07 \pm 0.080^{bcd}$ |
| May | 155 | $16.4 \pm 1.02^{a}$ | $1.08 \pm 0.080^{a}$ | $1.88 \pm 0.079^{ab}$ |
| Jun | 113 | $17.1 \pm 1.05^{ab}$ | $1.19 \pm 0.082^{b}$ | $2.01 \pm 0.081^{abc}$ |
| Jul | 184 | $16.4 \pm 0.93^{a}$ | $1.08 \pm 0.078^{a}$ | $1.94 \pm 0.077^{a}$ |
| Aug | 142 | $16.9 \pm 1.04^{ab}$ | $1.14 \pm 0.081^{ab}$ | $2.06 \pm 0.080^{abcd}$ |
| Sep | 169 | $18.5 \pm 1.03^{c}$ | $1.16 \pm 0.081^{b}$ | $2.13 \pm 0.080^{d}$ |
| Oct | 133 | $18.0 \pm 1.01^{c}$ | $1.14 \pm 0.079^{ab}$ | $2.08 \pm 0.079^{cd}$ |
| Nov | 131 | $17.0 \pm 1.03^{ab}$ | $1.10 \pm 0.081^{ab}$ | $2.01 \pm 0.080^{abc}$ |
| Dec | 195 | $17.5 \pm 1.01^{b}$ | $1.17 \pm 0.079^{b}$ | $2.08 \pm 0.078^{cd}$ |

*Values in the same column with different superscripts differ (P<0.05)*

NB: MaxB = Maximum birth weight within a litter;

MinB = Minimum birth weight within a litter;

TBWT = Litter weight at birth.

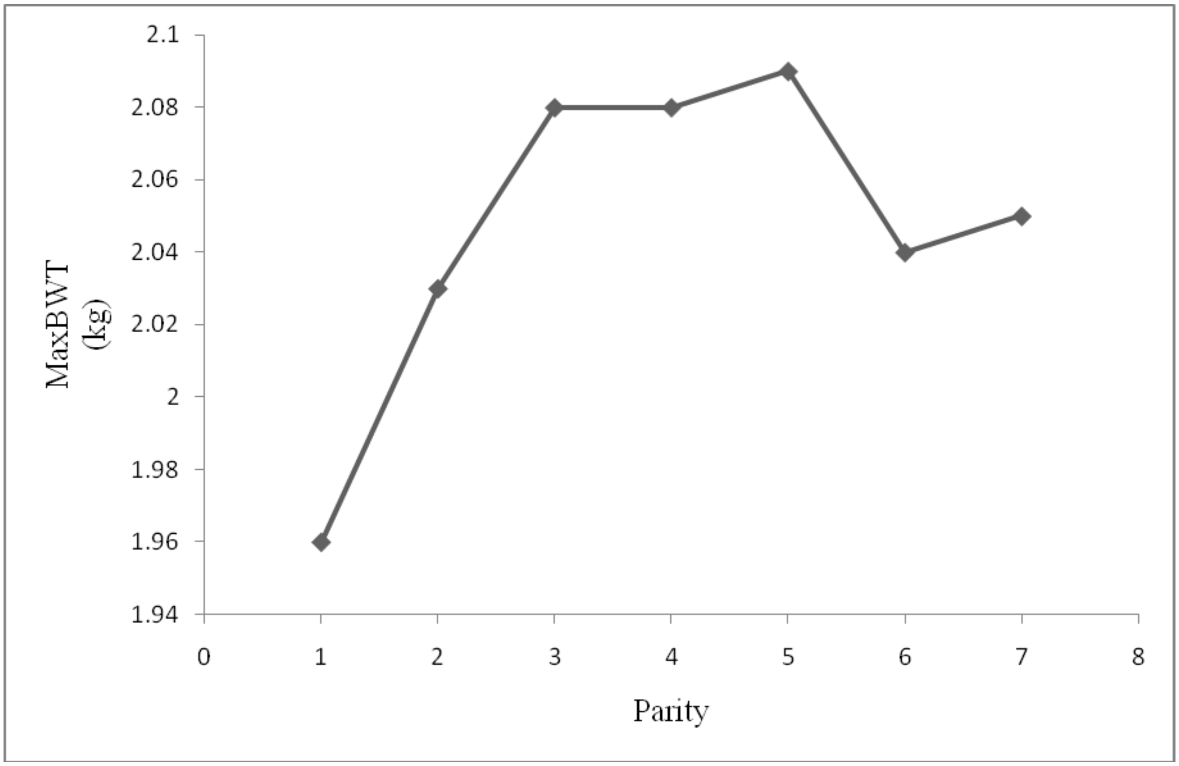


**Figure 3.1: Variation of maximum birth weight (MaxB) with parity**

a covariate, had a highly significant (P<0.01) effect on MaxB and MinB of piglets within litters (Table 3.2).

### *3.3.5 Mean birth weight*

Parity affected MBWT of piglets born alive in each litter (P<0.05). The MBWT increased to peak at Parity 2 and 3 (P<0.05) before declining thereafter. Parity 1, 6 and 7 had low MBWT (P<0.05) (Table 3.3). The TBWT and NBA, fitted as covariates, also affected MBWT (P<0.01). Breed of sow and month of farrowing had no significant effect on MBWT (P>0.05). Interactions between parity and breed of sow, parity and month of farrowing had no significant effects (P>0.05) on MBWT.

### *3.3.6 Birth weight variation*

The CVB for most litters was close to the mean (17.64) and the right (higher value) tail was longer, showing positive skewness (Figure 3.2). The SDB also had a longer right tail and most litters having SDB near the mean (0.27) (Figure 3.3). Positive values for skewness indicated that the distribution of both variables was asymmetric. As shown in Figures 3.2 and 3.3, the distributions of CVB or SDB were similar. As such, only CVB will be reported in this study. Parity had a significant (P<0.05) effect on CVB. Figure 3.4 illustrates how CVB varied with parity. The CVB was lowest in litters from gilts and highest in litters from multiparous sows. Litters born to sows in middle and late parities (3 and higher) showed larger CVB compared to those born to sows in their early age (1-2) (P<0.05). The TBWT and NBA, fitted as covariates, also affected CVB (P<0.05).

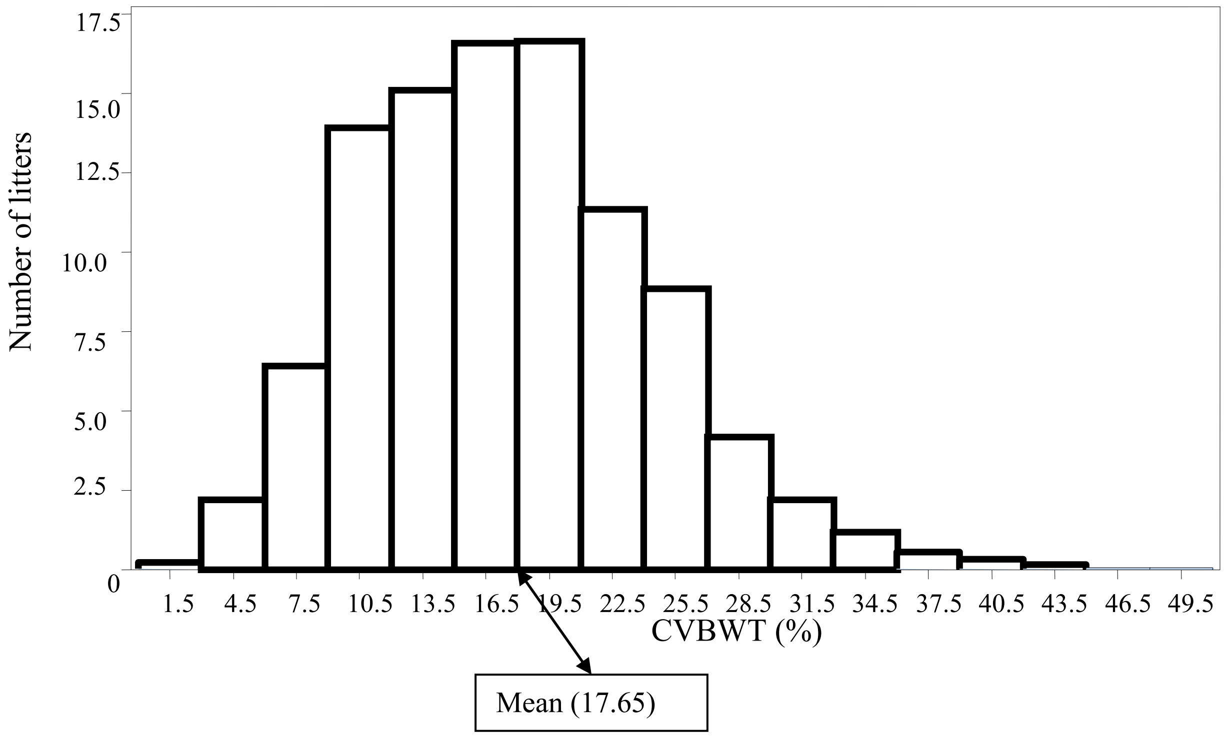


**Figure 3.2: Distribution of within-litter birth weight coefficient of variation (CVB) between litters**

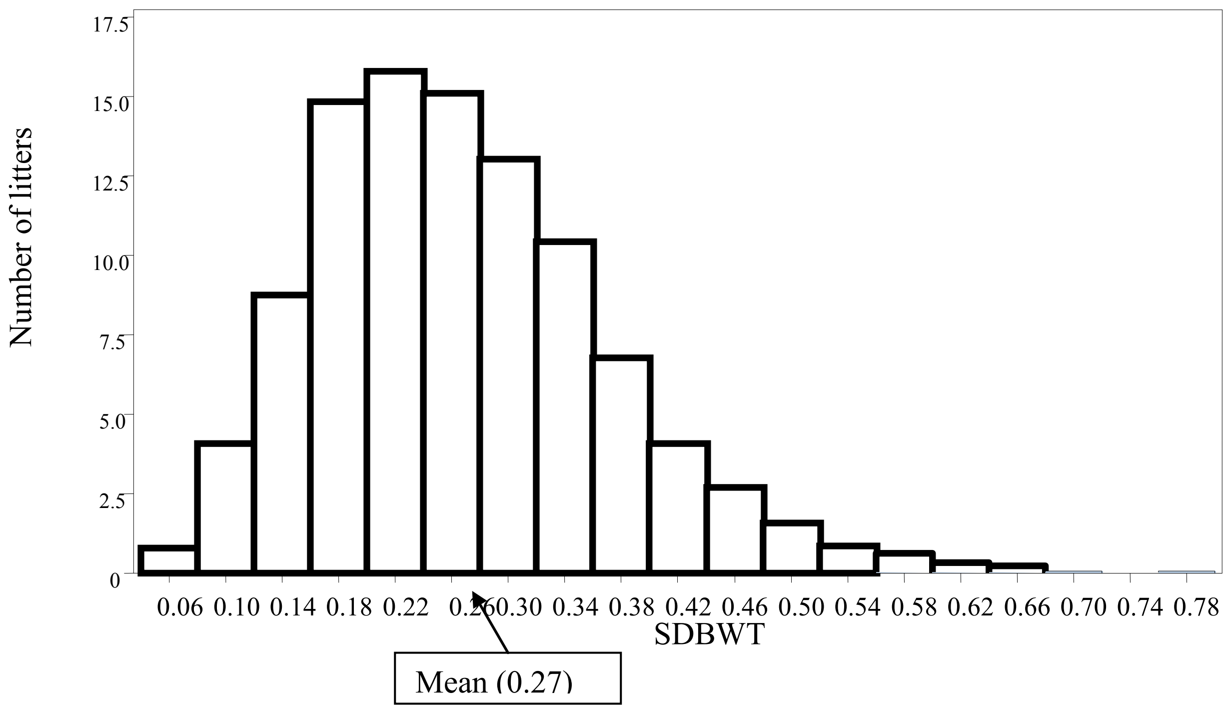


**Figure 3.3: Distribution of within-litter birth weight standard deviation (SDB) between litters**

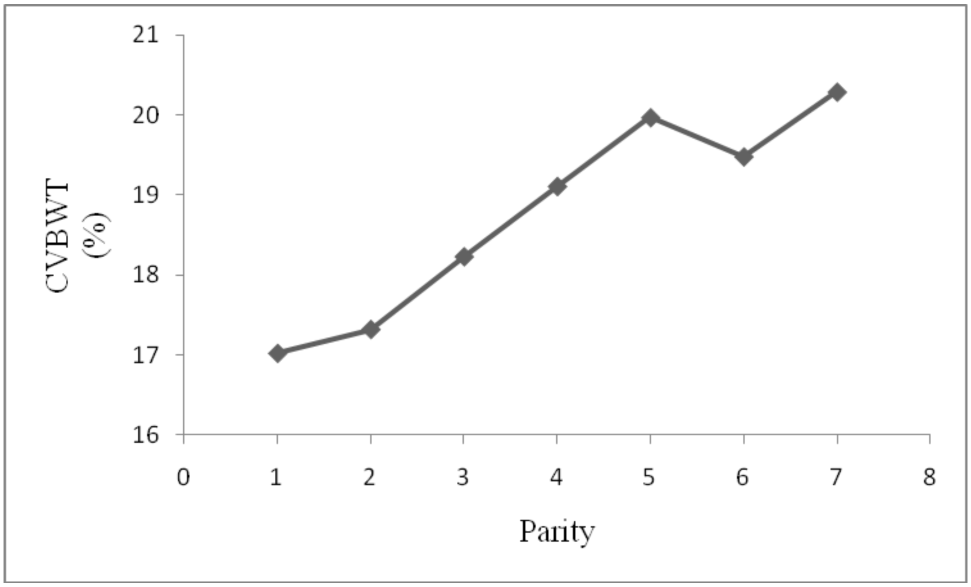


**Figure 3.4: Variation of within-litter birth weight coefficient of variation (CVB) with parity**

There was a significant interaction between parity and breed of sow on CVB. The rate of increase of CVB with parity differed among breeds. Neither breed of boar nor sow influenced within-litter birth weight variation (P>0.05). Likewise, no significant (P>0.05) month effects on within-litter birth weight variation were observed. Figures 3.5 and 3.6 show the relationship between CVB and NBA and CVB and parity, respectively. The CVB increased at an increasing rate as NBA increased. Similarly, CVB had an exponential relationship with parity.

### *3.3.7 Correlations*

The NBA was negatively correlated with MinB, MaxB, and MBWT and positively correlated with TBWT, CVB and SDB (Table 3.5). Litters with more piglets born alive (NBA) had lower MaxB and MinB. The positive correlation between NBA and CVB was relatively low. The correlation between MBWT and CVB was moderate (-0.309), whilst a positive correlation with SDB was observed. The correlation between TBWT and CVB was low, but significantly different from zero (Table 3.5).

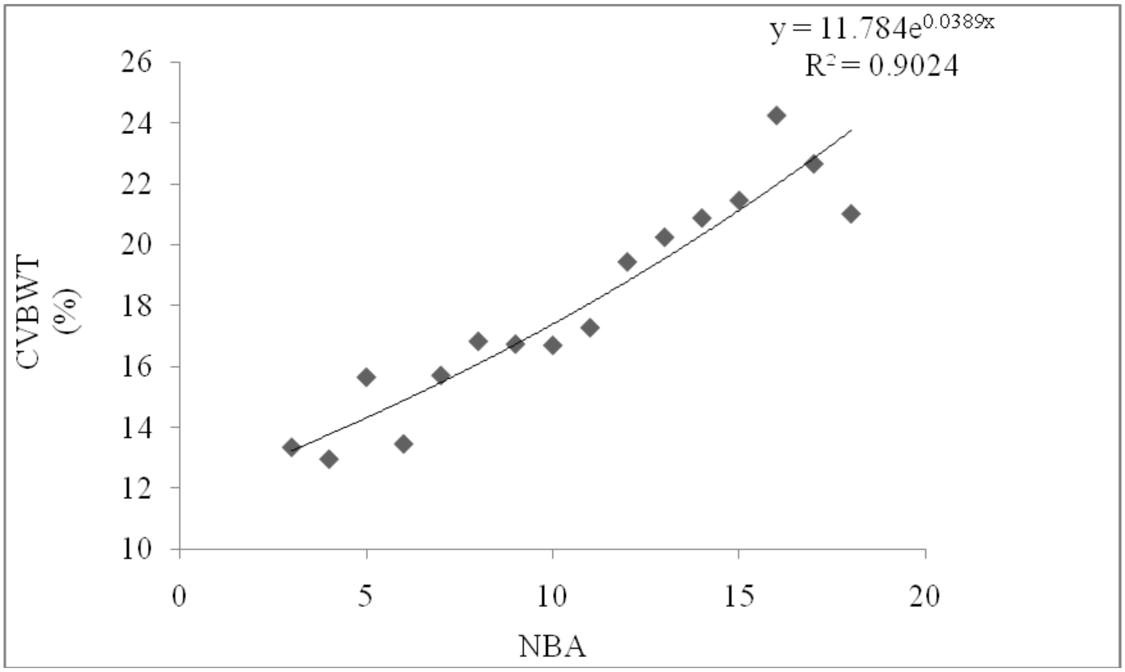


**Figure 3.5: Relationship between within litter birth weight coefficient of variation (CVB) and number born alive (NBA)**

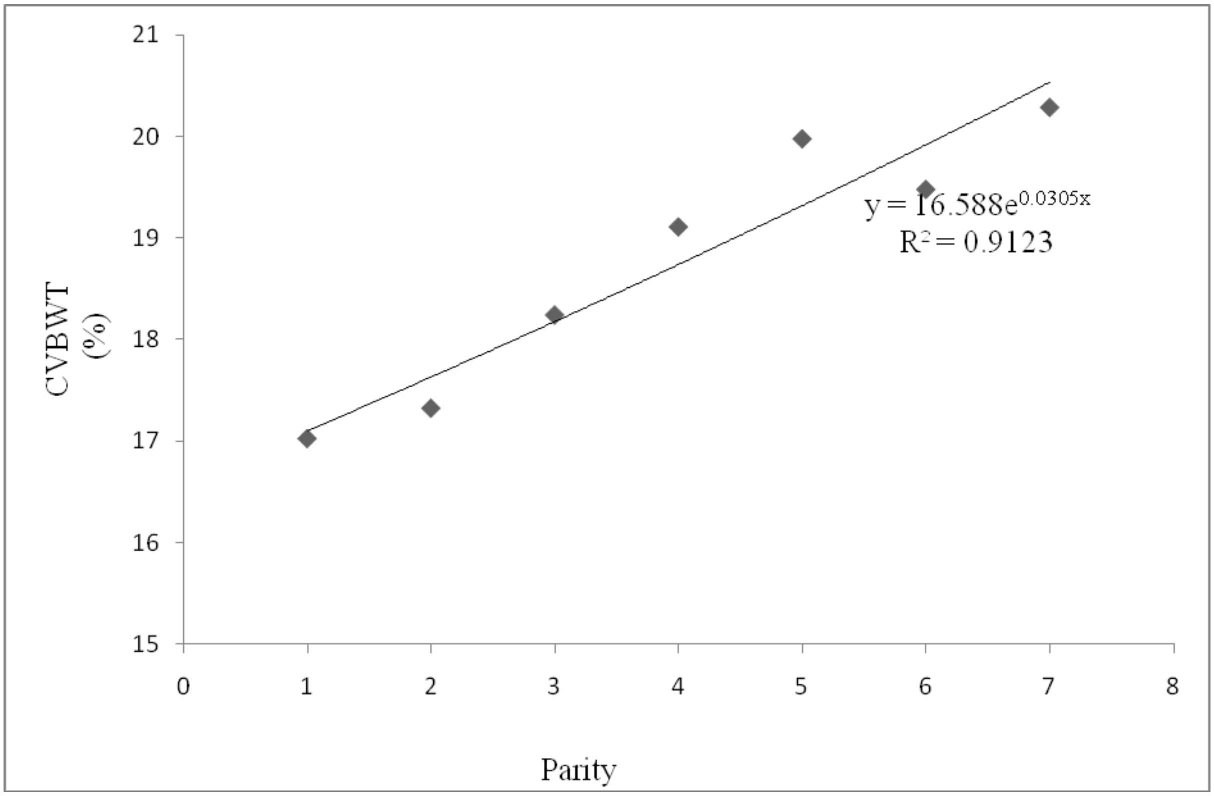


**Figure 3.6: Relationship between within litter birth weight coefficient of variation (CVB) and parity**

**Table 3.5: Correlations between number born alive (NBA), litter weight (TBWT); within-litter birth weight standard deviation (SDB), within-litter birth weight coefficient of variation CVB, minimum birth weight (MinB), maximum birth weight (MaxB) and mean birth weight (MBWT) in 1 788 litters**

| Variable | SDB | NBA | MinB | MaxB | MBWT | TBWT |
|---|---|---|---|---|---|---|
| CVB | 0.83** | 0.30** | -0.69** | 0.05 | -0.31** | 0.06* |
| SDB | | 0.17** | -0.31** | 0.53** | 0.22** | 0.32** |
| NBA | | | -0.44** | -0.09** | -0.26** | 0.73** |
| MinB | | | | 0.53** | 0.78** | 0.11* |
| MaxB | | | | | 0.89** | 0.52* |
| MBWT | | | | | | 0.44** |

*P<0.05

**P<0.01

NB: CVB = Within-litter birth weight coefficient of variation;

MaxB = Maximum birth weight within a litter;

MBWT = Mean birth weight;

MinB = Minimum birth weight within a litter;

NBA = Number born alive;

SDB = Within-litter birth weight standard deviation;

TBWT = Litter weight at birth.

### 3.4 Discussion

Although the herd structures used in this study may differ from other studies, the mean values of studied traits were within the range reported in other studies conducted under similar environmental conditions, such as the study conducted by Mungate *et al.* (1999). There are few published reports on the evaluation of within-litter birth weight variation in Czech Republic and Canada by Milligan *et al.* (2002) and Wolf *et al.* (2008). To our knowledge, no similar estimates have been reported on any pig breeds in the Southern Africa.

Within-litter birth weight variation can be quantified using the standard deviation (SD) or the coefficient of variation (CV) expressed relative to MBWT. Litters with different piglet birth weight ranges can have the same SD with different CV. For example, a litter of piglets weighing from 0.2 to 2 kg at birth can have the same SD value similar to those in a litter with birth weight from 0.5 to 3.0 kg, but with the CV smaller for the heavier litter. This is due to the fact that SD is derived from the mean of the data. The CV is a dimensionless number derived as a ratio of the SD to the mean. Most authors reported on the distribution of birth weight within a litter (Milligan *et al*., 2001; Knol *et al*., 2002). The current study analysed a range of statistics referring to the distribution of birth weight variation within a herd. Hence, the range of CVB reported in this study was larger than that reported by Wolf *et al*. (2008). This difference could be due to differences in herd structures and minimum NBA used for analysis. Nevertheless, The CVB mean of 17.65 % obtained from this study was within the typical range of 18 to 25 % reported by Dividich (1999). The finding that more litters had CVB higher than the herd's mean CVB implies that there is scope for improvement of within-litter birth weight homogeneity. In this study, the range and mean for CVB was higher than values reported by Wolf *et al. (*2008) and the difference could be ascribed to differences in environmental conditions and herd composition.

As expected, the variation in piglet birth weight within a litter was high in larger litters similar to earlier findings (Milligan *et al.,* 2002; Quiniou *et al*., 2002; Quesnel *et al.,* 2008). As NBA increased, within-litter birth weight variation also increased. Litter-mates are expected to be alike because they develop in the same uterus and are thus exposed to an environment remarkably uniform for members of the same litter but perhaps differing distinctly from litter to litter. Various studies (Milligan *et al*., 2002; Quiniou *et al*., 2002; Knol *et al*., 2002) concur with our finding that there were differences in within-litter birth weight, suggesting that the influence of non-genetic factors differ from one part of the uterus to the other. Due to the variation in birth weight, there are post-natal suckling ability differences among litter-mates. The indirect competition for resources that results from this difference may account for differences in weaning weight between litter-mates and is one mechanism through which within-litter heterogeneity could be explained (Milligan *et al*., 2001; Canario *et al*., 2010). Such findings heighten the need to quantify this variation.

The observed effect of NBA on within-litter birth weight variation confirms reports by Canario *et al*. (2010), who suggested that variation in birth weight of litter-mates could be due to differences in litter size and uterine capacity, size of placenta and interaction between these factors. The area of placenta available for each foetus in large litters is less than that available in smaller litters. The degree of placental growth is primarily influenced by the availability of space and vascular supply with litters near the placental walls where blood is higher receiving more nutrients than litter-mates positioned centrally (Pere and Etienne, 2000). If the optimal number of piglets per year per sow is to be achieved, future research in selection programmes should attempt to optimise both NBA and within-litter birth weight variation. This could be achieved through increasing our understanding of the physiological factors that influence litter size-uterine interactions.

Piglets from primiparous sows were more uniform than piglets from older sows, this being related to the effect of parity on NBA (Milligan *et al*., 2002). In this study, sows in parities 2 to 5 had larger NBA than early (Parity 1) and late parity sows and this agrees with the observations reported by Fernandez *et al*. (2008). Gilts and young sows have low ovulation rates compared to mature sows (Cole *et al*., 1994). Reduction in NBA in sows in parities greater than 6 can be attributed to high incidences of farrowing problems which lead to higher piglet mortalities which invariably reduced the NBA value. In support to this, English *et al.* (1988) reported an increase in the incidence of stillbirths after Parity 6. Therefore, to achieve consistent NBA, the parity structure of the herd should be stabilised by a regular flow of gilts into the herd, a high number of females in the most productive parity range (4 to 6) and strict culling after Parity 6.

Contrary to the suggestion that the effect of parity on CVB is related to parity effect on NBA, in the present study, there was no significant difference in CVB of first and second parity sows despite significance difference in NBA between the two parities. This would suggest that litter heterogeneity is partly influenced by parity. The dissension can also be due to the exclusion of litters with less than three piglets from the analysis. This eliminated mainly first parity sows, since NBA increases with sow parity (Fernandez *et al.,* 2008; Lutaaya *et al*., 2009; Saito *et al*., 2010). The effect of parity on within-litter birth weight variation suggests that there are some physiological factors reinforcing parity-uterine interaction which affects piglet placental growth hence homogeneity. Similarity in CVB across parity 1 and 2 with the NBA varying could be due to increase in uterine size as parity increases due to increase in body weight of the sow. This suggests that there could be a favourable relationship between weight of the sow and CVB but this could not be ascertained by this study. If so, CVB could be reduced by mating gilts when they are older and bigger or using breeds that have bigger frames. Since the observed relationship between parity and CVB reflects that older sows produce litters with much variation this suggests that sows in Parity 7 and above should account for a small percentage in the herd.

The observation that primiparous gilts and sows in their late parities had lower MBWT than sows in parities 2 to 5 agrees with previous reports (Milligan *et al.,* 2002). Gilts produce piglets of low birth weights because they are still physiologically immature and hence have to partition nutrients between their own nutrient requirements and those of the foetuses (Ncube *et al*., 2003). Age-associated physiological deterioration in sows in their late parities results in less efficient utilisation of feed to provide nutrition to foetuses hence, low MBWT (Mungate *et al.,* 1999). Seasonal variations in MaxB and MinB can be related to variation of TBWT with season, since there is a strong positive correlation between TBWT and both MaxB and MinB. These findings confirm results of other studies which indicate that during hot or warm seasons, sows produce not only smaller litters but also lighter piglets (Tummaruk and Khatiworavage, 2011). Since both CVB and MBWT increased with parity, a positive relationship was expected between CVB and MBWT, but we observed a negative correlation. The negative correlation agrees with Milligan *et al*. (2001) who reported a correlation of -0.491 compared to -0.309 in this study.

Similarities in the observed NBA in the hot-wet season and cool-dry season explain why there were no seasonal effects on CVB. This finding contradicts that of Mungate *et al.* (1999) and YinHua *et al.* (2000) who found differences in NBA across the two seasons. The fact that pigs were fed indoors under similar conditions throughout the year could have eliminated seasonal effects on nutrition and environmental physiology respectively. The contrary results might be due to other factors such as differences in prevailing environmental conditions such as heat, light and rainfall between the areas of study. The effect of NBA on MinB and MaxB could be related to effect of litter size in the uterus on piglet birth weight.

### 3.5 Conclusions

In conclusion, CVB is effective in quantifying within-litter birth weight variation. Large NBA was associated with increased within-litter birth weight variation. Parity also influenced CVB and within-litter birth weight variation was lowest in primiparous sows. Therefore, pig producers should strike a balance between NBA and within-litter birth weight variation to maximise piglets weaned per sow per year. Consequently, selection for NBA should be accompanied by increasing uniformity of piglet weights at birth. Although month of farrowing did not affect CVB, the influence of nutritional management of sows on litter variability, including appropriate feeding regimes, should be examined to enhance uniformity of piglets at birth. There was no difference in CVB between the studied breeds. Month of farrowing did not affect CVB. The CVB was not affected by interactions between parity and month of farrowing. There is need to determine the impact of within-litter birth weight variation on subsequent piglet performance. Heaviest litters were born in September and October whilst the lightest litters were born during

May to August. Litter weight increased with parity of sow up to parity 5 and declined thereafter. There were no effects of interactions between breed, parity of sow and month of farrowing on litter weight.

### 3.6 References

Canario, L., Lundgren, H., Haandlykken, M. and Rydhmer L., 2010. Genetics of growth in piglets and the association with homogeneity of weight within litters. Journal of Animal Science, 88: 1240-1247.

Casellas, J., Caja, G. and Piedrafita, J., 2007. Genetic determinism for within-litter birth weight variation and its relationship with litter weight and litter size in the Ripollesa ewe breed. Animal, 1: 637–644.

Chimonyo, M., Dzama, K. and Bhebhe E., 2006. Genetic determination of individual birth weight, litter weight and litter size in Mukota pigs. Livestock Production Science, 105: 67-69.

Cole, D.J.A., Wiseman, J. and Variety M.A., 1994. Principles of pig science. British cataloguing in publication data, Nottingham, UK.

Damgaard, L.H., Rydhmer, L., Lovendahl, P. and Grandinson K., 2003. Genetic parameters for within-litter variation in piglet birth weight and change in within-litter variation during suckling. Journal of Animal Science, 81: 604–610.

English, P.R., Smith, W.J. and Mclean A., 1988. The sow: improving her efficiency. Farming press Ltd. Suffolk, UK.

Fernandez, A., Rodriganez, J., Zuzuarregui, J., Rodriguez, M.C. and Silio L., 2008. Genetic parameters for litter size and weight at different parities in Iberian pigs. Spanish Journal of Agricultural Research, 6: 98-106.

Fix, J.S., Cassady, J.P., Holl, J.W., Herring, W.O., Culbertson, M.S. and See M.T., 2010. Effect of piglet birth weight on survival and quality of commercial market swine. Livestock Production Science, 123 (1-3): 98-106.

Gootwine, E., Rozov, A. and Weller J.I., 2006. Factors affecting within-litter variation in birth weight of lambs. 8th world congress on genetics applied to livestock production, August 13-18, Belo Horizonte, Brazil.

Hermesch, S., Luxford, B.G. and Graser, H.U., 2001. Genetic parameters for piglet mortality, within-litter variation of birth weight, litter size and litter birth weight. In: Proceedings of Advanced Animal Breeding and Genetics. Queenstown, NZ. 14: 211–214.

Hogberg, A. and Rydhmer, L., 2000. A genetic study of piglet growth and survival. Journal of Animal Science, 50: 300–303.

Huang, Y.H., Yang, T.S., Lee, Y.P, Roan, S.W. and Liu S.H., 2003. Effects of sire breed on the subsequent reproductive performances of landrace sows Asian-Australasian Journal of Animal Science, 16(4): 489-493.

Kaufmann, D., Hofer, A., Bidanel, J.P. and Kunzi, N., 2000. Genetic parameters for individual birth and weaning weight and for litter size of Large White pigs. Journal of Animal Breeding and Genetics, 117: 121–128.

Kim, J.S., Jin, D.I., Lee, J.H., Son, D.S., Lee, S.H., Yi, Y.J. and Park, C.S., 2005. Effects of teat number on litter size in gilts. Animal Reproduction Science, 90: 111-116.

Knol, E.F. 2002. Genetic aspects of piglet survival. PhD Thesis, Institute for Pig Genetics and Animal Breeding and Genetics Group, Wageningen Universitet, Netherlands.

Le Dividich, J. 1999. Review: management to reduce variation in pre- and post-weaned pigs. In: Cranwell, P.D. (Ed.), Manipulating Pig Production VII. Australasian Pig Science Association, 135–155.

Lutaaya, E., Nakafeero, A. and Nemaire, S., 2009. Reproductive performance of two sow lines under arid climatic conditions. South African Journal of Animal Science, 39: 39.

McCaw, M.B., 2000. Effect of reducing crossfostering at birth on piglet mortality and performance during an acute outbreak of porcine reproductive and respiratory syndrome. Swine Health Production, 8(1): 15–21.

Milligan, B.N., Fraser, D. and Kramer D.L., 2002. Within-litter birth weight variation in the domestic pig and its relation to pre-weaning survival, weight gain, and variation in weaning weights. Livestock Production Science, 76: 181–191.

Milligan, B.N., Fraser, D. and Kramer, D.L., 2001. Birth weight variation in the domestic pig: effects on offspring survival, weight gain and suckling behaviour. Applied Animal Behaviour Science, 73: 171–191.

Mungate, F., Dzama, K., Mandisonza, K. and Shoniwa, A., 1999. Some non-genetic factors affecting commercial pig production in Zimbabwe. South African Journal of Animal Science, 29: 164-173.

Ncube, M., Dzama, K., Chimonyo, M. and Kanengoni A., 2003. Effect of boar genotype on reproductive performance of the local sows of Zimbabwe. Livestock Research for Rural Development, 15: 2.

Opschoor, C., Bloemhof, T.S. and Knol, E.F., 2009. Management influences on birth weight: High Low study. TOPIGS.

Pere, M.C. and Etienne, M., 2000. Uterine blood flow in sows: Effects of pregnancy stage and litter size. Reproduction Nutrition Development, 40 :369 -382.

Prasanna, S.J., Prakash, G.M., Gupta, B.R. and Mahender M., 2009: Genetic study on reproductive traits in crossbred pigs. Livestock Research for Rural Development, 2 : 142.

Quesnel, H., Brossard, L., Valancogne, A. and Quiniou N., 2008. Influence of some sow characteristics on within-litter variation of piglet birth weight. Animal, (2): 1842-1849.

Quiniou, N., Dagorn, J. and Gaudre, D., 2002. Variation of piglet's birth weight and consequences on subsequent performance. Livestock Production Science, 78: 63–70.

Roehe, R. 1999. Genetic determination of individual birth weight and its association with sow productivity traits using Bayesian analyses. Journal Animal Science, 77: 330-343.

Saito, H., Sasaki, Y., Hoshino, Y. and Koketsu Y., 2010. The occurrence of decreased numbers of pigs born alive in parity 2 sows does not negatively affect herd productivity in Japan. Livestock Production Science, 128 (1-3): 189-192.

Straw, B.E., Burgi, E.J., Dewey, C.E and Duran, C.O., 1998. Effects of extensive crossfostering on performance of pigs on a farm. Journal of the American Veterinary Medical Association, 212: 855–856.

Tummaruk, P., and Khatiworavage, C., 2011. Seasonal effect on the litter size at birth in sows differed among parity groups. Proceedings of the 5$^{th}$ Asian Pig Veterinary Society Congress 7-9 March, Pattaya, Thailand.

Tantasuparuk, W. N., Lundeheim, A., Dalin, M., Kunavongkrit, A. and Einarsson, S., 2000. Reproductive performance of purebred Landrace and Yorkshire sows in Thailand with special reference to seasonal influence and parity number. Theriogenology, **54:** 481–496.

Umesiobi, D. O., 2009. Vitamin E supplementation to sows and effects on fertility rate and subsequent body development of their weanling piglets. Journal of Agriculture and Rural Development in the Tropics, 110: 155–168.

Van Engelen, M.A.J, Nielsen, M.K. and Ribeiro E.L., 1995. Differences in pup birth weight, pup variability within litters, and dam weight of mice selected for alternative criteria to increase litter size. Journal of Animal Science, 73: 1948-1953.

Wolf, J., Zakova, E. and Groeneveld, E., 2008. Within-litter variation of birth weight in hyper prolific Czech Large White sows and its relation to litter size traits, stillborn piglets and losses until weaning. Livestock Production Science, 115: 195–205.

YinHua, H., Han, S. and DengQun, S., 2000. The effect of litter number and mating season on litter size of different breed pigs. Acta Agriculturae Universitatis Pekinensis, 22: 106-109.

Zhu, M.J., Ding, J.T., Liu, B., Yu, M., Fan, B., Li, C.C. and Zhao, S.H., 2008. Estimation of genetic parameters for four reproduction component traits in two Chinese indigenous pig breeds. Asian-Australasian Journal of Animal Science, 21(8): 1109-1115.

# Chapter 4: Effect of within-litter birth weight variation on percent survival, mean litter weight, total litter weight and within-litter weight variation at three weeks

**Abstract**

The objective of the study was to determine the relationship between within-litter birth weight variation (CVB) and percent survival at three weeks (SURVT), within-litter weight variation at three weeks (CVT), mean litter weight at three weeks (MWTT) and litter weight at three weeks (LWTT). A total of 1 836 litter records, collected between January 1998 and September 2010 at the Agricultural Research Council (ARC), Irene, were used in this study. The PROC STEPWISE (SAS, 2008) was used to select variables which best described variation in within-litter weight variation at three weeks (CVT), mean litter weight at three weeks (MWTT) and total litter weight at three weeks (LWTT). The PROC REG (SAS, 2008) was then used to test whether the relationships between CVT, SURVT, MWTT and LWTT and each of the selected independent variables were linear, quadratic or exponential. The CVB had a linear relationship ($P<0.05$) with SURVT and CVT (SURVT = 83.21 - 0.20 CVB; CVT = 16.71 + 0.50 CVB). Litters with high CVB had more deaths at three weeks and high CVT ($P<0.05$). The increase of CVT with CVB depended on parity ($P<0.05$). The rate of increase of CVT with CVB was highest in Parity 1 (b=0.41) followed by Parity 2 (b=0.36) then middle aged (Parity 3-5) sows (b=0.32).The CVB did not affect MWTT and LWTT ($P>0.05$). The NBA was negatively correlated with MWTT (- 0.15) and SURVT (-0.21). The NBA had a strong positive correlation with LWTT ($r=0.57$; $P<0.05$). Piglets of similar weight are likely to reduce pre-weaning mortality and increase uniformity at three weeks.

**Keywords:** Correlations, Litter weight at three weeks, Within-litter weight variation at three weeks

## 4.1 Introduction

Most pig enterprises routinely record three weeks performance. As at birth, farmers record litter traits such as litter size at three weeks (LST) and total litter weight at three weeks (LWTT), and not individual pig weights. Individual pig weights at three weeks are time consuming and labour intensive to record which may explain why farmers prefer recording LST and LWTT than individual piglet birth weight and then compute mean litter weight at three weeks (MWTT). Farmers prefer not to waste time and money on recording individual birth weight which they consider unimportant at three weeks. The general practice is to record the individual pig performance beyond weaning. However, it has been shown that heavier piglets are more likely to survive until three weeks of age than their lighter littermates (Le Dividich, 1999). Rydhmer *et al*. (1989) suggested that, generally, piglets with larger birth weights have better lifetime performance than their litter littermates. This suggestion indicate the importance of considering the role of within-litter weight variation at three weeks, defined as the spread of individual weight within a litter, in breeding programs.

There are significant biological and immunological changes that simultaneously occur at the age three weeks that have great impact on subsequent performance. The pig's active immune system begins developing at approximately three weeks of age (Stokes *et al.,* 2004). At the same age, the levels of maternally-derived antibodies decline to very low levels; hence piglets will have reduced inherent resistance to diseases (Coffey *et al*., 2000). There are also many digestive and metabolic changes occurring at this stage. Levels and activity of enzymes associated with the digestion of milk carbohydrates decline rapidly whilst those associated with cereal carbohydrate and protein digestion increases (Lindberg and Ogle, 2001), hence performance at this stage is crucial to subsequent growth, vitality and survival (Taylor and

Roese, 2006; Chimonyo *et al.,* 2011). Piglets are more susceptible to death during the first three weeks, once they exceed three weeks they have better chances to survive up to marketing. This because they are more susceptible to crushing, bleeding from the navel, starvation and diseases during this period. De Passille and Rushen (1989) reported that about 65% of mortalities in pigs occur during the first three weeks after farrowing. Against this background, it is necessary to understand and be able to predict litter performance to three weeks. Predicting performance of litters to three weeks using CVB would make planning and management easier.

The effects of litter traits at birth on performance to three weeks are not clearly understood. Mungate *et al.* (1999) estimated the effect of NBA, month of farrowing, parity of sow and MBWT on LWTT and MWTT, but not on within-litter weight variation at three weeks (CVT) and survival to three weeks. The CVT is a possible predictor of market weight variation which impacts throughput. A clearer understanding of the relationships between these traits could be a useful tool for management and planning. Furthermore, it helps to fathom how selection for litter traits at birth may affect performance at three weeks. To our knowledge, no studies have been conducted on the effects of CVB on performance to three weeks. The CVB, described in Chapter 3, has been reported to have a huge impact on pig enterprises (Wolf *et al*., 2007). The objective of the current study was to determine the relationship between within-litter birth weight variation and within-litter weight variation, litter weight and percent survival at three weeks (SURVT). It was hypothesized that litter performance at birth influenced CVT, SURVT, MWTT and LWTT.

## 4.2 Materials and methods

### *4.2.1 Study site*

The study site was described in section 3.2.1.

### *4.2.2 Data structure and preparation*

Data used in the study included 20 741 piglets from 1 836 litter records obtained from January 1998 until September 2010. The records consisted of piglet identity, breed of sow, Parity number, farrowing month, farrowing year, NBA, individual piglet birth weight, litter size at three weeks and individual piglet weight at three weeks. The MWTT, LWTT, CVT and SURVT were computed as derivatives. Percent survival was calculated as the proportion of litter size at three weeks to the number of live piglets at birth (NBA). The MBWT, TBWT and CVB computed in Chapter 3 were also used.

### *4.2.3 Descriptive statistics*

The PROC UNIVARIATE (SAS, 2008) was used to examine the distribution of CVB, CVT, SURVT, LWTT and MWWT. Skewness was calculated to describe the deviation of the distribution of CVB, CVT, SURVT, LWTT and MWTT between litters from the (symmetric) normal distribution.

### *4.2.4 Model development and analyses*

The PROC STEPWISE (SAS, 2008) was used to select and eliminate variables in model development for the relationship between CVB and CVT, MWTT and LWTT. The PROC STEPWISE was used to choose candidate variables for model development assuming entry and exit significance level of 0.15. After the STEPWISE procedure terminated, the sequence of variables added and deleted was studied, considering whether the variables that were included or excluded made sense. A few variables would be added or removed to drive the best models.

After deriving the appropriate model, the variables which best described variation in CVT, SURVT, MWTT and LWTT, PROC REG (SAS, 2008) were used to test whether the relationships between CVT, SURVT, MWTT and LWWT and each of the selected independent variables were linear, quadratic or exponential. Exponential and quadratic relationships were not significant in all models. Non-significant interaction effects were excluded from the final models. Parity of sow was included in all models. Sows were divided into four Parity groups representing gilts (Parity 1), second parity sows (Parity 2), middle aged sows (Parity 3 -5) and old sows (Parity 6 and above). This classification was premeditated by Milligan *et al*. (2002). Litter size at three weeks (LST), incorporated as a covariate, was tested and found non-significant in the model for CVT; hence it was excluded from the final model. The following models were used to determine the effects of CVB on CVT, SURVT, MWTT and LWTT.

*Model 1: Within-litter weight coefficient of variation at 3 weeks*

$$CVT = \beta_0 + \beta_1 P + \beta_2 CVBWT + \beta_3 NBA + \beta_4 MBWT + \beta_5 MWTT + \beta_6 (P \times CVB) + E$$

*Model 2: Mean litter weight at 3 weeks*

$$MWTT = \beta_0 + \beta_1 P + \beta_2 CVB + \beta_3 NBA + \beta_4 MBWT + \beta_7 TBWT + \beta_8 LST + \beta_9 LWTT + E$$

*Model 3: Litter weight at 3 weeks*

$$LWTT = \beta_0 + \beta_1 P + \beta_2 CVB + \beta_3 NBA + \beta_4 MBWT + \beta_5 MWTT + \beta_7 TBWT + \beta_8 LST + E$$

*Model 4: Percent survival to 3 weeks*

$$SURVT = \beta_0 + \beta_1 P + \beta_2 CVBWT + \beta_3 NBA + \beta_4 MBWT + \beta_5 MWTT + \beta_7 TBWT + \beta_8 LST + E$$

Where:

CVT = within-litter weight variation at three weeks

MWWT = mean litter weight at three weeks

LWTT = total litter weight at three weeks

SURVT = percent survival to three weeks

CVB= within-litter birth weight variation

NBA= number born alive

MBWT= mean birth weight

TBWT= total litter weight at birth

LST = litter size at three weeks

P = Parity of sow

P x CVB is the interaction between Parity of sow and within-litter birth weight variation

$\beta_0$ = intercept

$\beta_1 - \beta_8$ = linear regression coefficients.

E = residual error~ N $(0; I\sigma^2)$

Correlations analyses among litter traits at birth (NBA, MBWT, LBWT and CVB) and the dependant variables SURVT, MWTT, LWTT were performed using the PROC CORR procedure (SAS, 2008).

## 4.3 Results

### *4.3.1 Summary statistics*

The summary statistics for the traits analysed are shown in Table 4.1. The CVB, CVT had wide ranges, 0.5 to 50.65 % and 2.94 to 66.25 % respectively. Significance levels for all effects included in the final regression models for relationship between fixed effects and relevant covariates and CVT, MWTT and LWTT are shown in Table 4.2. Estimates and standard errors of the estimates for all effects included in final models are provided in Table 4.3.

### *4.3.2 Mean litter weight at three weeks*

The LST was selected by stepwise as the most powerful predictor of MWTT, with a partial R-square of 0.58. The variables that contributed considerable variation in MWTT were LWTT, LST, NBA, TBWT, MBWT then CVT in that order ($P<0.15$). The CVB, MWTT and Parity of sow were not significant. Linear regression analysis showed that NBA, MBWT, TBWT, LWTT and LST had a linear relationship with MWTT ($P<0.05$). Parity of sow and CVB did not have a significant relationship with MWTT (Table 4.3).

The MBWT, LWTT and TBWT had significant positive correlations with MWTT. The MWTT had a relatively strong correlation with both LWTT and MBWT ($P<0.01$). The correlation ($P<0.01$) between MWTT and TBWT was relatively weak (0.19) (Table 4.4). The NBA and LST had negative correlations with MWTT ($P<0.01$). Although significant, the correlation between LST and MWTT was very weak (-0.08).

**Table 4.1: Means for within-litter birth weight variation and litter traits used in evaluating the impact of CVB on sow performance at 3 weeks**

| Trait | Mean | SD | Minimum | Maximum | Skewness |
|---|---|---|---|---|---|
| CVB | 17.44 | 6.00 | 0.50 | 50.65 | 0.54 |
| CVT (%) | 18.80 | 8.11 | 2.94 | 66.25 | 0.93 |
| MWTT(kg) | 5.97 | 1.33 | 1.75 | 12.55 | 0.20 |
| LWTT(kg) | 9.31 | 2.40 | 2.00 | 16.00 | 0.04 |
| SURVT (%) | 90.16 | 12.64 | 20.00 | 100.00 | -1.58 |

NB: CVB = within-litter birth weight variation; CVT = Within-litter weight variation at three weeks; MWTT = Mean litter weight at three weeks; LWWT= Total litter weight at three weeks; SURVT = Percent survival to three weeks; N = Experimental litters = 1495.

**Table 4.2: Significance levels for fixed effects and covariates tested for statistical models used to estimate the impact of CVB, SURVT, LWTT, MWTT and CVT**

| | Covariates | | | | | | | | Fixed Effects |
|---|---|---|---|---|---|---|---|---|---|
| | NBA | CVB | MBWT | MWTT | TBWT | LWTT | LST | Parity | ParityxCVB |
| CVT | * | ** | ** | * | - | - | - | * | * |
| LWTT | ** | NS | ** | ** | ** | - | ** | NS | - |
| MWTT | ** | NS | ** | - | ** | ** | ** | NS | - |
| SURVT | ** | ** | ** | ** | ** | - | ** | NS | - |

*P<0.05 * *P<0.01 NS- Not significant; NBA: number born alive; CVB: within-litter birth weight variation; MBWT: mean birth weight; MWTT: mean weight at three weeks; TBWT: total litter weight at birth; LWTT: total litter weight at three weeks; LST: litter size at three weeks; SURVT: percent survival to three weeks; CVT: within-litter weight variation at three weeks

**Table 4.3: Estimates (±SE) for fixed effects and covariates from statistical models used to determine the impact of CVB on SURVT, LWTT, MWTT and CVT**

| | Intercept | NBA | CVB | MBWT | MWTT | TBWT | LWTT | LST | Parity x CVB | Parity |
|---|---|---|---|---|---|---|---|---|---|---|
| SURVT | 83.21 | -7.80 | -0.20 | 8.40 | 0.21 | -0.80 | - | 8.90 | 0.01 | -0.33 |
| SE | 2.20 | 0.30 | 0.06 | 1.00 | 0.01 | 0.10 | - | 0.07 | 0.01 | 0.10 |
| LWTT | -27.20 | -2.23 | -0.01 | -15.2 | 8.60 | 1.63 | - | 5.63 | 0.01 | 0.20 |
| SE | 2.20 | 0.31 | 0.06 | 1.00 | 0.07 | 0.10 | - | 0.07 | 0.01 | 0.10 |
| MWTT | 3.10 | 0.24 | 0.003 | 1.80 | - | -0.18 | 0.10 | -0.60 | 0.001 | -0.01 |
| SE | 0.20 | 0.03 | 0.01 | 0.11 | - | 0.01 | 0.01 | 0.001 | 0.001 | 0.02 |
| CVT | 16.71 | -1.00 | 0.50 | 12.00 | -3.40 | - | - | - | -0.04 | 1.21 |
| SE | 4.31 | 0.40 | 0.10 | 4.50 | 0.80 | - | - | - | 0.03 | 0.0003 |

NBA: number born alive; CVB: within-litter birth weight variation; MBWT: mean birth weight; MWTT: mean weight at three weeks; TBWT: total litter weight at birth; LWTT: total litter weight at three weeks; LST: litter size at three week; SURVT: percent survival to three weeks; CVT: within-litter weight variation at three weeks

**Table 4.4: Correlations between MWTT, LWTT, SURVT, CVTand independent variables NBA, MBWT, TBWTand CVB and LST**

| Variable | MWTT | LWTT | SURVT | CVT |
|---|---|---|---|---|
| NBA | -0.15** | 0.57** | -0.21** | 0.15** |
| MBWT | 0.47** | 0.20* | 0.20** | -0.11** |
| TBWT | 0.19** | 0.67** | -0.03 | 0.05 |
| CVB | -0.13** | 0.02 | -0.28** | 0.30** |
| LST | -0.08** | 0.75** | 0.35** | 0.06* |
| MWTT | | 0.58** | 0.13** | -0.27** |
| LWTT | | | 0.35** | -0.12** |
| SURVT | | | | -0.16** |

*P<0.05; * *P<0.01; NBA: number born alive; CVB: within-litter birth weight variation; MBWT: mean birth weight; MWTT: mean weight at three weeks; TBWT: total litter weight at birth; LWTT: total litter weight at three weeks; LST: litter size at three week; SURVT: percent survival to three weeks; CVT: within-litter weight variation at three weeks

### *4.3.3 Litter weight at three weeks*

The LST was selected by stepwise as the most powerful predictor of LWTT with a partial R-square of 0.55 followed by MWTT, NBA, MBWT then TBWT in that order ($P<0.15$). The CVB, LST, CVT and Parity of sow were not significant. Linear regression analysis showed that NBA, MBWT, MWTT, TBWT and LST had a linear relationship with LWTT (P<0.05). Parity of sow and CVB did not have a significant relationship with LWTT (Table 4.3). The NBA, TBWT, LST and MWTT had strong positive correlations with LWTT (P<0.01). Although significant, the correlation between LWTT and MBWT was relatively weak (0.20) (Table 4.4).

### *4.3.4 Survival at three weeks*

Very few litters (<10%) had SURVT less than 50%. About 40% of the litters had a percent survival of 100% (Figure 4.1). The NBA was selected by stepwise as the most powerful predictor of SURVT with a partial R-square of 0.80 followed by LST, MBWT, TBWT, CVB, MWTT and CVT in that order ($P<0.15$). The LWTT and Parity of sow were not significant. Linear regression analysis showed that NBA, CVB, MBWT, MWTT and LST had significant linear relationships with SURVT. Parity of sow did not have a significant relationship with SURVT (Table 4.3). The MBWT, LST and MWTT had positive correlations with SURVT (P<0.01). The NBA, CVB were negatively correlated to SURVT (P<0.01) (Table 4.3).

### *4.3.5 Within-litter coefficient of variation at three weeks*

More litters had CVT higher than the herd mean, the right (higher value) tail was longer, showing positive skewness (Figure 4.2). The CVB was selected by stepwise as the most powerful predictor of CVT with a partial R-square of 0.098 followed by MWTT, Parity of sow, MBWT, LST and NBA in that order ($P<0.15$). The TBWT, LWTT and CVT were not

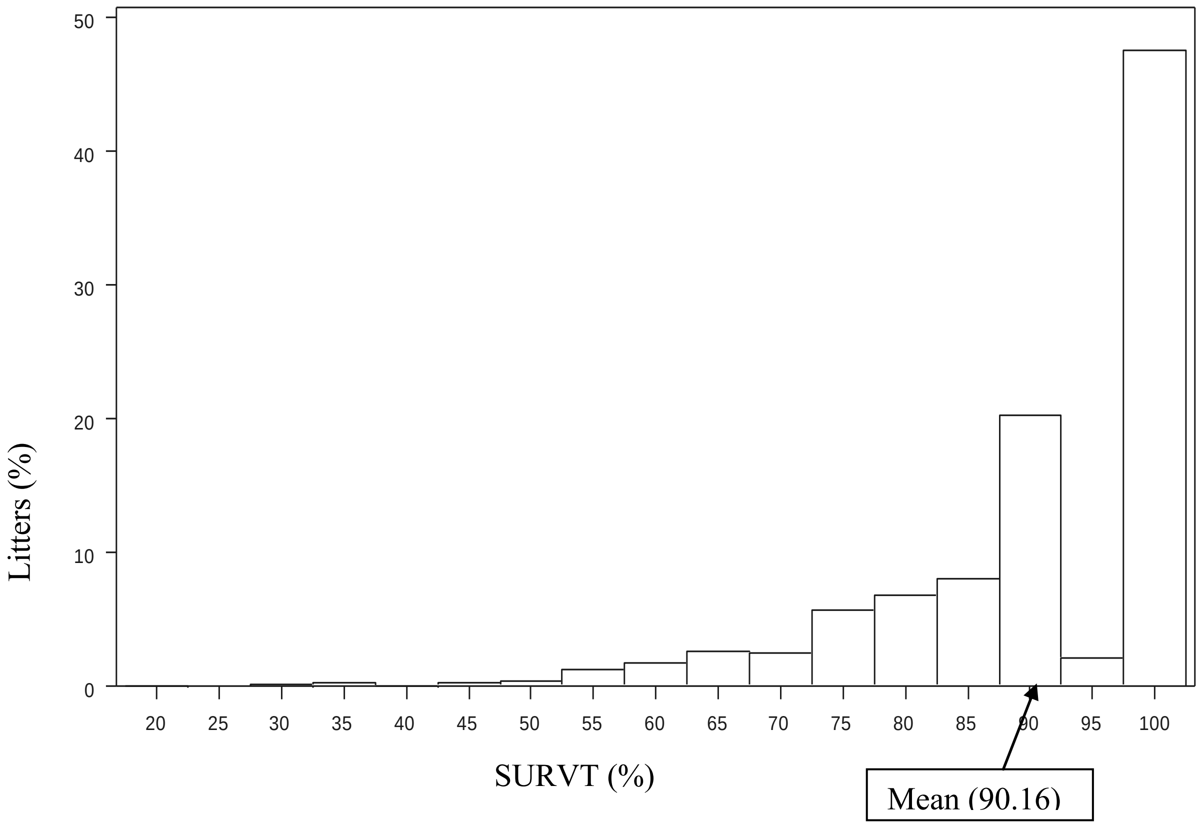


**Figure 4.1: Distribution of percent survival of litters at three weeks (SURVT)**

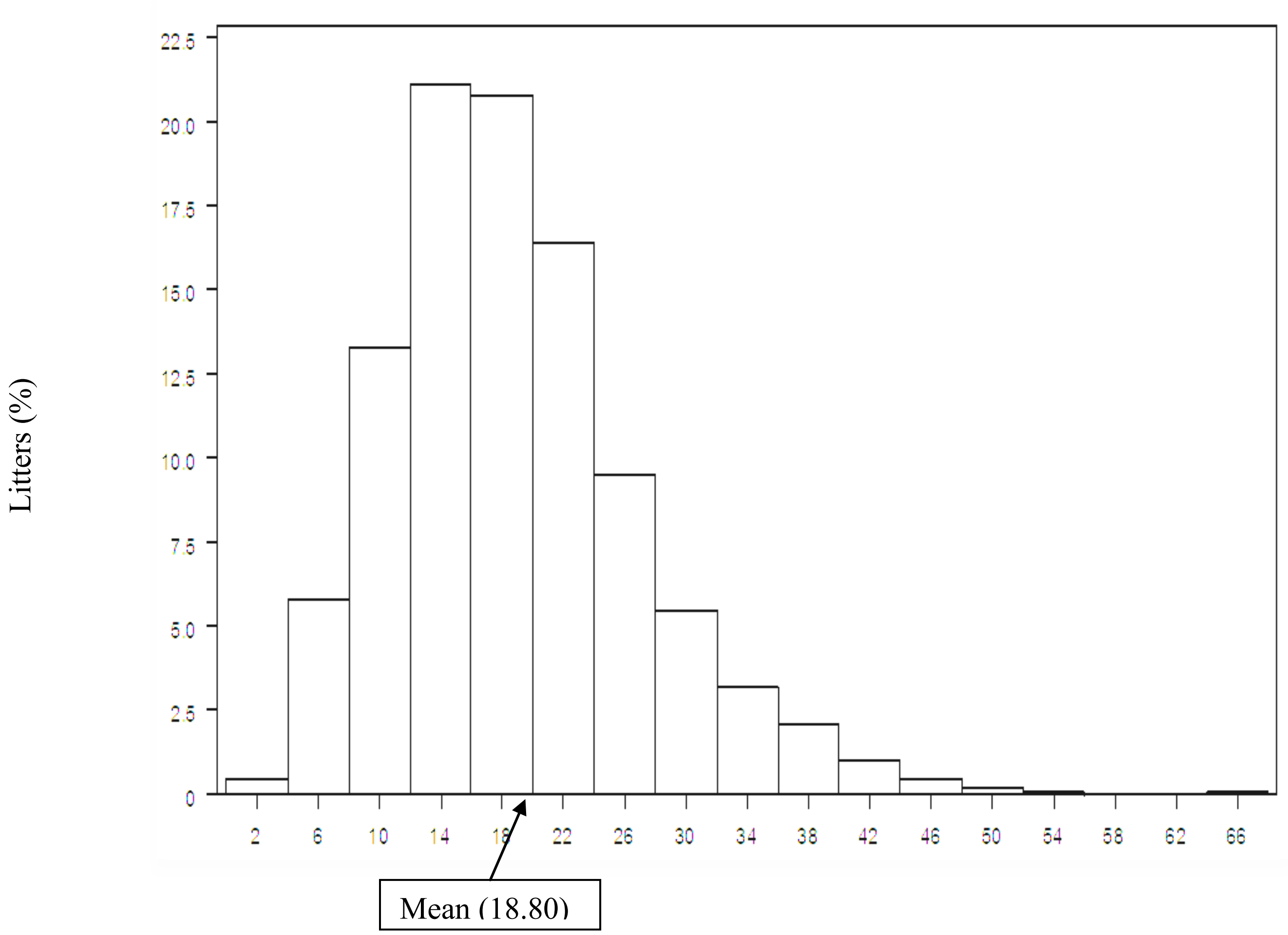


**Figure 4.2: Distribution of within-litter weight variation of litters at three weeks (CVT)**

significant. Linear regression analysis showed that CVB, Parity of sow, NBA, MBWT and MWTT had significant linear effects on CVT (Tables 4.2 and 4.4). The interaction between parity of sow and CVB was also significant. There was a significant linear relationship between CVB and CVT of litter from Parity 1, 2 and middle aged sows. Figure 4.3 shows the trends of CVT with CVB for the different parities. The rate of increase of CVT with CVB was highest in Parity 1 (b = 0.41) followed by Parity 2 (b = 0.36) then middle aged (Parity 3-5) sows (b = 0.32). There was no relationship between CVB and CVT in old sows (Parity 6 and above) ($P>0.05$). The NBA, fitted as a covariate, also affected ($P<0.05$) CVT. The CVT increased with increase in NBA (Table 4.4). The NBA accounted for 54% of variation in CVT.

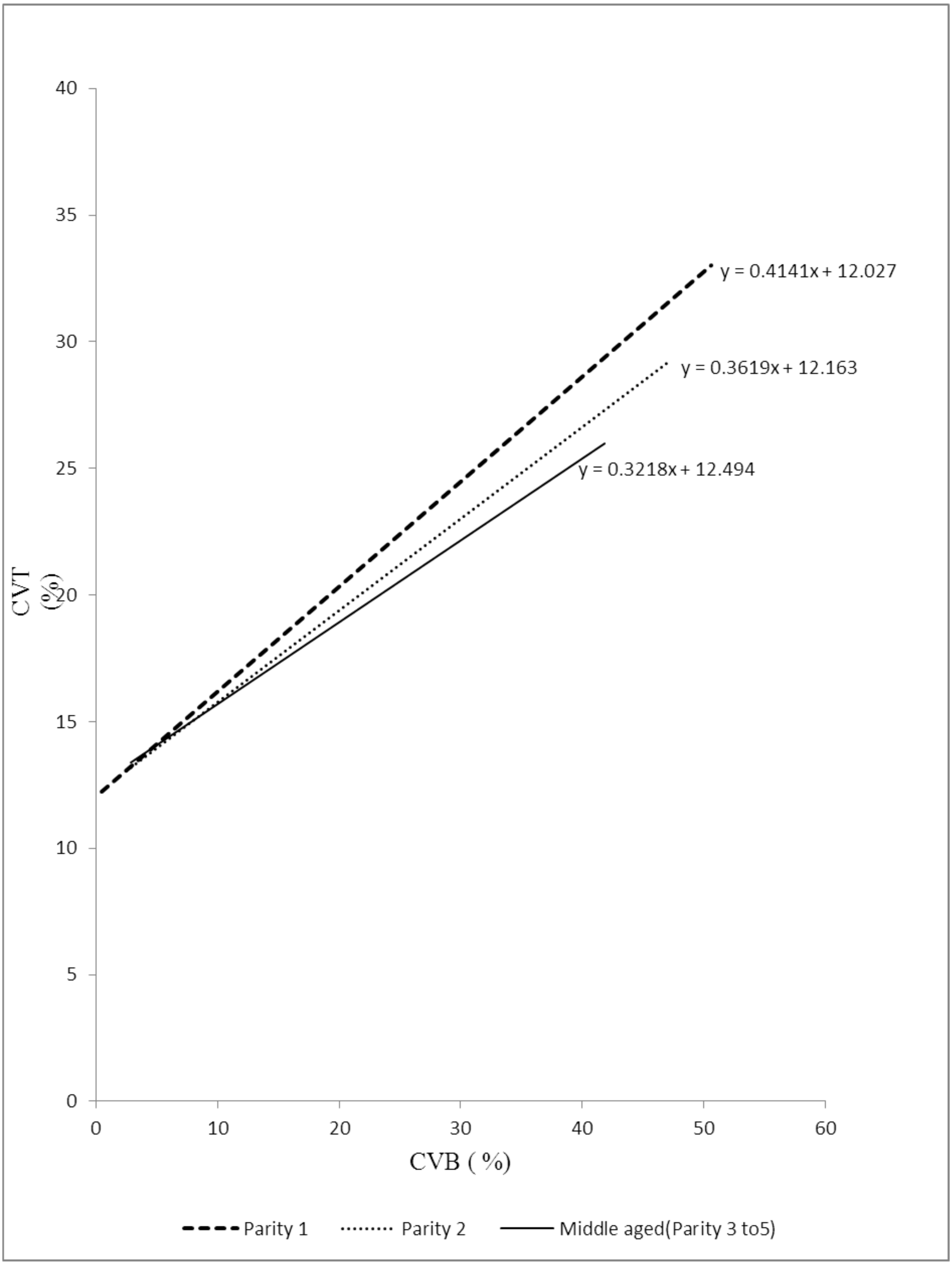


**Figure 4.3 : Relationship between w ithin-litter b irth w eight coefficient of var iation (CVB) and within-litter weight variation at three weeks (CVT)**

### 4.4 Discussion

The current study had a large number of potential independent variables. To determine the factors which best describe the response variables, stepwise selection was used to sift and identify candidate variables in model development in this study. A few variables were either added or removed from the candidates identified by stepwise selection, depending on whether the variables that were included or excluded by stepwise were justifiable, coupled with their effects on the adjusted R-square. For instance, environmental effects have been reported to have substantial effect on many traits in pig breeding (Wolf *et al.,* 2008), hence Parity of sow was included in all models.

The observed SURVT mean and range was similar to that reported by Wolf *et al*. (2008) who reported a mean of 88 % and a range of between 15 and 97 % survival to three weeks. The observed MWTT and its standard deviation (SD) did not differ much from findings by Mungate *et al*. (1999) who reported a MWTT of 5.09 kg and an SD of 0.75. The CVT showed distribution which is similar to that of CVB; thus a wide range in CVT could be attributed to high variation in CVB in the herd. The major determinants of sow performance at three weeks were MBWT and NBA as they influence all the litter production records in this study. By inference NBA is therefore, the key determinant as it also affects the MBWT. This is in agreement with Varley (1990) and Dunshea *et al*. (2003) who pointed out NBA as a key determinant of sow performance.

The finding that CVB had no significant relationship with MWTT was in agreement with Milligan *et al*. (2002). The observed effect of NBA, TBWT and MBWT on MWTT confirmed the work of Chabo *et al*. (2000) and Mungate *et al*. (1999). The MBWT and TBWT were expected to affect MWTT since piglet birth weight is correlated to subsequent performance (Rehfeldt and Kuhn, 2006). The effect of MBWT on MWTT can be because large piglets are able to stimulate teats to produce more milk as compared to small piglets (King *et al*., 1997). The reasons for the effect of NBA and MBWT on LWTT are probably the same as were discussed in regard to their relationships with MWTT.

In the current study, CVB was not a major contributor of SURVT with a smaller partial R-square compared to other significant variables (NBA, MBWT, MWTT and LST). Conflicting results from studies by Wolf *et al.* (2008) suggest that CVB is a major contributor to SURVT.

The finding in the present study that SURVT had a negative correlation with CVB agrees with Lay *et al.* (2001) who reported that within-litter variability in piglet weights is associated with higher losses to three weeks. There are contradicting reports by Van der Lende and Jager (1991) who found that birth weight distribution had no significant effect on survival to three weeks. The finding that variation of percent survival with CVB was independent of parity is in agreement with Milligan *et al. (*2002). Litters with high CVB have more light piglets (Milligan *et al*., 2002) and these light piglets are thought to be at a greater possibility of death (English 1998, Quiniou *et al.,* 2002) because they take longer to consume colostrum which they consume in fewer amounts and are more susceptible to crushing by the sow (Cutler *et al.,* 1999). Consumption of low amounts of colostrum is associated with poor acquisition of passive immunity hence lower the piglets' chances for surviving to three weeks (Quiniou *et al*., 2002). Fighting success for more productive teats among littermates has been found to be associated with birth weight. Heavier littermates are more successful fighters and achieve teat specificity earlier than their lighter littermates. It can be inferred that as CVB increases more piglets within a litter take much time trying to achieve specificity hence are more susceptible to death.

The negative correlation between NBA and SURVT agrees with Marchant *et al.* (2000) who found that piglet losses after birth to three weeks are greater in large litters. These losses are largely attributed to the within-litter variation in piglet body weight. As the NBA increases the CVB also increases hence survival rates to three weeks decreases. In agreement with Wolf *et al*. (2008) and Milligan *et al*. (2002) it was found in this study that SURVT was particularly low in litters with low MBWT. This could be due to the strong positive correlation between MBWT and minimal birth weight in a litter (Wolf *et al*., 2008). Although there is a correlation between MBWT and SURVT, improving SURVT by selecting for MBWT might not be successful. The positive correlation between SURVT and LST could be due to arithmetic reasons.

Wolf *et al*. (2008) and Knol *et al*. (2001) concluded in agreement that attempts to reduce piglet losses to weaning through selection for higher MBWT might not be very successful and this might also apply to three weeks. Reducing NBA to increase survival to three weeks is not an option for farmers aim to maximize NBA in order to achieve high piglets weaned per sow per year. Basing on these arguments reducing CVB is the best way to increase SURVT.

The CVT had a moderate correlation with CVB but only weakly correlated to both MBWT and MWTT. This shows that CVB is more effective in predicting CVT than MBWT and MWTT. A study by Milligan *et al.* (2002) yielded similar results on the effect of CVB on within-litter weaning (four weeks) weight variation concluding that CVB is a good predictor of within-litter weight variation at four weeks. The effect of CVB on CVT can be attributed to the fact that small piglets tend to have lower growth rates to three weeks compared to their littermates (Foxcroft and Town, 2004). Heavier piglets tend to out-compete litter mates because they are more vigorous thus they can claim more productive teats, stimulate higher milk production hence intake and have greater fighting success (Lay *et al*., 2001). All this leads to differences in weight gain to three weeks hence CVT. Low but significant correlations between CVB and CVT confirmed findings by Milligan *et al.* (2002). This shows that there are other factors other than CVB that influence CVT. Fraser *et al*. (1992) suggested that variation in weight gain to three weeks which can be a source of CVT can be due to differences in milk production capacity of teats.

According to findings in this study NBA is by far a better predictor of CVT than CVB. This confounds with Milligan *et al*. (2002) who found similar correlation coefficients (0.4) between both NBA and CVB with within-litter weight variation after four weeks. The increase in CVT as NBA increases can be attributed to the relationship between CVB and NBA. It can also be due to the fact that as NBA increases some piglets will have to suckle from low producing teats (Lay *et al.*, 2001).

Contrary to reports by Milligan *et al*. (2002) which indicate that there are no interaction effects of parity of sow and CVB on CVT, observations from the current study suggest that the linear relationship between CVB and CVT is different across parities. This can be due to changes in total milk production of the sow as parity changes. Low milk yield is a well-known problem in first parity sows due to high stress levels and much inflammation of mammary glands (Tantasuparuk *et al*., 2000). Perhaps high CVB tends to be perpetuated or even enhanced to three weeks in first parity sows due to effects of more drastic within-litter competition for milk as compared to later parities. Findings in this study suggest that in order to achieve minimal CVT, in addition to reducing CVB the parity structure of the herd should be stabilised by a high number of females in the 3 to 5 parity range.

### 4.5 Conclusions

Although CVB did not significantly influence mean litter weight at three weeks, it is an important determinant of sow productivity due to its effects on CVT and SURVT. Piglets of similar weight are likely to reduce pre-weaning mortality and increase uniformity at three weeks. The relationship between CVT and CVB varied across parities with mid-parity sows showing the least rate of increase of CVT with CVB. A sow herd structure comprised mainly of mid-parity sows best minimizes CVT. It is, however, unclear whether CVB has a significant influence on performance of litters at weaning.

### 4.6. References

Akdag, F., Arslan, S. and Demir, H., 2009. The effect of Parity and litter size on birth weight and the effect of birth weight variations on weaning weight and pre-weaning survival. Journal of Animal and Veterinary Advances, 8(11): 2133-2138.

Chimonyo, M., Dzama, K., Bhebhe, E. and Mapiye, C., 2011. Pre-weaning performance of the Zimbabwean Mukota and Large White × Mukota pigs under low-input production systems. Research Opinions in Animal and Veterinary Sciences, 1(6): 352-359.

Damgaard, L.H., Rydhmer, L., Lovendahl, P. and Grandinson, K., 2003. Genetic parameters for within-litter variation in piglet birth weight and change in within-litter variation during suckling. Journal of Animal Science, 81: 604–610.

De Passillet, A.M.B. and Rushen, J., 1989. Using early suckling behavior and weight gain to identify piglets at risk. Canadian Journal of Animal Science, 69: 535-544.

Dunshea, F.R., Kerton, D.K., Cranwell, P.D., Campell, R.G., Mullan, B.P., King, R.H., Power, G.N. and Pluske, J.R., 2003. Lifetime and post-weaning determinants of performance indices of pigs. Australian Journal of Agricultural Research, 54: 363-370.

Coffey, R.D., Parker, G.R. and Laurent, K.M., 2000. Feeding and managing the weanling pig. Cooperative extension service. University of Kentucky, Lexington, UK.

Cutler, R.S., Fahy, V.A., Spicer, E.M. and Cronin, G.M., 1999. Preweaning mortality. In: Straw, B.E., D'Allaire, S., Mengel- ing, W.L., Taylor, D.J. (Eds.), Diseases of Swine. Iowa State University Press, Ames, IA, pp. 985–1002.

Gondret, F., Lefaucheur, L., Louveau, I., Lebret, B., Pichodo, X. and Le Cozler, Y., 2005. Influence of piglet birth weight on postnatal growth performance, tissue lipogenic capacity and muscle histological traits at market weight Livestock Production Science 93: 137–146.

Chabo, R.G., Malope, P. and Babusi, B., 2000. Pig productivity: A case study for South-Eastern Botswana Livestock Research for Rural Development, 12: 3.

English, J.G.H. and Bilkei, G., 2004. The effect of litter size and littermate weight on pre-weaning performance of low-birth-weight piglets that have been cross fostered. Animal science, 79: 439-443.

Foxcroft, G.R., and Town, S., 2004. Prenatal programming of postnatal performance – The unseen cause of variance. Advanced Pork Production, 15: 269–279.

Fraser, D., Thompson, B.K. and Rushen, J., 1992. Teat productivity in second lactation sows: influence of use or non-use during the first lactation. Animal Production, 55: 419–424.

King, R.H., Mullan, B.P., Dunshea, F.R. and Dove, H., 1997. The influence of piglet body weight on milk production of sows. Livestock Production Science, 47: 169–174.

Knol, E.F. 2002. Genetic aspects of piglet survival. PhD Thesis, Institute for Pig Genetics and Animal Breeding and Genetics Group, Wageningen Universitet, Netherlands.

Lay, D.C. Jr., Matteri, R.L., Carroll, J.A., Fangman, T.J. and Safranski, T.J., 2002. Preweaning survival in swine. Journal of Animal Science, 1: 74-86.

Le Dividich, J., 1999. Neonatal and weaner pig: Management to reduce variation. Manipulating Pig Production, Adelaide, Australasian Pig Science Association.

Lindberg, J.E. and Ogle, B., 2001. Digestive physiology of pigs: proceedings of the 8th Symposium. Conference Publication. New York.

Marchant, J.N., Rudd, A.R., Mendl, M.T., Broom, D.M., Meridith, M.J., Corning, S. and Simmons, P.H., 2000. Timing and causes of piglet mortality in alternative and conventional farrowing systems. Veterinary Record, 147: 209–214.

Milligan, B.N., Fraser, D. and Kramer, D.L., 2001. Birth weight variation in the domestic pig: effects on offspring survival weight gain and suckling behaviour. Applied Animal Behaviour Science, 73: 171–191.

Milligan, B.N., Fraser, D., and Kramer, D.L., 2002. Within-litter birth weight variation in the domestic pig and its relation to pre-weaning survival, weight gain, and variation in weaning weights. Livestock Production Science, 76: 181–191.

Mungate, F., Dzama, K. Mandisonza, K. and Shoniwa, A., 1999. Some non-genetic factors affecting commercial pig production in Zimbabwe. South African Journal of Animal Science, 29: 3.

Pandey, A., Singh, S.K. and Pandey, A.K., 2010. Studies on genetic and non-genetic factors affecting reproductive traits in landrace desi and their crossbred pigs. Journal of Ecology and Environmental Sciences, 1: 7-10.

Rehfeldt, C. and Kuhn, G., 2006. Consequences of birth weight for postnatal growth performance and carcass quality in pigs as related to myogenesis. Journal of Animal Science, 84: 13.

Rydhmer, L., Eliasson, L., Stern, S., Andersson, K. and Einarsson S., 1989. Effects of piglet weight and fraternity size on performance, puberty and farrowing results. Acta Agriculturae Scandinavia, 39: 397-406.

Stokes, C.R, Bailey, M, Haverson, K., Harris, C., Jones, P, Inman, C., Pie, S., Oswald, P.I, Williams, B.A., Akkerman, A.D.L., Sowa, E., Rothktter, H. and Miller B.G., 2004. Postnatal development of intestinal immune system in piglets: implications for the process of weaning. Animal Research, 53: 325-334.

Tantasuparuk, W., Lundeheim, N., Dalin, A.M., Kunavongkrit, A. and Einarsson, S., 2000. Reproductive performance of purebred Landrace and Yorkshire sows in Thailand with special reference to seasonal influence and Parity number. Theriogenology, 54: 481-496.

Taylor, G. and Roese, G., 2006. Market weight variation in the pork industry. Livestock officers pigs, Intensive Industries Development, Tamworth.

Quiniou, N., Dagorn, J., and Gaudre D., 2002. Variation of piglets' birth weight and consequences on subsequent performance. Livestock Production Science, 78: 63–70.

Quinton, V.M., Wilton, J.W., Robinson, J.A. and Mathur, P.K., 2006. Economic weights for sow productivity traits in nucleus pig populations. Livestock Science, 99: 69–77.

Varley, A.M., 1990. Factors affecting the reproductive performance of sows. CIHEAM - Options Mediterraneennes.

Van der Lende, T. and de Jager, D., 1991. Death risk and pre-weaning growth rate of piglets in relation to the within-litter weight distribution at birth. Livestock Production Science, 28: 73–84.

Wolf, J., Zakova, E. and Groeneveld E., 2008. Within-litter variation of birth weight in hyper prolific Czech Large White sows and its relation to litter size traits, stillborn piglets and losses until weaning. Livestock Production Science, 115: 195–205.

## Chapter 5: Effect of within-litter birth weight variation on percent survival, mean litter weight, total litter weight and within-litter weight variation at weaning


### Abstract

The objective of the study was to determine the relationship between within-litter birth weight variation and within-litter weaning weight variation (CVW), mean weaning weight (MWWT) and total litter weaning weight (LWWT). The study was conducted using 1 836 litter records collected between January 1998 and September 2010 at the Agricultural Research Council (ARC), Irene. In model development, the PROC STEPWISE (SAS, 2008) was used to select variables which best described variation in CVW, MWWT and LWWT. The PROC REG (SAS, 2008) was then used to test whether the relationships between CVW, SURVW, MWWT and LWWT and each of the selected independent variables were linear, quadratic or exponential. The PROC CORR (SAS, 2008) was used to estimate correlations among number born alive (NBA), mean birth weight (MBWT), total litter weight at birth (TBWT) and CVB and the dependant variables SURVW, MWWT, LWWT. The distribution of (CVW) in the herd was positively skewed (0.81) with a mean of 18.4 %. The SURVW ranged from 13.3 to 100 % with a mean of 87.6 %. The CVB had a linear relationship ($P<0.05$) with both CVW and SURVW (CVW= 15.8 + 0.5CVB; SURW = 87.9 – 0.04CVB). There was no significant relationship between CVB and MWWT ($P>0.05$). There was an positive relationship between CVB with CVW. Decreasing CVB will help decrease CVW and increase SURVW. The results clearly indicate that CVB is an important determinant of litter performance at weaning.



**Key words:** Litter traits, coefficient of variation, litter weight at weaning, percent survival.

## 5.1 Introduction

Sow productivity, defined as the number of pigs weaned per sow per year, depends on the ability of the sow to wean large numbers of healthy piglets (Quinton *et al.,* 2006). Traits such as mean litter weight and percent survival to weaning are influenced by birth traits such as NBA, MBWT and TBWT as well as environmental factors such as season at farrowing, year of farrowing and breed (Mungate *et al*., 1999; English and Bilkei, 2004; Pandey *et al.,* 2010). Piglets are usually weaned at the age of four to five weeks (Andersen *et al*., 2005).

Traditionally, improving NBA has been a major focus to maximise sow productivity (Zhu *et al*., 2008; Dube *et al.,* 2011). Internationally, there has been an increase in average NBA from less than 10.2 piglets per litter in 1999 up to 11piglets per litter in 2009 (Fix *et al.,* 2010). Recent studies, however, show that increasing NBA is negatively correlated with survival to weaning, pre-weaning daily gain and mean weaning weight (Milligan *et al.,*2002; Damgaard *et al.,*2003). These negative effects of increasing NBA on survival to weaning and weaning weight have been a major drawback on efforts by pig producers to maximise productivity through selection for sow prolificacy. Low survival rates and weaning weights in large litters are mainly due to high variation in weight among littermates at birth (Milligan *et al.,* 2002; Wolf *et al.,* 2008). Selection for uniformity of piglets at birth and its impact on performance at weaning have, however, not received much research priority.

Due to its effects on survival of piglets at weaning and mean weaning weight, homogeneity of litters at weaning is becoming an essential component of successful pork production (Korthals, 2001). Variation in the market weight of pigs impacts on profitability through inefficiencies in management and processing, since large variation in carcase size and shape affects the handling of carcases and the uniformity of their products (Graeme and Greg, 2006). Furthermore, reducing pig weight variation is essential in maintaining pig flow strategies such as scheduling pig in batches of the same age. Slow growing pigs within a litter increases the complexity of managing pigs, especially in the modern all-in-all-out systems. Numerous management strategies have been evaluated to correct for, and reduce, market weight variation (Whitney, 2003; Graeme and Greg, 2006). This involves sorting pigs prior to entering weaner or grower facilities to achieve uniformity at marketing. These attempts have, however, not been of much success. One way to reduce weaning weight variation (hence market weight variation) could be selection for sows which produce more uniform litters (Foxcroft and Town, 2004). Milligan *et al. (*2002) found that within-litter birth weight is strongly positively correlated to within-litter weight variation at weaning.

Although there is some evidence that within-litter birth weight variation influences within-litter weaning weight variation, mean litter weaning weight and survival to weaning (Milligan *et al.,* 2002; Wolf *et al.,* 2008), little effort has been put to predict performance at weaning using within-litter birth weight variation. A clearer understanding of these relationships could be useful to pig management, planning and marketing. The objective of the current study was to determine the relationship between within-litter birth weight variation and within-litter weight variation, litter weight and percent survival at weaning.

## 5.2 Materials and methods

### *5.2.1 Study site*

The study site was described in section 3.2.1.

*5.2.2 Data structure and preparation*

Data included records on 20 741 piglets from 1836 litters, obtained between January 1998 and September 2010. The records collected were litter size and individual piglet weight. Mean litter weaning weight (MWWT), litter weight at weaning (LWWT), within-litter weaning weight coefficient of variation (CVW) and percent survival at weaning (SURVW) were computed. Percent survival was calculated as the proportion of litter size at weaning to the NBA. Litters used in this study were weaned at the age of 35 days.

*5.2.3 Descriptive statistics for CVB, CVW, MWWT, LWWT and SURVW*

The PROC UNIVARIATE procedure (SAS, 2008) was used to examine the distribution of CVB, CVW, SURVW, LWWT and MWWT and frequency distributions. Skewness was calculated to describe the deviation of the distribution of CVB, CVW, SURVW, LWWT and MWWT among litters from the (symmetric) normal distribution.

*5.2.4 Model development and analyses*

The PROC STEPWISE procedure (SAS, 2008) was used to select and eliminate variables in model development for the relationship between CVB and CVW, MWWT and LWWT. The PROC STEPWISE was used to choose candidate variables for model development with the assumption that the entry and exit significance level equals 0.15. Using STEPWISE, the strongest candidate predictor was selected first, then additional candidate predictors were tested, one at a time, for inclusion in the model. At each step, checks were made to see whether a new candidate predictor will improve the model significantly. Checks were also made to see whether, the new predictor is appropiately included in the model, any other predictors already in the model were allowed to stay or removed from the model. Where a newly entered predictor did explained the dependant variable better, a predictor already in the model was removed mostly if it did not appropiately described the dependent variable.

After compiling the variables which best described the variation in CVW, SURVW, MWWT and LWWT, PROC REG (SAS, 2008) was used to test whether the relationships between CVW, SURVW, MWWT and LWWT and each of the selected independent variables were either linear, quadratic or exponential. Exponential and quadratic relationships were excluded from all models because they were not significantly related. Interactions that were not significant were excluded from the final models. Parity of sow was included in all models. Sows were divided into four parity groups, representing gilts (parity 1), second parity sows (parity 2), middle aged sows (parity 3 -5) and old sows (parity 6 and above). This classification was premeditated by Milligan *et al*. (2002). The litter size at weaning (LSW), incorporated as a covariate, was tested and found non-significant in the model for CVW hence it was excluded in the final model. The following models were used to determine the effects of CVB on CVW, SURVW, MWWT and LWWT:

*Model 1: Within-litter weaning weight coefficient of variation*

$$CVW = \beta_0 + \beta_1 P + \beta_2 CVB + \beta_3 TBWT + \beta_4 MWWT + E$$

*Model 2: Mean weaning weight*

$$MWWT = \beta_0 + \beta_1 P + \beta_2 CVB + \beta_3 TBWT + \beta_5 NBA + \beta_6 MBWT + \beta_7 LWWT + \beta_8 LSW + E$$

*Model 3: Litter weight at weaning*

$$LWWT = \beta_0 + \beta_1 P_j + \beta_2 CVB + \beta_3 TBWT + \beta_4 MWWT + \beta_5 NBA + \beta_6 MBWT + \beta_8 LSW + E$$

*Model 4: Percent survival to weaning*

$$SURVW = \beta_0 + \beta_1 P + \beta_5 NBA + \beta_2 CVB + \beta_3 TBWT + \beta_8 LSW + E$$

where:

CVW = within-litter weight variation at weaning,

MWWT = mean litter weight at weaning,

LWWT = total litter weight at weaning,

SURVW = percent survival to weaning,

CVW= within-litter birth weight variation,

NBA= number born alive,

MBWT= mean birth weight,

TBWT= total litter weight at birth,

LSW = litter size at weaning,

P = parity of sow,

$\beta_0$ = intercept,

$\beta_1 - \beta_8$ = linear regression coefficients, and

E = residual error~ N (0; $I\sigma^2$).

Analyses for correlations among litter traits at birth (NBA, MBWT, TBWT and CVB) and the dependant variables SURVW, MWWT, LWWT were performed using PROC CORR (SAS, 2008).

## 5.3 Results

### *5.3.1 Summary statistics, levels of significance and estimates of fixed factors and covariates*

The summary statistics for the traits analysed are shown in Table 5.1. The CVB and CVW had wide ranges, 0.5 to 50.7 % and 1.0 to 54.9 %, respectively. Significance levels for all

**Table 5.1: Summary statistics of CVB, CVW, MWWT, LWWT and SURVW used in evaluating the impact of CVB on sow performance at weaning**

| Trait | Mean | Standard deviation | Minimum | Maximum | Skewness |
|---|---|---|---|---|---|
| CVB (%) | 17.44 | 6.0 | 0.50 | 50.65 | 0.54 |
| CVW (%) | 18.35 | 7.82 | 1.02 | 54.86 | 0.81 |
| MWWT (Kg) | 7.92 | 1.87 | 2.88 | 17.95 | 0.67 |
| LWWT (Kg) | 70.92 | 24.34 | 8.10 | 184.10 | 0.30 |
| SURVW (%) | 87.63 | 15.48 | 13.33 | 100 | -1.69 |

NB: CVB =Within-litter birth weight variation;

CVW = Within-litter weaning weight variation;

LWWT = Total litter weight at weaning;

MWWT = Mean weaning weight;

N = Experimental litters = 1495;

SURVW = Percent survival to weaning.

effects included in the final regression models for relationship between fixed effects and relevant covariates and CVW, MWWT and LWWT are shown in Table 5.2. Estimates and standard errors of the estimates for all effects included in the final models are provided in Table 5.3.

### *5.3.2 Mean litter weight at weaning*

Stepwise selection showed that LWWT, LSW, NBA, TBWT, MBWT and CVW were the appropriate candidate variables used in explaining variation in MWWT (P<0.15). The LSW was noted to be the most appropriate candidate predictor. Regression analysis showed NBA, MBWT, TBWT, LWWT and LSW had a significant relationship with MWWT. The CVB and Parity of sow had no significantrelationship with MWWT (P>0.05) (Table 5.2). The MBWT and LWWT had strong positive correlations with MWWT (P<0.01). The TBWT had a weak (0.15) positive correlation with MWWT (P<0.01). The MWWT was negatively correlated to both LSW (-0.14) and NBA (-0.13) (P>0.05) (Table 5.4).

### *5.3.3 Litter weight at weaning*

Stepwise selection chose NBA, MBWT, MWWT, TBWT, LSW and CVW as candidate independent variables for predicting LWWT (P<0.15). The LSW was the most appropriate candidate predictor with a partial R-square value of 0.57 followed by MWWT, MBWT, CVW, NBA and TBWT in that order. The CVB, LWWT and Parity of sow were not the appropriate candidate predictors of LWWT (P>0.15). Linear regression analysis showed there was a linear relationship between LWWT and independent variables NBA, MBWT, MWWT, TBWT and LSW (P<0.01) (Table 5.2). The CVB and Parity of sow had no significant relationship with LWWT (P>0.05). The LWWT had strong positive correlations with NBA,

**Table 5.2: Significance levels for fixed effects and covariates tested for statistical models used to estimate the impact of CVB SURVW, LWWT, MWWT and CVW**

| | Covariates | | | | | | | Fixed Effects |
|---|---|---|---|---|---|---|---|---|
| Trait | NBA | CVB | MBWT | MWWT | TBWT | LWWT | LSW | Parity |
| CVW | - | ** | - | ** | ** | - | - | * |
| LWWT | ** | NS | ** | ** | ** | - | ** | NS |
| MWWT | ** | NS | ** | - | ** | ** | ** | NS |
| SURVW | ** | * | - | - | * | - | ** | NS |

*P<0.05 * *P<0.01 NS- Not significant; NBA: number born alive; CVB: within-litter birth weight variation; MBWT: mean birth weight; MWWT: mean weaning weight; TBWT: total litter weight at birth; LWWT: total weaning weight; LSW: litter size at weaning; CVW: Within-litter weaning weight variation; SURVW: percent survival to weaning.

**Table 5.3: Estimates for fixed effects and covariates from statistical models used to determine the impact of CVBSURVW, LWWT, MWWT and CVW**

| | Intercept | NBA | CVB | MBWT | MWWT | TBWT | LWWT | LSW | Parity |
|---|---|---|---|---|---|---|---|---|---|
| SURVW | 87.95 | -7.46 | -0.04 | - | - | -0.08 | - | 8.69 | 0.02 |
| SE | 0.56 | 0.08 | 0.02 | - | - | 0.04 | - | 0.09 | 0.07 |
| LWWT | -45.03 | -2.18 | -0.05 | -12.2 | 7.96 | 1.36 | - | 8.02 | -0.04 |
| SE | 3.12 | 0.25 | 0.16 | 1.67 | 0.09 | 0.16 | - | 0.09 | 0.53 |
| MWWT | 5.93 | 0.22 | 0.003 | 1.46 | - | -0.13 | 0.11 | -0.88 | 0.01 |
| SE | 0.36 | 0.03 | 0.02 | 0.19 | - | 0.02 | 0.001 | 0.01 | 0.06 |
| CVW | 15.76 | - | 0.50 | - | -0.98 | 0.12 | - | - | 0.81 |
| SE | 1.61 | - | 0.12 | - | 0.11 | 0.05 | - | - | 0.33 |

NBA: number born alive; CVB: within-litter birth weight variation; MBWT: mean birth weight; MWWT: mean weight at weaning; TBWT: total litter weight at birth; LWWT: total weaning; LSW: litter size at weaning; CVW: Within-litter weaning weight variation; SURVW: percent survival to weaning.

**Table 5.4: Correlations between MWWT, LWWT, SURVW, CVW and independent variables NBA, MBWT, TBWT and CVB and LSW**

| Variable | MWWT | LWWT | SURVW | CVW |
|---|---|---|---|---|
| NBA | -0.13** | 0.55** | -0.18** | 0.16** |
| MBWT | 0.38** | 0.13** | 0.14** | -0.12** |
| TBWT | 0.15** | 0.61** | -0.06* | 0.06* |
| CVB | -0.18** | 0.01 | -0.23** | 0.28** |
| LSW | -0.14** | 0.75** | 0.47** | 0.08** |
| MWWT | | 0.50** | -0.02 | -0.24** |
| LWWT | | | 0.40** | -0.07* |
| SURVW | | | | -0.10** |

*P<0.05; **P<0.01

NB: CVB =Within-litter birth weight variation;

CVW = Within-litter weaning weight variation;

LSW = Litter size at weaning;

LWWT = Total litter weight at weaning;

MWWT = Mean weaning weight;

NBA = Number born alive;

SURVW = Percent survival to weaning;

TBWT = Litter weight at birth.

TBWT, LSW and MWWT (P<0.01). There was a weak (0.13) but positive correlation between LWWT and MBWT (P<0.01) (Table 5.4)

### *5.3.4 Percent survival at weaning*

Less than 10 % of the litters had SURVW less than 50%. About 65% of the litters had SURVW more than the mean (87.63) with about 40% of the litters having no mortalities to weaning (Figure 5.1). Stepwise analysis shows that NBA was the strongest candidate predictor of SURVW with a partial R-square of 0.70 followed by LSW, TBWT, MBWT, LWWT and CVW in that order (P<0.15). The CVB and Parity of sow were not candidate predictors of SURVW (P>0.15). Regression analysis showed that NBA, CVB, TBWT and LSW had a linear relationship with SURVW (P<0.05). Parity of sow had no significant relationship with SURVW (P>0.05).

### *5.3.5 Within-litter coefficient of variation at weaning*

The CVW was positively skewed (0.81) (Table 5.1) with most of the litters close to the mean CVW (18.35) (Figure 5.2). Stepwise analysis showed that CVB was the strongest candidate predictor of CVW followed by MWWT, TBWT and parity of sow in that order (P<0.15). The NBA, MBWT, LWWT and LSW were not significant. Regression analysis showed that CVW was influenced by CVB, MWWT, TBWT and parity of sow (P<0.05) (Tables 5.2 and 5.3). The CVW increased with increase in parity (Table 5.3). The CVW was highest in litters with high CVB, TBWT and low MWWT (Table 5.4).

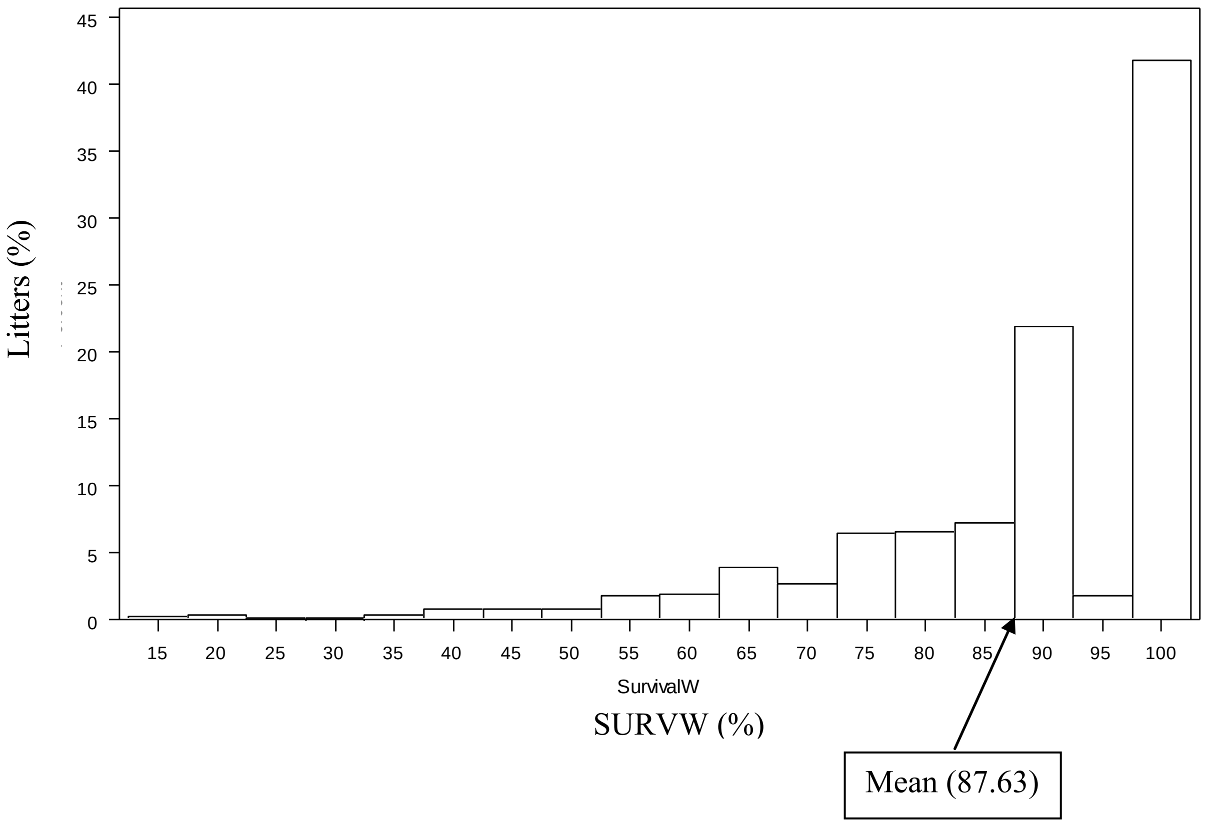


**Figure 5.1: Distribution of percent survival to weaning (SURVW) among litters**

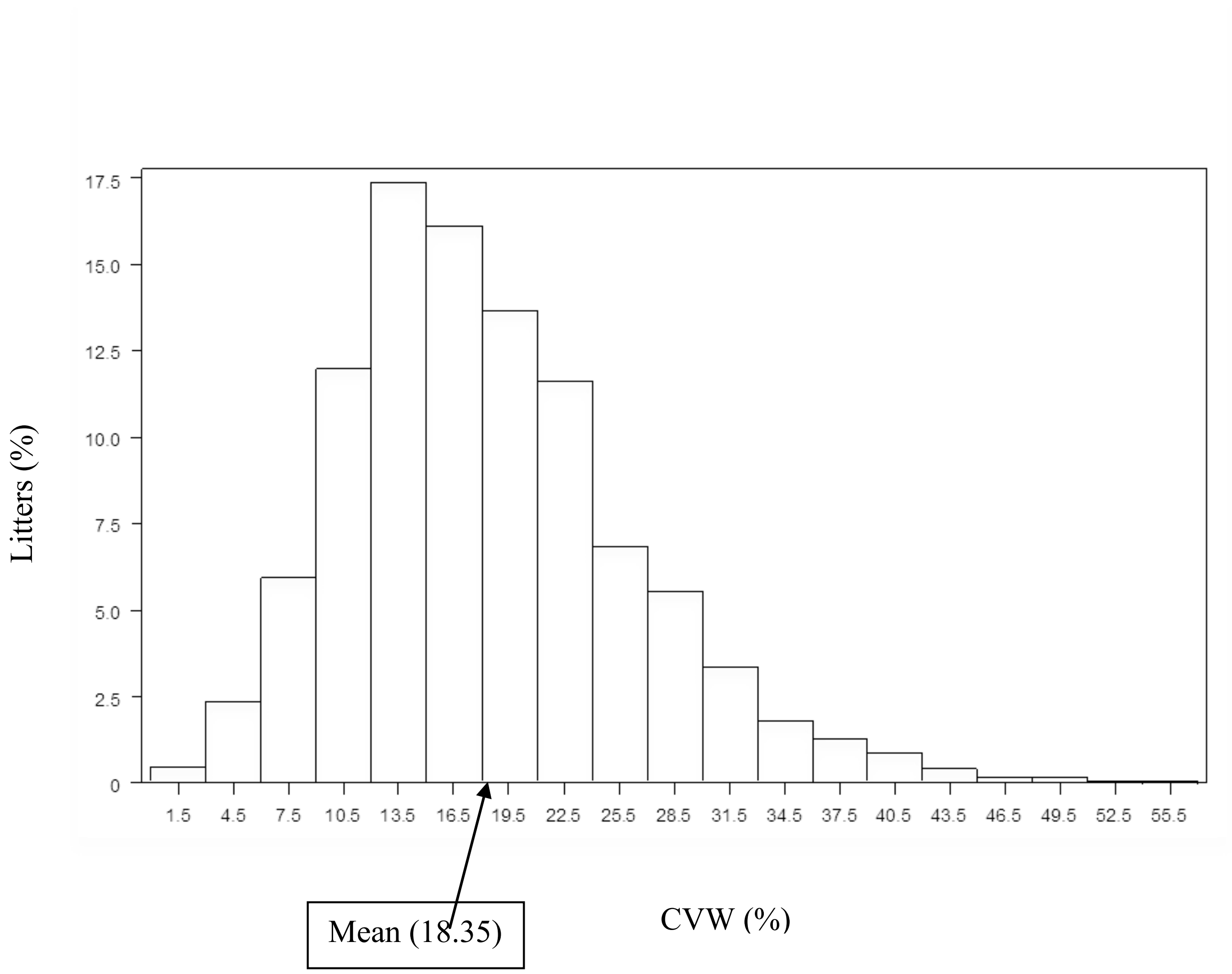


**Figure 5.2: Distribution of within-litter weaning weight variation (CVW) among litters**

## 5.4 Discussion

The mean SURVW of 87.63 % recorded in this study is similar to results from comparable studies (Knol, 2002). The litters in this study demonstrated a wide variation in SURVW and this was in agreement with findings from other studies (Lund *et al*., 2002). The distribution of CVW showed a similar pattern to that of CVB, thus a wide range in CVW could be attributed to high variation in CVB in the herd. The results clearly indicate that the major determinants of sow performance at weaning are CVB, parity and NBA. The NBA appears to be the key determinant of sow productivity as it influenced most of the litter performance traits at weaning in this study. Although CVB did not significantly influence MWWT, it can be deduced that CVB is an important determinant of sow productivity due to its significant effects on CVW and SURVW.

Milligan *et al.* (2002) documented results similar to those of this study on the effect of CVB on CVW, and which suggested that CVB is a good predictor of CVW. Though, their study used piglets that were weaned at four weeks. The effect of CVB on CVW can be attributed to the fact that small piglets tend to have lower preweaning growth rates compared to their littermates (Foxcroft and Town, 2004). Heavier piglets tend to out-compete their litter mates because they are more vigorous. Thus, they can dominate the most milk productive teats and stimulate higher milk production in sows when suckling. Hence, they have higher feed intake and have greater fighting success (Lay *et al*., 2002). This results in differences in pre-weaning weight gain and, therefore, the variation in within-litter weaning weight.

Low but significant correlations between CVB and CVW confirmed findings by Milligan *et al.* (2001, 2002) and this shows that many other factors other than CVB influence CVW. Fraser *et al*. (1992) suggested that variation in weight gain to weaning (which can be a source of CVW), can be due to differences in milk production capacity of teats. Our finding that CVB is the strongest predictor of CVW agrees with Milligan *et al*. (2002). However, Milligan *et al*. (2002) found similar correlation coefficients (0.4) between both NBA and CVB with CVW. The confounding results are probably due to differences in weaning age because, Milligan *et al.* (2002) used litters weaned at four weeks whilst litters used in this study were weaned at five weeks. The effect of parity of sow and TBWT on CVW could be because of the relationship between both traits and CVB. As parity increases CVB increases (Fernandez *et al*., 2008); hence CVW increases since there is a positive correlation between CVB and CWV. The TBWT is positively correlated to CVB and this could be a possible reason for the observed positive correlation between TBWT and CVW.

The CVB *Per se* was the most important factor in litter survivability in this study, followed by NBA, MBWT and TBWT, in that order. The finding in the present study that percent survival at weaning decreased linearly with CVB contradicts with reports by Van der Lende and Jager (1991) who found that birth weight distribution had no significant effect on pre-weaning survival. Milligan *et al. (*2002) reported similar results with those in this study in terms of variation of percent survival with CVB. Litters with high CVB have more lighter piglets (Milligan *et al*., 2002) and these lighter piglets are thought to be at a greater possibility of death (English 1998, Quiniou *et al.,* 2002) because they take longer to consume fewer amounts of colostrum and are more susceptible to crushing by the sow (Cutler *et al.,* 1999). Consumption of low amounts of colostrum is associated with poor acquisition of passive immunity hence lowers the piglets' chances for surviving to weaning (Quiniou *et al*., 2002). Fighting success for more productive teats among littermates has been found to be associated with birth weight. Heavier littermates are more successful fighters and achieve teat specificity earlier than their lighter littermates. It can be inferred that as CVB increases, more piglets within a litter take much time trying to achieve specificity hence become more susceptible to death. Though some studies have reported that minimizing birth weight variation does not improve SURVW (Van der Lende and Jager, 1991), basing on our findings, manipulating CVB in addition to NBA, MBWT and TBWT helps increase SURVW.

The observed unfavorable correlation between SURVW and NBA was in agreement with the reports ofJonson *et al.* (1999). Lund *et al*. (2002) found a negative genetic correlation between pre-weaning survival and litter size. Basing on the finding, sows with high NBA are expected to have poor mothering ability and consequently low SURVW. Farmers tend to rely on cross fostering to reduce the burden of nursing large litters from sows in an attempt to increase SURVW. Some studies (Straw *et al.,* 1998) have however shown that cross fostering is not enough to achieve high survival rates due to its negative effects such as reduced growth rates. Furthermore, reducing NBA to increase SURVW can be a drawback to achieving the maximum number of piglets weaned per sow per year. This leaves manipulation CVB as a better way to reduce mortalities to weaning than reducing NBA. Higher losses to weaning in large litters can also be attributed to high CVB which is known to be associated with reduced SURVW (English *et al*., 1982; Marchant *et al*., 2000).

The finding that CVB had no significant relationship with MWWT was in agreement with Milligan *et al*. (2002). The effect of NBA and MBWT on MWWT found in this study confirmed the work of Mungate *et al*. (1999). In contrast with the results of this study, Mungate *et al. (*1999) reported effects of parity on MWWT but Milligan *et al*. (2002) reported that there was no significant relationship between the two variables. The effect of MBWT on MWWT can be because of the large piglets that are able to stimulate teats to produce more milk than that stimulated through small piglets (King *et al*., 1997). The reasons for the effect of NBA and MBWT on LWWT are probably the same as were discussed in regard to their relationships with MWWT.

## 5.6 Conclusions

As CVB increased CVW increased and percent survival to weaning decreased. It can be concluded that CVB is a good predictor of CVW, percent survival to weaning but not MWWT and LWWT. Although CVB had no significant relationship with MWWT and LWWT, it can be concluded that it is an important determinant of litter performance to weaning due to its relationship with CVW and SURVW.

## 5.7 References

Andersen, L., Jensen, K.K., Jensen, K.H., Dybkjaer, L. and Andersen, B.H., 2005. Weaning age in organic pig production. Proceedings from NJF-seminar No. 303 Horsens, Denmark 16-17 September 1999.

Akdag, F., Arslan, S. and Demir, H., 2009. The effect of parity and litter size on birth weight and the effect of birth weight variations on weaning weight and pre-weaning survival. Journal of animal and veterinary advances, 8(11): 2133-2138.

Cutler, R.S., Fahy, V.A., Spicer, E.M. and Cronin, G.M., 1999. Preweaning mortality. In: Straw, B.E., D'Allaire, S., Mengel- ing, W.L., Taylor, D.J. (Eds.), Diseases of Swine. Iowa State University Press, Ames, IA, pp. pp. 985–1002.

Gondret, F., Lefaucheur, L., Louveau, I., Lebret, B., Pichodo, X. and Le Cozler, Y., 2005. Influence of piglet birth weight on postnatal growth performance, tissue lipogenic capacity and muscle histological traits at market weight. Livestock Production Science, 93: 137–146.

Chabo, R.G., Malope, P. and Babusi, B., 2000. Pig productivity: A case study for South-Eastern Botswana Livestock Research for Rural Development (12) 3.

Dube, B., Mulugeta, S.D., van der Westhuizen, R.R. and Dzama, K., 2011. Non-genetic factors affecting growth performance and carcass characteristics of two South African pig breeds. South African Journal of Animal Science, 41 (2): 161-176..

English, J.G.H. and Bilkei, G., 2004. The effect of litter size and littermate weight on pre-weaning performance of low-birth-weight piglets that have been cross fostered. Animal science, 79: 439-443.

English, P.R., Smith, W.J. and Maclean, A., 1982. The Sow: Improving Her Efficiency. Farming Press, 186–218. LTD, Ipswitch, U.K.

Fernandez, A., Rodriganez, J., Zuzuarregui, J., Rodriguez, M.C. and Silio, L., 2008. Genetic parameters for litter size and weight at different parities in Iberian pigs. Spanish Journal of Agricultural Research, 6: 98-106.

Fix, J.S., Cassady, J.P., Holl, J.W., Herring, W.O., Culbertson, M.S. and See, M.T., 2010. Effect of piglet birth weight on survival and quality of commercial market swine. Livestock Production Science, 123: 98-106.

Foxcroft, G.R., and Town, S., 2004. Prenatal programming of postnatal performance – The unseen cause of variance. Advances in Pork Production, 15: 269–279.

Fraser, D., Thompson, B.K. and Rushen, J., 1992. Teat productivity in second lactation sows: influence of use or non-use during the first lactation. Animal Production, 55: 419–424.

Graeme, T. and Greg, R., 2006. Market weight variation in the pork industry. Livestock officers pigs, Intensive Industries Development, Tamworth.

King, R.H., Mullan, B.P., Dunshea, F.R. and Dove, H., 1997. The influence of piglet body weight on milk production of sows. Livestock Production Science, 47, 169–174.

Knol, E.F., 2002. Genetic aspects of piglet survival. PhD Thesis, Institute for Pig Genetics and Animal Breeding and Genetics Group, Wageningen Universitet, Netherlands.

Korthals, R.L., 2001. Monitoring growth and statistical variation of grow-finish swine. Proceedings International Livestock Environment Symposium VI. 64-71.

Lay, D.C. Jr., Matteri, R.L., Carroll, J.A., Fangman, T.J. and Safranski, T.J., 2002. Preweaning survival in swine Journal of Animal Science, 1: 74-86.

Lund, M.S., Puonti, M., Rydhmer, L. and Jensen, J., 2002. Relationship between litter size and perinatal and pre-weaning survival in pigs. Animal Science, 74: 217-222.

Marchant, J.N., Rudd, A.R., Mendl, M.T., Broom, D.M, Meridith, M.J, Corning, S. and Simmons, P.H., 2000. Timing and causes of piglet mortality in alternative and conventional farrowing systems. Veterinary Record, 147: 209-214.

Milligan, B.N., Fraser, D. and Kramer, D.L., 2002. Within-litter birth weight variation in the domestic pig and its relation to pre-weaning survival, weight gain, and variation in weaning weights. Livestock Production Science, 76: 181–191.

Milligan, B.N., Fraser, D. and Kramer, D.L., 2001. Birth weight variation in the domestic pig: effects on offspring survival weight gain and suckling behaviour. Applied Animal Behaviour Science, 73: 171–191.

Mungate, F., Dzama, K., Mandisonza, K. and Shoniwa, A., 1999. Some non-genetic factors affecting commercial pig production in Zimbabwe. South African Journal of Animal Science, 29: 164-173.

Pandey, A., Singh, S.K. and Pandey, A.K., 2010. Studies on genetic and non-genetic factors affecting reproductive traits in landrace desi and their crossbred pigs. Journal of Ecology and Environmental Sciences, 1: 7-10.

Straw, B.E., Burgi, E.J., Dewey, C.E. and Duran, C.O., 1998. Effects of extensive crossfostering on performance of pigs on a farm. Journal of the American Veterinary Medical Association, 212: 855-856.

Quiniou, N., Dagorn, J., and Gaudre D., 2002. Variation of piglets' birth weight and consequences on subsequent performance. Livestock Production Science, 78: 63–70.

Quinton, V.M., Wilton, J.W., Robinson, J.A. and Mathur, P.K., 2006. Economic weights for sow productivity traits in nucleus pig populations. Livestock Science, 99: 69–77.

Van der Lende, T. and de Jager, D., 1991. Death risk and pre-weaning growth rate of piglets in relation to the within-litter weight distribution at birth. Livestock Production Science, 28: 73–84.

Wolf, J., Zakova, E. and Groeneveld, E., 2008. Within-litter variation of birth weight in hyper prolific Czech Large White sows and its relation to litter size traits, stillborn piglets and losses until weaning. Livestock Science, 115: 195–205.

Zhu, M.J., Ding, J.T., Liu, B., Yu, M., Fan, B., Li, C.C. and Zhao, S.H., 2008. Estimation of genetic parameters for four reproduction component traits in two Chinese indigenous pig breeds. Asian-Australasian Journal of Animal Science, 21 (8): 1109-1115.

# Chapter 6: General Discussion, Conclusions and Recommendations

## 6.1 General Discussion

Selection for improved litter size at birth has been the most widely practised method to increase number of pigs weaned (Foxcroft, 2008). In addition to litter size, commonly recorded reproductive traits at birth include MBWT and TBWT. Individual piglet weights at birth are overlooked by farmers mainly because they are regarded as unimportant, time consuming and labour intensive to record. However, focus on improving litter size alone can lower birth weights and decreased uniformity because litter size and piglet quality traits such as birth weight are negatively correlated. This, in turn, affects piglet survival and growth performance. Individual piglet birth weight has a fairly high heritability. It is the variation in piglets' birth weight within litters rather than the individual piglet birth weight which is more influential to survival and growth rate. As a result, within-litter birth weight variation is becoming a prominent trait in pig production. Furthermore, homogenous litters at birth reduce the need for cross fostering; hence fewer pens will be required, reducing the cost of housing, cleaning needs and general management. Just like other reproductive traits, the heritability of within-litter birth weight variation is expected to be low. Much of the variation in within-litter birth weight could be explained by non-genetic factors. Therefore, identification of non-genetic factors that influence within-litter birth weight variation may be useful in improving the trait.

Factors affecting within-litter birth weight variation were determined in Chapter 3. Within-litter birth weight variation was lowest in litters from gilts and highest in litters from multiparous sows. This indicates that there are some physiological differences among parities which influence CVB. The Uterine environment has significant effect on the size of the foetus and as the uterine environment varies across parities, piglet placental growth also varies thereby affecting piglet weight homogeneity. Differences in CVB across parities were also likely to be a result of the effect of parity on litter size, which in turn affects CVB. The CVB was found to be higher in large litters. This could be due to stiffer competition for nutrients in the uterus in large litters as compared to smaller ones.

The production of large litters of high quality piglets with good, uniform birth weights is an important aspect of maximizing sow productivity. Sow performance is usually evaluated at three weeks of age and at weaning. Three weeks' performance is regarded as crucial to subsequent piglet performance due to the fact that it is at this stage when active immunity starts to develop (Chimonyo *et al*., 2011). Due to the same reasons as at birth, farmers prefer to record litter weights at three weeks at the expense of individual piglet weight. Weaning weight variation is a problem in most pig enterprises due to drawbacks such as piglets not achieving market weight within the target period and reduced barn utilization. Reducing within-litter weight variation can have much impact on reducing weight variation within batches. This, in turn, reduces market and carcass weight variation. Producing uniform litters at birth may help reduce within-litter weight variation at three weeks and weaning. Predicting litter performance at three weeks and weaning using birth traits makes planning and management easier.

As reported by Campos *et al.,* 2011 the use of highly prolific sows in morden commercial pig production systems has resulted in an increase in within-litter birth weight variation. This increase in within-litter birth weight could be critical to litter performance to three weeks. The relationships between CVB and (CVT), MWTT, LWTT and SURVT were determined in

Chapter 4. The CVB had a significant relationship with both CVT and SURVT. There was no significant relationship between CVB and both MWTT and LWTT. In chapter 5 the relationships between CVB and CVW, MWWT, LWWT and SURVW were determined. Besides NBA, CVB was found to be a major determinant of litter performance at three weeks and at weaning, although it did not have significant relationships with MWTT and LWTT. High CVB was associated with high losses to three weeks, most probably due to the presence of more light piglets in litters with high CVB which have a greater possibility of dying. Light piglets are more susceptible to crushing and diseases. The rate of increase of CVT with CVB decreased with parity. Parity 1 had the highest rate followed by parity 2, then middle aged sows (i.e. parity 3-5). This was most likely due to differences in milk production across parities. Sows in early parities have low milk yield, with the result that competition for milk tends to be more intense as compared to those in higher parities. This tends to propagate or surge CVB to three weeks in sows in their early parities.

The effects of litter performance traits at birth on performance at weaning (Chapter 5) did not differ much from that observed at three weeks (Chapter 4). Variation of sow performance at weaning with CVB had the same pattern as at three weeks. It was found that percent survival to weaning varied marginally from survival to three weeks, suggesting that the most critical period for the new-born pig is during the first three weeks, as death losses after three weeks are normally very small.

## 6.2 Conclusions

Within-litter birth weight variation was mainly affected by NBA and parity of sow. Large NBA was associated with increased within-litter birth weight variation. Within-litter birth weight variation was lowest in primiparous sows. The CVB affected survival of piglets and within-litter weight variation at three weeks and weaning but not mean litter weight. The CVB was an important predictor of litter performance to three weeks and weaning. Litters with high CVB are expected to have higher losses to three weeks and weaning than those with low CVB. Producing uniform litters at birth improves litter homogeneity at three weeks and weaning.

## 6.3 Recommendations and further research

To maximise profitability of pig enterprises, it is recommended that within-litter birth weight variation be considered a trait of economic importance and be included, in addition to NBA, in pig breeding programs. To estimate the within-litter weight variation on farm, farmers should record individual piglet weight at birth, three weeks and weaning and compute the coefficient of variation as a measure of within-litter weight variation.

Herd-parity structures with high number of sows in parity range 3 to 5 are recommended on pig farms if CVB is to be minimised. Farmers should strictly cull sows from parity six and above to ensure that within-litter birth weight variation on the herd is kept at acceptable levels.

Further research should focus on ways to reduce within-litter birth weight variation in pig herds. This requires further understanding. Possible study areas include:

1. To determine acceptable levels of within-litter birth weight variation on farm which farmers can target.
2. Physiological mechanisms in the uterus that affect within-litter birth weight variation and how they can be manipulated to reduce it, e.g. nutrient distribution during gestation and uterine crowding.

3. Determination of the genetic parameters of within-litter birth weight variation to determine the genetic progress if within-litter birth weight is to be improved through selection.

## 6.4 References


Campos, P. H. R. F., Silva, B. A. N, Donzele, J. L., Oliveira, M. R. F. and Knol, E. F.,2011. Effects of sow nutrition during gestation on within-litter birth weight variation: a review. Animal, 1-10.

Chimonyo, M., Dzama, K., Bhebhe, E. and Mapiye, C., 2011. Pre-weaning performance of the Zimbabwean Mukota and Large White × Mukota pigs under low-input production systems. Research Opinions in Animal and Veterinary Sciences, 1(6): 352-359.

Foxcroft, G., 2008. Hyper Prolificacy and acceptable post-natal development- a possible contradiction. Advances in pork production, 19: 205.