FARROWING DURATION AND ITS EFFECTS ON PIG PERFORMANCE

by

MARIO SAMBILE SUBA

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Approved by:

John D. Wheat

Major Professor

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CHAPTER I

INTRODUCTION

Farrowing is one of the most critical stages in the whole process of swine production, in relation to the well being of both the sows and the pigs. Several problems can arise resulting in reduced efficiency in the sow as well as in the pigs and in extreme cases death of the sow and/or the pigs.

English et al. (1977) reported that prolonged farrowing significantly affects litter viability by causing some pigs which were alive as farrowing began, to die in the uterus from suffocation. Longer farrowing intervals between pigs appeared to decrease the chances of survival of later born pigs, largely due to deprivation of oxygen. Later born pigs also have reduced opportunities for suckling colostrum which offers disease resistance and nutrition. The longer the period from delivery of the first pig, the longer it takes a later born pig to reach the udder and to suckle. The same authors stated that longer delays in suckling possibly indicate a depression of vigor because of greater competition later born pigs face in reaching the udder of the sow.

Intrapartum stillbirths and reduced litter viability due to longer farrowing can reflect decreased sow efficiency and productivity (English et al., 1977). Also postulated was that prolonged farrowing and longer intervals posed an additional stress to the sow which decreased her efficiency in delivering later born pigs.

Several detailed observations have been made on farrowing of sows of different breeds, but no reference was found concerning the genetic component

of farrowing duration. However, due to wide variation within the same herd, it appears that a portion of the variation is genetically determined. If this is the case, selection for reduced farrowing should result in more live and vigorous pigs at birth, which should be especially important when early weaning is practiced.

The objectives of this study were:

A. To determine farrowing duration, birth sequence and farrowing intervals between individual pigs.

B. To estimate heritability and repeatability of farrowing interval.

C. To determine individual sow productivity index as formulated by the National Swine Improvement Federation and its association with farrowing duration and interval.

D. To determine if order of birth within the litter influences subsequent pig performance.

E. To determine if time intervals between individual pigs influence subsequent performance.

F. To determine if sire of the litter influences farrowing duration and interval.

G. To determine if season of the year influences farrowing duration and interval.

CHAPTER II

REVIEW OF LITERATURE

Farrowing duration and farrowing interval

Farrowing is the process of delivery in the sow. It can be subdivided into three phases, namely: the preparatory stage (dilation of the cervix), stage two, when the pigs are expelled and the last stage when the placenta is expelled. Most reviews concern the second phase of farrowing and define it as farrowing duration.

Farrowing duration (time from birth of the first pig to the birth of the last pig in the litter) varies markedly between sows. Several authors noted that farrowing can be accomplished within an hour to several hours. Clegg (1959) reported that farrowing in sows lasts from one hour to four hours which is similar to farrowing duration reported by Smith (1952) who stated that average farrowing duration from 23 sows was four hours and 19 minutes, ranging from 53 minutes to 18 hours.

Even when the litter is large (12 to 14 pigs), Arthur (1964) reported that farrowing probably can be completed within a period of four hours, while Davidson (1948) indicated that two to six hours is the usual normal farrowing duration in sows, though it may be completed in less than an hour or prolonged for more than 12 hours. The same was observed by Goodwin (1973) who reported that the majority of sows took around four to six hours to farrow, while some farrowed in a couple of hours and others took 18 hours or more.

Giving birth to a total of 184 pigs in 16 litters took an average of 186 minutes (DeRoth and Downie, 1976). The total expulsion of subsequent pigs from the uterus averaged 16.5 minutes. The same authors found a

positive correlation between farrowing duration and number of pigs in the litter (r = .59). In contrast, Friend et al. (1962) found no significant relationship between litter size and farrowing duration in litter sizes up to 16, though larger litters tended to take longer. They concluded that total farrowing time was unaffected by litter size at birth and that interval between pigs is a better criterion for measuring speed of delivery. Friend and his co-workers (1962) also reported that the longest duration for 212 Yorkshire sows was 16.5 hours for a litter of 16 pigs and the shortest was one hour for litters of 10 and nine pigs.

Average farrowing duration involving 35 sows producing 396 pigs (11.3 pigs per litter) was six hours and 54 minutes (Jones, 1966b). The shortest duration was two hours and two minutes for a litter of five and the longest was 16 hours and 15 minutes for a litter of 12. Longer intervals were common between births of the first and the second pigs and before the last, while shorter intervals occurred for pigs in the middle of the farrowing process. Similar findings were reported by Randall (1972a) who found that the intervals between the first and the second and between the last two pigs were commonly longer than intervals between other pigs in the litter. These results were from sows observed in Canada and England. He further observed that farrowing duration ranged from 30 minutes for a litter of three pigs to 10.5 hours for a litter of 18 pigs, for 103 sows, the mean duration was two hours and 36 minutes. Mean interval between the delivery of individual pigs within a litter ranged from 4.2 to 48.4 minutes.

Farrowing duration is a variable trait even among sows in the same herd according to English et al (1977). In their sample of 31 farrowings, average duration was 140 minutes with an average farrowing interval of 16

minutes. Gilts had the shortest average farrowing interval (12 minutes) while older sows had the longest (21 minutes). They also reported a wide range in farrowing durations of 42 to 374 minutes and a range in average within litter farrowing intervals of six to 81 minutes and for individual intervals the range was from zero to 177 minutes.

In a study by Fahmy and Friend (1981), the least squares means were 3.9 hours for farrowing duration for litters adjusted to 11.2 pigs, 1.14 kg for pig weight and 114.6 days for gestation length. They also found that farrowing duration increased significantly as the number of pigs born per litter increased. Their calculated repeatability for farrowing duration was .14 which indicated the trait is mostly affected by environmental factors and its genetic component is small.

Birth order and birth weight

Arganosa and Penalba (1971) found the sequence of birth had a significant effect on birth weight ($P < .05$). They reported that the first pigs born were significantly heavier at birth than later born pigs in the same litter. A similar result was reported by Harmon et al. (1972) who found a significant correlation between birth order and birth weight ($r = -.58$, $P < .05$). They also concluded that the first pigs in the litter were likely to be heavier and to have a better chance of surviving to weaning than later born pigs. Friend and Cunningham (1966) supported the above findings based on the records of 202 farrowings. They also reported a significant difference between birth weights of the first pigs born and the last born (1174 vs 1130 gm., $P < .05$). Pigs born at mid-farrowing tended to have lighter weights.

Fahmy and Friend (1981) reported that sows farrowing their 11th or later litters had the smallest and lightest litters, whereas the heaviest litters were farrowed by sows in their 4th parity. Wilson et al. (1961) found a relationship between litter size at birth and litter birth weight. They also suggested that 11 to 14 pigs is the optimum litter size for a sow.

Earlier born pigs were heavier at birth enabling them to fight more successfully and therefore suckle from the anterior teats of the sow more often than later born littermates (Hartsock et al., 1976). Their calculated correlation between birth order and percent mortality was .77 ($P < .01$) indicating that pigs born earlier in the birth sequence have the greatest survival rate by suckling relatively large amounts of colostrum. Correlation between birth order and birth weight was -.41 as compared to the one reported for the recalculated data of Arganosa and Penalba ($r = -.80$, 1971). Above results were supported by findings of Scheel et al. (1977) who stated that pigs larger at birth gained higher dominance ranks, were able to suckle the anterior teats and exhibited faster gains than subordinates.

In contrast, Hemsworth et al. (1976) reported that birth order and location of preferred teat did not significantly influence milk intake and growth performance of pigs though growth rate was significantly correlated with birth weight and milk intake of the pigs.

A strong inverse correlation ($r = -.70$) was reported by DeRoth and Downie (1976) between litter weight and number of pigs born per litter. Larger litter size can cause a prenatal reduction in weight gain which results in small pigs at birth thus increasing the chances of still births. They also noted that 72% of the pigs with low birth weights (less than 800 grams) were born in the first half of parturition. On the other

hand, English et al. (1977) reported that 88.63% of intrapartum deaths occurred in the second half of farrowing and 70.50% were among the last three pigs born. As birth order increases, incidence of still births also increases as a result of intra-uterine anoxia (suffocation).

State of umbilical cord at birth

The umbilical cord is the lifeline connection between the mother and the fetus. It serves as a passageway of nutrients and oxygen from the sow and is responsible for the elimination of prenatal waste products (English et al., 1977).

Davidson (1948) found that the umbilical cord was not always broken during the farrowing stages in the sow, and pigs can walk around steadily searching for the sow's udder while the cord is still attached in the membrane. In an experiment conducted by Jones (1966), 72% of the 396 pigs involved were born with their umbilical cords still intact and connected with fetal membranes of the sow's genital tract. Umbilical detachment from the sow was recorded, one to 30 minutes per pig. This was accomplished through persistent manuevering of the pig to suckle.

A similar report was made by Randall (1972a) who observed that 61.1% of 1,044 pigs studied had intact umbilical cords and were attached to fetal membranes at birth. Also, the proportion of pigs with ruptured umbilical cords increased significantly in the later stages of parturition ($P < .01$). Breakage of intact umbilical cords took five minutes after birth in most cases.

English et al. (1977) reported that earlier born pigs were less likely to have broken umbilical cords at birth than pigs born later. Only 20% of all pigs born have broken umbilical cords. Pigs born with intact umbilical

cords took 20 minutes to detach if from the sow. They also observed that pigs with severed cords at birth took slightly longer time to suckle colostrum, yet they appeared to survive and grow equally with those with intact cords.

Majority of the reported stillborn pigs by DeRoth and Downie (1976) were farrowed with broken umbilical cords, which may have been due to torsion or damage caused by pinching between sows' and pigs' bodies. Most stillbirths appeared to have died while still in the uterus due to prolonged hypoxia during the farrowing process. Results reported by Randall (1972b) agreed with DeRoth and Downie's findings (1976). Randall observed that the umbilical cord was ruptured in 93.6% of the intrapartum deaths and was considered as the major factor causing these losses. Later born pigs are more likely to be born with broken umbilical cords than earlier born littermates. He also pointed out that 82% of the intrapartum deaths were among the pigs in the last one third of the farrowing, whereas the pre-partum deaths (where the pigs had been dead for several days) were more evenly distributed throughout the farrowing.

Sex of the pigs

Bereskin et al. (1973) reported that the mean percentage of males born alive (51.4) slightly exceeded that of females in 9,302 litters. Males weighed 30 grams more, but females had five to nine percentage higher survival rate to weaning than males. Also, rate of survival of males relative to females significantly decreased as litter size at birth increased.

Proportion of males (52.6%) was greater than that of females (47.4%) with a widening ratio after the birth of the seventh pig (Friend and

Cunningham, 1966). Friend et al. (1962) reported a similar proportion of male pigs (52.3%) to female pigs born alive (47.7%).

Scheel et al. (1977) observed that males won more litter mate fights and positioned themselves at the anterior teats. This was due largely to the slightly heavier birth weight of males.

In the findings of Arganosa and Penalba (1971), sex had no significant effect on weaning weight of pigs.

Litter size and weaning weight

Arganosa and Penalba (1971) reported that weaning weight is not affected by birth order. They also found that heavier pigs at birth had heavier weaning weights and higher survival rates within the litter. Similarly, litter birth weight and litter size were positively correlated ($P < .01$) as reported by Scheel et al. (1977). Pigs from larger litters had lower individual birth weights. Sovljanski (1965) found that litter size at birth was correlated with litter weaning weight ($r = .95$), and birth weight was correlated with percentage of pigs weaned ($r = .96$). He concluded that 12 was the optimum litter size at birth.

Litters of seven to eight and six to seven had the lowest prenatal and preweaning mortality in a study conducted by Fahmy and Bernard (1971). They concluded that larger pig losses occur in very small litters and extremely large litters. Further, they found that an increase in birth weights of pigs caused a corresponding decrease in mortality both at birth and during the preweaning period. Larger pigs can compete well with other litter mates and are more developed and mature as compared to lighter weight pigs.

In another experiment conducted by Fahmy and Bernard (1972), they found that litter weight at weaning is the best estimate of sow productivity

since it is a function of all preweaning effects. They also found that litter sizes (total and alive) at birth and at weaning were positively correlated with litter birth and weaning weights. The same authors reasoned that as litter size increases, both litter birth and weaning weights increase while average pig weight decreases. This can be due to increased competition for the dam's available nutrient supply.

Survival rate

Increases in death losses at birth and during the preweaning period were due to lighter pig weights in large litters (Fahmy and Bernard, 1972). Arganosa and Penalba (1971) stated that pigs weighing less than .90 kg at birth had only 64.8% survival rate while pigs weighing at least 1.0 kg had 90.3% ($P < .05$) of surviving. Omtvedt (1970) reported that no pig weighing less .45 kg at birth survived, and mortality rate decreased as pig birth weight increased.

Friend and Cunningham (1966) reported that 70% of the still born pigs are born during the last third of the farrowing in Yorkshire sows. Friend et al. (1962) found the percentage of stillborn pigs and percentage of litters containing stillbirths increased as farrowing duration increased from within one to three hours to more than eight hours. Males had a higher mortality rate than females. Data from 120 farrowing showed that longer farrowing increased the percentage of stillbirths (Timoshenko, 1974).

A correlation ($r = -.61$, $P < .05$) between birth order and percent survival to 28 days was reported by Harmon et al. (1972). First born pigs in the litter have a higher probability of surviving. Hartsock et al. (1976) reported that high neonatal mortality in the domestic pig is due to reduction in birth weights and increased competition at the sow's udder brought about by larger litter size ($r = -.61$, $P < .05$, between mortality rate and litter size).

Fahmy and Bernard (1972) reported a 25.6% mortality rate of Yorkshire pigs from birth to 20 weeks of age, 7.2% occurred at farrowing time. Of the total mortality rate, 15.3% occurred in the first day after birth and 43.7% occurred during the first week. The major causes were congenital weakness and overlaying by the dam (26.9 and 19.2% respectively). Increased mortality rate was observed by Nielsen et al. (1974) in litters of more than 15 pigs (39.3%) as compared to litters with eight or fewer pigs (14.3%). Of the total farrowing losses stillbirths accounted for 26.1%, and 58.2% occurred during the first three days after parturition.

Bereskin et al. (1973) found that as birth weight increased, males and females had higher survival rates. They also reported that highest survival rates occurred in litters of 8.6 pigs born alive. Birth weight of pigs caused eight percent of the variation in survival rates within gilt litters whereas the number born alive caused only 0.5% of the variation.

A difference ($P < .05$), was noted, by DeRoth and Downie (1976), in the weights of pigs born alive and those born dead. Lower birth weights were associated with increased mortality rate. They further found that high pig death rate normally occurred during the first day after birth and gradually decreased as pigs grew older. Intra-uterine asphyxiation caused a large proportion of fetal mortality and reduced viability of pigs at the time of delivery (Randall, 1972).

Sow weight loss during lactation

Larger and heavier litters had a depressing effect on lactation weight gains by the sow (Bereskin and Frobish, 1981). Omtvedt et al. (1965, 1966), as reported by Fahmy and Bernard (1972), noted that as litter size increased, there was a tendency for the sow to lose more weight during lactation. There

was a 4.0 kg loss in weight during lactation for each pig increase in litter size at birth.

Effects of sires on sow productivity

Wilson et al. (1961) reported that for 267 crossbred gilts, their sires exerted a significant effect ($P < .10$) on the number of pigs farrowed per litter and litter weight at farrowing ($P < .25$). Sire of the dam had no significant effect on number of pigs weaned per litter or litter weight at weaning.

Effects of season on farrowing duration and farrowing interval

Season of the year had no significant effect on farrowing duration as reported by Fahmy and Bernard (1981).

CHAPTER III

MATERIALS AND METHODS

Experimental animals

Data were obtained from farrowings of Yorkshire and crossbred females in the Kansas State University departmental farrowing unit from October, 1979 to August, 1982. Of the 205 sows and gilts, 80 were purebred Yorkshires and 125 were Yorkshire x Duroc crossbreds (39.02 and 60.98% respectively). There were 2,156 pigs born (alive and dead) in 217 litters.

Three semen mixtures namely: A. I. mix, Duroc mix and Yorkshire mix were used to inseminate 75.80% of the sows with Duroc mix most frequently used (52.97%). The other sows were bred by 29 different individual boars, five Yorkshires and 24 crossbreds.

Methods

Experimental Plan. Observations were made during the farrowings for sows and gilts in the departmental farrowing unit. When the onset of labor was known, it was recorded. The times the first pig and all subsequent pigs were born, dead or alive, were recorded. Sex and state of umbilical cord (whether intact or broken) were recorded as soon as the pig was totally expelled from the uterus. Immediately after the pig's umbilical cord was detached from the sow, the pig was dried and weighed. Pigs were numbered according to their sequence of birth in the litter. Iron dextran was administered as an early source of iron to prevent anemia.

Pigs presented abnormally in the birth canal were pulled as soon as detected to prevent death and to hasten the delivery of other pigs present in the uterus. Expulsion of the placenta was observed to confirm completion

of individual farrowing.

Pigs born in litters of more than 12 were transferred to smaller litters to avoid a sow's nursing fewer than six or more than 12 pigs. A sow's milk production and an effort to prevent excessive competition within extra large litters were factors considered from making this decision.

Most pigs were weaned at three weeks, while others as early as 14 days to go into nutritional trials and others were weaned at 23 days. All weaning weights were adjusted to a 21-day basis using adjustments recommended by the National Swine Improvement Federation.

Traits studied

1. Farrowing duration, birth sequence and intervals between individual pigs.
    a. Correlation between farrowing interval and 21-day weaning weight.
    b. Correlation between birth order and birth weight.
    c. Correlation between birth weight and 21-day weaning weight.
    d. Correlation between farrowing duration and weaning weight of the litter.
2. Heritability and repeatability of farrowing interval between pigs in the litter.
3. Individual sow productivity index as formulated by the National Swine Improvement Federation and its association with farrowing duration and interval.
4. Order of birth within the litter and its subsequent effects on pig performance.
5. The time interval between births of consecutive pigs and its influence on performance of the pigs.
6. Influence of the sire of the litter on farrowing duration and interval.
7. Effects of the season of the year on farrowing duration and interval within the litter.

8. Other observations:

    a. Sex ratio within the litter

    b. State of umbilical cord and its relation to pig mortality

    c. Sow's weight loss during lactation and its relation to litter size and weight at birth and at weaning.

Each farrowing year was subdivided into four equal periods called seasons to determine the effect of season of the year on farrowing duration and intervals between pigs. October through December, 1979 was Period 1, January through March, 1980, Period 2 up to July through September, 1982 as Period 12.

Farrowing duration was the time from the birth of the first pig to the birth of the last pig in the litter while farrowing interval was the time between the delivery of subsequent pigs within the litter.

Individual sow productivity index (SPI) was calculated using the equation formulated by the National Swine Improvement Federation, where

SPI = 6.5 (number of pigs born alive) + adjusted 21-day litter weaning weight.

Sow's loss of weight during lactation was estimated by subtracting the weight of the sow after her litter was weaned from her weight before farrowing.

Heritability estimates of farrowing interval

Heritability estimates refer to the portion of the phenotypic variance in a population that is due to heredity (Lasley, 1978). They can be used either in narrow or broad sense. Heritability in the narrow sense includes additive gene action or the average effects which the individual gene have in that particular population while estimates of heritability in the broad sense include, in addition to variations due to additive gene action, those

due to dominance and epistasis.

Heritability can be estimated in several ways, such as from resemblance between full sibs, half sibs, identical and fraternal twins, between parent and offspring, as well as between other relatives. Sire, dam and error variance components were used to estimate the heritability of farrowing interval in this research from both full-sib and half-sib correlations.

Repeatability estimates of farrowing interval

Repeatability is a concept closely resembling heritability. Repeatability refers to the similarity of repeated observations of the same trait in the same animal. It indicates the likelihood that a certain individual will tend to repeat records for a particular trait throughout its life. Repeatability, like heritability, varies from one population to another and from time to time within the same population and is descriptive of only that population at a given time. It should be as large or larger than heritability in the broad sense since it includes permanent environmental influences on the individual.

Repeatability estimates in this study were estimated as intra-class correlations among records of traits for the same individual. Repeatabilities of farrowing interval both for full sibs and half sibs were obtained in this study.

The analysis of variance scheme used in this study to estimate heritabilities and repeatabilities of farrowing interval is presented in Table 1.

TABLE 1. ANALYSIS OF VARIANCE FOR ESTIMATING HERITABILITIES AND REPEATABILITIES OF FARROWING INTERVAL

Source of variation	df	Variance components and coefficients
Periods	$p - 1$	
Between sires (Period)	$s - p$	$E + K_3D + K_4S$
Between dams (Sires and Period)	$d - s$	$E + K_2D$
Sex	$a - 1$	$E + K_1Sex$
Within litter	$N - p - s - d - a + 1$	E

p = number of periods

s = number of sires

d = number of dams

a = number of sexes

N = total number of pigs

E = variance due to differences among pigs within litter

D = variance due to differences among dams

S = variance due to differences among sires

Statistical Methods

The model used for the analyses of variance for farrowing interval, birth weight and 21-day weaning weights of purebred and crossbred pigs was,

$$Y_{ijklm} = U + P_i + S_j(P_i) + D_k(S_j) + A_l + e_{ijklm}$$

where:

Y_{ijklm} = the farrowing interval, birth weight or 21-day weaning weight of the mth pig with the lth sex of the kth dam within the jth sire in the ith season of the year.

U = the population mean

P_i = the effect of the ith season of the year

$S_j(P_i)$ = the effect of the jth sire within the ith season of the year

$D_k(S_j)$ = the effect of the kth dam mated with the jth sire

A_l = the effect of the lth sex of the pig, and

e_{ijklm} = the error term associated with the ijklmth pig.

In the analyses of variance for different litter traits, the model used was,

$$Y_{ijk} = U + P_i + S_j(P_i) + e_{ijk}$$

where:

Y_{ijk} = the litter trait such as farrowing interval (boar and gilt), farrowing duration, number of pigs born alive, birth weight (boar and gilt), 21-day weaning weight (boar and gilt), farrowing weight and weaning weight of the sow, sow's weight loss during lactation and sow productivity index of the kth litter of the jth sire within the ith season of the year.

U, P_i and $S_j(P_i)$ = the same as above, and

e_{ijk} = the error term associated with the ijkth litter.

Simple and partial correlation coefficients were used to determine the relationships between different traits being studied.

The t - test was used to determine the significant differences among average farrowing interval, birth weight and 21-day weaning weights of purebred and crossbred pigs.

CHAPTER IV

RESULTS AND DISCUSSION

I. EFFECTS OF SEASON OF THE YEAR, PARENTS OF THE LITTERS AND SEX ON PIGS' FARROWING INTERVALS, BIRTH WEIGHTS AND 21-DAY WEANING WEIGHTS

Farrowing intervals

Analyses of variance in farrowing intervals of purebred Yorkshire pigs and pigs out of crossbred dams sired by mixed semen (crossbreds) are presented in Tables 2 and 3. Mean farrowing interval of purebred Yorkshire pigs was 16.58 minutes and that of crossbred pigs was 17.21 minutes. These results were similar to those reported by English et al. (1977). The t - test revealed no significant difference between the two groups of pigs for average farrowing interval.

Season of the year and sire of the litter did not significantly affect farrowing intervals for either purebred Yorkshire pigs or crossbreds. Similarly, sex of the pig had no significant effect on intervals in either group of pigs. Dam of the litter significantly affected farrowing intervals of both purebred Yorkshire pigs ($P < .05$), and crossbreds ($P < .01$). Gilts had shorter average farrowing intervals than older sows (English et al, 1977), indicating better muscular tone in gilts making abdominal contractions more effective in expelling pigs from the uterus.

Heritability and repeatability estimates of farrowing interval. Estimates of heritability and repeatability of farrowing interval were calculated using the sire, dam and error variance components obtained from the analysis of variance scheme presented in Table 1.

TABLE 2. ANALYSIS OF VARIANCE IN FARROWING INTERVALS OF PUREBRED YORKSHIRE PIGS

Source of variation	df	Mean Squares
Periods	8	819.86
Between sires (Period)	24	803.78
Between dams (Sires and Period)	18	838.70*
Sex	1	500.94
Within litter	352	321.92

* ($P < .05$)

TABLE 3. ANALYSIS OF VARIANCE IN FARROWING INTERVALS OF CROSSBRED PIGS

Source of variation	df	Mean Squares
Periods	7	1543.59
Between sires (Period)	15	1223.04
Between dams (Sires and Period)	139	1041.60**
Sex	1	104.80
Within litter	1192	700.02

** ($P < .01$)

Over-all, heritability for farrowing interval estimated from the full-sib correlation was .18. Estimated heritability for the same trait using the paternal half-sib correlation was .05. Repeatability values for farrowing interval for sire and dam estimated by using sire and dam components of variance were .01 and .08, respectively. These values were lower than the .14 reported by Fahmy and Friend (1981).

Heritability estimated from the full-sib correlation for farrowing interval in Yorkshire pigs was .37. The negative variance component for sire was set to zero. Repeatability estimates for this trait among the same pigs were .19 and 0 for dam and sire, respectively.

Heritability estimates from full-sib and paternal half-sib correlations for farrowing interval of crossbred pigs were .18 and .14, respectively. Since mixed semen was used to inseminate the different crossbred dams, paternal half-sibs as well as full sibs were present within the litters, thus the full-sib correlation was also used to calculate heritability estimates for this group of pigs. Estimated repeatabilities of this trait for sire and dam were .04 and .05 respectively.

Although no heritability estimates for farrowing interval are reported in literature, the values obtained in this study indicate that farrowing interval like other reproductive traits is lowly heritable. These results agreed with the conclusion made by Fahmy and Friend (1981) that this trait is mostly afftected by environmental factors and its genetic component is small. However, since heritability of farrowing interval is apparently not zero, reduction in interval as well as farrowing duration can be reduced by selection.

Birth weights

Analyses of variance in birth weights of Yorkshire pigs and crossbred pigs are presented in Tables 4 and 5. Mean birth weights of Yorkshire pigs and crossbreds were 1.30 kg and 1.35 kg. No significant difference was found between the two means using the t - test.

Birth weights of purebred and crossbred pigs were affected significantly by the season of the year ($P < .05$). Dams of the litters also significantly affected birth weights for both groups ($P < .01$). Sex of the pig had a significant effect on birth weights of crossbreds ($P < .01$) but not on purebred pigs.

Results from previous nutrition trials where some dams in this study were fed alfalfa haylage during gestation caused a reduction in energy intake which decreased ($P < .01$) individual pig birth weight by .05 kg compared with the control group. Maternal effects on birth weights were significant for both groups of pigs.

21-day weaning weights

The analyses of variance in 21-day weaning weights of purebred and crossbred pigs are presented in Tables 6 and 7. Mean 21-day weaning weights of purebred and crossbred pigs were 4.92 and 4.60 kg, respectively. A comparison of the two means using the t - test revealed that purebred pigs were heavier at 21 days than crossbreds ($P < .05$). Superior mothering ability of Yorkshire sow caused a significant increase in weaning weights of her litters.

Season of the year and dam of the litter affected ($P < .01$) 21-day weaning weights of Yorkshires as well as the crossbreds. Sex of the pigs affected ($P < .05$) the 21-day weaning weights of crossbred pigs, but sire of the litter did not affect 21-day weaning weights of pigs in either group.

TABLE 4. ANALYSIS OF VARIANCE IN BIRTH WEIGHTS OF YORKSHIRE PIGS

Source of variation	df	Mean Squares
Periods	8	5.25*
Between sires (Period)	24	1.61
Between dams (Sires and Period)	19	2.22**
Sex	1	.73
Within litter	413	.26

* ($P < .05$)

** ($P < .01$)

TABLE 5. ANALYSIS OF VARIANCE IN BIRTH WEIGHTS OF CROSSBRED PIGS

Source of variation	df	Mean Squares
Periods	7	7.01*
Between sires (Period)	15	2.40
Between dams (Sires and Period)	140	1.77**
Sex	1	10.42**
Within litter	1462	.38

*(P $\leq$ .05)

**(P $\leq$ .01)

TABLE 6. ANALYSIS OF VARIANCE IN 21-DAY WEANING WEIGHTS OF PUREBRED YORKSHIRE PIGS

Source of variation	df	Mean Squares
Periods	8	7.27**
Between sires (Period)	23	18.44
Between dams (Sires and Period)	19	34.93**
Sex	1	20.37
Within litter	310	4.37

** ($P < .01$)

TABLE 7. ANALYSIS OF VARIANCE IN 21-DAY WEANING WEIGHTS OF CROSSBRED PIGS

Source of variation	df	Mean Squares
Periods	7	390.18**
Between sires (Period)	15	72.75
Between dams (Sires and Period)	136	57.35**
Sex	1	18.32*
Within litter	1172	4.31

* ($P < .05$)

** ($P < .01$)

Twenty one-day weaning weight depends largely on birth weight as indicated by the positive correlation between these two traits ($r = .40$, $P < .01$, Table 9).

Relationship between farrowing interval, birth order, birth weight and 21-day weaning weights of pigs

Over-all estimates. Over-all means, standard deviations and ranges for farrowing interval, birth order, birth weight and 21-day weaning weights of pigs (purebreds and crossbreds) are presented in Table 8.

Mean farrowing interval for 1813 pigs was 16.78 minutes with a range from 0 to 432 minutes. Birth order ranged from 1 to 16. Average birth weight of pigs (dead or alive) was 1.34 kg ranging from .23 to 2.55 kg. Adjusted weaning weights of pigs at 21 days ranged from 1.80 to 9.36 kg, with a mean of 4.65 kg.

No significant correlation was found between farrowing interval and birth order or between farrowing interval and 21-day weaning weight (Table 9). The correlation between farrowing interval and birth weight was .17 ($P < .01$). Although no report on relationship between these two traits is available in the literature, this significant correlation indicates that heavier pigs took longer to be expelled from the uterus as compared to smaller pigs. First pigs born were significantly heavier than later born pigs in the same litter, thus a negative correlation was found between birth order and birth weight ($r = -.05$, $P < .05$). This result agreed with the findings of Arganosa and Penalba (1971), Harmon et al. (1972), Friend and Cunningham (1966) and Hartsock et al. (1976). The correlation between birth order and 21-day weaning weight was -.03 ($P > .05$). However, a strong positive correlation was found between birth weight and 21-day weaning weight ($r = .40$, $P < .01$). Heavier pigs can compete well with litter mates and are more developed and mature as compared to smaller pigs (Fahmy and

TABLE 8. OVER-ALL MEANS, STANDARD DEVIATIONS AND RANGES FOR FARROWING INTERVAL, BIRTH ORDER, BIRTH WEIGHT AND 21-DAY WEANING WEIGHT

Variable	N	Mean	S. D.	Range
Farrowing interval, min.	1813	17.68	25.37	0 - 432
Birth order	2214	6.04	3.56	1.00 - 17
Birth weight, kg	2138	1.34	.73	.59 - 2.55
21-day weaning weight, kg	1716	4.65	3.43	1.80 - 9.36

TABLE 9. CORRELATION COEFFICIENTS OF FARROWING INTERVAL, BIRTH ORDER, BIRTH WEIGHT AND 21-DAY WEANING WEIGHT

	Farrowing interval	Birth order	Birth weight	21-day weaning weight
Farrowing interval, min.	1.00	-.02	.17**	.02
Birth order		1.00	-.05*	-.03
Birth weight, kg			1.00	.40**
21-day weaning weight, kg				1.00

* ($P < .05$)

** ($P < .01$)

Bernard, 1971). Further, Scheel et al. (1977) reported that pigs larger at birth gained higher dominance ranks, were able to suckle the anterior teats and exhibited faster gains than subordinates.

Partial correlation coefficients. Partial correlation coefficients involving the four variables mentioned above are presented in Table 10. The partial correlation between birth order and 21-day weaning weight independent of farrowing interval and the one between birth order and 21-day weaning weight independent of birth weight were nonsignificant (r's = -.04 and -.03). Birth order apparently did not affect subsequent performance of pigs.

Similarly, nonsignificant partial correlations were found between farrowing interval and 21-day weaning weight independent of birth order and between farrowing interval and 21-day weaning weight independent of birth weight. Thus, farrowing interval did not affect subsequent pig performance during the first 21 days.

Estimates according to sex. Over-all means, standard deviations and ranges for farrowing intervals, birth orders, birth weights and 21-day weaning weights of boars and gilts are presented in Tables 11 and 12. Mean farrowing intervals for boars and gilts were 17.29 and 16.42 minutes, respectively, with a range from 0 to 432 minutes for boars and 0 to 263 for the gilts. Ranges of birth order were the same for both sexes (1 to 17). Average birth weight of boars was 1.37 kg (.23 to 2.54 kg) and that for gilts was 1.36 kg (.41 to 2.32 kg). Comparison among means using the t - test revealed that boars were significantly heavier at birth than females ($P < .05$). Heavier boars at birth may be explained by the fact that the male fetus has a higher growth competence before birth than females (Hafez, 1968). The range for adjusted 21-day weaning weights for gilts was 1.80 to 8.00 kg with a mean of 4.66 kg and that for boars was 1.96 to 9.36 kg with 4.68 kg as the average

Table 10. PARTIAL CORRELATION COEFFICIENTS INVOLVING FARROWING INTERVAL (A), BIRTH ORDER (B), BIRTH WEIGHT (C) AND 21-DAY WEANING WEIGHT (D)

$r_{AB.C} = -.01$	$r_{BD.C} = .01$
$r_{AB.D} = -.02$	$r_{CD.A} = .41^{**}$
$r_{AC.B} = .17^{**}$	$r_{CD.B} = .40^{**}$
$r_{AC.D} = .18^{**}$	$r_{AB.CD} = -.01$
$r_{AD.B} = .02$	$r_{AC.BD} = .18^{**}$
$r_{AD.C} = -.06$	$r_{AD.BC} = -.06$
$r_{BC.A} = -.04$	$r_{BC.AD} = -.04$
$r_{BC.D} = -.04$	$r_{BD.AC} = .01$
$r_{BD.A} = -.03$	$r_{CD.AB} = .40^{**}$

$^{**}(P < .01)$

TABLE 11. OVER-ALL MEANS, STANDARD DEVIATIONS AND RANGES FOR FARROWING INTERVALS, BIRTH ORDERS, BIRTH WEIGHTS, AND 21-DAY WEANING WEIGHTS OF BOARS

Variable	N	Mean	S. D.	Range
Farrowing interval, min.	894	17.29	28.78	0 - 432
Birth order	1083	6.06	3.54	1.00 - 17
Birth weight, kg	1049	1.37	.72	.23 - 2.54
21-day weaning weight, kg	846	4.68	3.51	1.96 - 9.36

TABLE 12. OVER-ALL MEANS, STANDARD DEVIATIONS AND RANGES FOR FARROWING INTERVALS, BIRTH ORDERS, BIRTH WEIGHTS AND 21-DAY WEANING WEIGHTS OF GILTS

Variable	N	Mean	S. D.	Range
Farrowing interval, min.	865	16.42	21.97	0 - 263
Birth order	1078	5.95	3.54	1.00 - 17
Birth weight, kg	1043	1.36	.70	.41 - 2.32
21-day weaning weight, kg	848	4.66	3.31	1.80 - 8.00

weaning weight at 21-days.

Correlation coefficients involving farrowing interval, birth order, birth weight and 21-day weaning weights for boars and gilts are presented in Tables 13 and 14. Farrowing intervals for both sexes were positively correlated with birth weight ($r = .19$ and $.16$, $P < .01$). However, non-significant correlations were found between farrowing interval and birth order and between farrowing interval and 21-day weaning weight for both boars and gilts. Birth orders of boars and gilts were not significantly correlated with birth weight and 21-day weaning weights. A strong positive correlation existed between birth weight and 21-day weaning weight ($r = .40$ for both sexes, $P < .01$). This was expected since this represents a part-whole relationship. Regardless of sex, heavier pigs at birth required longer farrowing intervals during delivery and were expected to have heavier weaning weights.

TABLE 13. CORRELATION COEFFICIENTS OF FARROWING INTERVAL, BIRTH ORDER, BIRTH WEIGHT AND 21-DAY WEANING WEIGHT OF BOARS

	Farrowing interval	Birth order	Birth weight	21-day weaning weight
Farrowing interval, min.	1.00	-.05	.18**	.04
Birth order		1.00	-.05	-.02
Birth weight, kg			1.00	.40**
21-day weaning weight, kg				1.00

** ($P < .01$)

TABLE 14. CORRELATION COEFFICIENTS BETWEEN FARROWING INTERVALS, BIRTH ORDERS, BIRTH WEIGHTS AND 21-DAY WEANING WEIGHTS OF GILTS

	Farrowing interval	Birth order	Birth weight	21-day weaning weight
Farrowing interval, min.	1.00	.03	.16**	-.02
Birth order, kg		1.00	-.04	-.03
Birth weight, kg			1.00	.41**
21-day weaning weight, kg				1.00

**(P / .01)

CHAPTER V

II. EFFECTS OF SEASON OF THE YEAR AND SIRE OF THE LITTER ON DIFFERENT LITTER TRAITS

Farrowing duration and farrowing interval

Analyses of variance between litters for average farrowing interval and farrowing duration are presented in Table 15. Average farrowing duration and interval within litters were not significantly affected by either season of the year or sire of the litter. Similarly, neither factor significantly afftected farrowing intervals for boars and gilts within a litter (Table 16). Similar results were found by Fahmy and Bernard (1981) who reported that season of the year had no significant effect on farrowing duration.

Number of pigs born alive and litter birth weight

Analyses of variance in number of pigs born alive and litter birth weight are presented in Table 17. Season of the year significantly affected litter birth weight ($P < .01$) but not the number of pigs born alive. Sires within periods significantly affected the number of pigs born alive ($P < .05$). Litter birth weight was not affected by the sire of the litter.

Dams which received alfalfa haylage during their gestation period had less energy intake which resulted in a significant reduction in litter birth weight ($P < .01$). Fertility of the sires most likely accounted for a portion of the variability in the number of pigs born.

Table 18 reveals that season of the significantly affected birth weights of gilts ($P < .01$) but not those of boars. Boars have greater competence for prenatal growth than females (Hafez, 1968). Sire of the litter had no effect on birth weights of boars or gilts.

TABLE 15. ANALYSIS OF VARIANCE BETWEEN LITTERS' AVERAGE FARROWING INTERVALS AND FARROWING DURATIONS

Source of variation	df	Mean Squares	
		farrowing interval	farrowing duration
Periods	10	104.53	4767.23
Between sires (Period)	45	190.31	4741.06
Within litter	159	155.57	9926.90

TABLE 16. ANALYSIS OF VARIANCE IN FARROWING INTERVALS FOR BOARS AND GILTS WITHIN A LITTER

Source of variation	df	Mean Squares	
		boar interval	gilt interval
Periods	10	164.62	135.52
Between sires (Period)	44	362.79	304.18
Within litter	150	269.61	284.88

TABLE 17. ANALYSIS OF VARIANCE IN LITTER BIRTH WEIGHTS AND NUMBER OF PIGS BORN ALIVE

Source of variation	df	Mean Squares	
		birth weight	pigs born alive
Periods	10	.78**	11.66
Between sires (Period)	45	.21	12.18*
Within litter	161	1.72	7.87

*(P / .05)

**(P / .01)

TABLE 18. ANALYSIS OF VARIANCE IN BIRTH WEIGHTS OF GILTS AND BOARS DUE TO PERIODS AND SIRES

Source of variation	df	Mean Squares	
		boar birth weight	gilt birth weight
Periods	10	.58	.81**
Between sires (Period)	45	.33	.27
Within litter	158	.27	.27

** ($P < .01$)

Average individual 21-day weaning weight, 21-day litter weaning weight and sow productivity index

Analyses of variance in average individual pig weaning weights adjusted to 21 days, litter 21-day weaning weights and sow productivity index are presented in Table 19.

Season of the year affected average pig 21-day weaning weight ($P < .05$), however, litter 21-day weaning weight and sow productivity index were not affected by season of the year. Sire of the litter exerted nonsignificant effects on individual pig 21-day weaning weight, litter 21-day weaning weight and sow productivity index.

Sire of the litter and season of the year did not significantly affect boars' 21-day weaning weights (Table 20), however, gilts' 21-day weaning weights were affected by season of the year ($P < .01$, Table 21). Sire had no significant effect on his daughter's 21-day weaning weight.

Pigs heavier at birth tended to have heavier weaning weights because they were more mature, well developed and compete more successfully for milk from their dams than smaller pigs within the litter (Fahmy and Bernard, 1971, Scheel et al., 1977). Gilts were less competent towards growth as compared to boars before birth (Hafez, 1968).

Sow's farrowing weight, weaning weights and weight losses during lactation

Analyses of variance in sow's farrowing weights, weaning weight and weight losses during lactation are presented in Tables 22 and 23. Season of the year affected ($P < .05$) weight of the sow before farrowing. An effect was exerted by the sire of the litter (within season) on sow farrowing weight ($P < .01$) but not her weaning weight and weight loss during lactation.

TABLE 19. ANALYSIS OF VARIANCE IN AVERAGE INDIVIDUAL 21-DAY WEANING WEIGHTS, 21-DAY LITTER WEANING WEIGHTS AND SOW PRODUCTIVITY INDEX (SPI)

Source of variation	df	Mean Squares		
		21-day wwgt, kg	21-day litter wwgt, kg	SPI
Periods	10	14.43*	739.21	1680.65
Between sires (Period)	44	6.72	1244.50	2558.72
Within litter	157	7.18	1235.90	2142.96

*(P $\leq$ .05)

wwgt = weaning weight, kg

TABLE 20. ANALYSIS OF VARIANCE IN BOARS' 21-DAY WEANING WEIGHTS

Source of variation	df	Mean Squares
Periods	10	12.81
Between sires (Period)	43	8.05
Within litter	149	7.77

TABLE 21. ANALYSIS OF VARIANCE IN GILTS' 21-DAY WEANING WEIGHTS

Source of variation	df	Mean Squares
Periods	10	23.05**
Between sires (Period)	44	7.65
Within litter	153	7.74

**(P $\leq$ .01)

TABLE 22. ANALYSIS OF VARIANCE IN SOW FARROWING WEIGHTS

Source of variation	df	Mean Squares
Periods	10	5906.67*
Between sires (Period)	45	2614.65**
Within litter	157	1419.67

*(P < .05)

**(P < .01)

TABLE 23. ANALYSIS OF VARIANCE IN SOW WEANING WEIGHTS AND WEIGHT LOSSES DURING LACTATION

Source of variation	df	Mean Squares	
		weaning weight	weight loss
Periods	10	6912.47**	4602.08**
Between sires (Period)	33	1110.63	751.57
Within litter	113	1671.08	926.70

** (P < .01)

Season of the year affected sow's weaning weights and weight losses during lactation ($P < .01$). Smaller sows and gilts tended to lose less weight during lactation. Also, factors like excessive cold and heat at various seasons to which the dams were exposed before entering the farrowing units can help explain the significant season effect of farrowing weight of the sow.

Sire influence on litter size (possibly because of varying number of eggs fertilized) most likely resulted in the sire effect on farrowing weight ($P < .01$), but since litter size was standardized within 24 hours, sire effects on the sow's weaning weight and weight losses during lactation were nonsignificant.

Relationship between litter traits

Over-all estimates. Over-all means, standard deviations and ranges for different litter traits are presented in Table 24.

Average number of pigs born alive in 217 litters was 9.72 ranging from 1 to 17. Mean farrowing interval was 18.84 minutes with a range from 0 to 85 minutes. The shortest farrowing duration was 11 minutes for one recorded pig born and 618 minutes (10.30 hours) for a litter of 12 pigs. Average farrowing duration was 141.51 minutes.

Average birth weight for pigs in 217 litters was 1.37 kg (.82 to 2.24 kg) and the range for weaning weights at 21 days was 1.80 to 7.93 kg with a mean of 4.74 kg. Average litter 21-day weaning weight was 37.67 kg ranging from 3.32 kg for one pig to 85.54 kg for a litter of 17 pigs.

Heaviest farrowing weight of the sow was 254.55 kg while the smallest was 132.72 kg, with an average of 159.93 kg. Mean weaning weight of the sows was 159.93 kg ranging from 111.36 to 212.27 kg. Weight losses of the sows during lactation ranged from -15.00 to 70.45 kg. Mean weight loss was

TABLE 24. OVER-ALL MEANS, STANDARD DEVIATIONS AND RANGES FOR NUMBER OF PIGS BORN ALIVE, FARROWING INTERVALS, BOAR AND GILT FARROWING INTERVALS, FARROWING DURATIONS, LITTER BIRTH WEIGHTS, BOAR AND GILT BIRTH WEIGHTS, 21-DAY WEANING WEIGHTS, BOAR AND GILT 21-DAY WEANING WEIGHTS, LITTER 21-DAY WEANING WEIGHTS, SOW'S FARROWING WEIGHT, SOW'S WEANING WEIGHT, SOW'S WEIGHT LOSS DURING LACTATION AND SOW PRODUCTIVITY INDICES

Variable	N[a]	Mean	S. D.	Range
Number of pigs born alive	217	9.72	3.00	1.00 - 17.00
Farrowing intervals, min.	215	18.84	12.79	0 - 85.00
Boar farrowing intervals, min.	205	18.53	16.91	0 - 104.00
Gilt farrowing intervals, min.	205	18.43	17.33	0 - 166.00
Farrowing durations, min.	215	141.51	93.96	11.00 - 618.00
Birth weights, kg	217	1.37	.51	.82 - 2.24
Boar birth weights, kg	214	1.40	.56	.59 - 2.40
Gilt birth weights, kg	214	1.34	.56	.64 - 2.08
21-day weaning weights, kg	212	4.74	2.92	1.80 - 7.93
Boar 21-day weaning weights, kg	203	4.81	3.05	1.95 - 8.32
Gilt 21-day weaning weights, kg	208	4.67	3.07	1.80 - 7.73
Total 21-day weaning weights, kg	212	37.67	35.29	3.32 - 85.54
Sows' farrowing weights, kg	213	184.02	44.60	132.73 - 254.55
Sows' weaning weights, kg	157	159.93	45.98	111.36 - 212.27
Sows' weight losses, kg	157	24.02	34.49	-15.00 - 70.45
Sow productivity indices	212	146.30	47.12	33.30 - 298.70

[a]number of litters

24.02 kg. These values indicate that some of the sow suckling the fewest number of pigs gained weight during lactation. Sow productivity indices ranges from 33.30 to 298.70 with an average index of 146.30.

Relationship between number of pigs born alive, farrowing interval, farrowing duration, litter birth weight and 21-day weaning weight.

Correlation coefficients between litter traits are presented in Table 25. Number of pigs born alive and farrowing intervals were negatively correlated ($r = -.39$, $P < .01$), while the correlation between farrowing duration and number of pigs born alive was .22 ($P < .01$). The relationship between litter birth weight and number of pigs born alive was -.42 ($P < .01$) and between farrowing interval and litter birth weight the correlation was .25 ($P < .01$). A negative correlation was found between a pig's 21-day weaning weight and number of pigs born alive in its litter ($r = -.25$, $P < .01$). On the other hand, the correlation between birth weight and 21-day weaning weight was .41 ($P < .01$).

Shorter farrowing intervals increased the number of pigs born alive (English et al., 1977). Larger litter size at birth tended to have longer farrowing duration as reported by Fahmy and Friend (1981). As the number of pigs born alive increased, their birth weight decreased. This is best explained by the findings of Fahmy and Friend (1972) who reported that as litter size increases, average pig weight decreases due to increased competition for the dams available nutrient supply.

Relationship between sow's weight loss during lactation, sow productivity index, number of pigs born alive, farrowing duration, farrowing interval, litter birth weight and 21-day weaning weight.

The correlation between weight loss of the sow during lactation and number of pigs born alive was .42 ($P < .01$). No significant correlation was found between sow's weight loss and litter birth weight. However,

TABLE 25. CORRELATION COEFFICIENTS BETWEEN LITTER TRAITS SUCH AS NUMBER OF PIGS BORN ALIVE (A), FARROWING INTERVALS (B), BOAR FARROWING INTERVALS (C), GILT FARROWING INTERVALS (D), FARROWING DURATIONS (E), BIRTH WEIGHTS (F), BOAR BIRTH WEIGHTS (G), GILT BIRTH WEIGHTS (H), 21-DAY WEANING WEIGHTS (I), BOAR 21-DAY WEANING WEIGHTS (J), GILT 21-DAY WEANING WEIGHTS (K), LITTER 21-DAY WEANING WEIGHTS (L), SOWS' FARROWING WEIGHTS (M), SOWS' WEANING WEIGHTS (N), SOWS' WEIGHT LOSS DURING LACTATION (O) AND SOW PRODUCTIVITY INDICES (P)

Trait	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
A. Number of pigs born alive	1.00	-.39**	-.25**	-.37**	.22**	-.42**	-.33**	-.38**	-.25**	-.27**	-.26**	.45**	.15*	-.18*	.42**	-.20**
B. Farrowing intervals, min.		1.00	.80**	.66**	.57**	.25**	.20**	.23**	.12	.13	.11	-.19**	.01	.09	-.15	-.30**
C. Boars farrowing intervals, min.			1.00	.09	.05	.23**	.26**	.19**	.08	.12	.08	-.17*	.04	.00	.00	-.11
D. Gilts farrowing intervals, min.				1.00	.27**	.15	.10	.17**	.12	.12	.09	-.08	-.02	.16*	-.23**	-.21**
E. Farrowing durations, min.					1.00	.00	.05	-.02	-.05	.00	-.08	.09	.07	-.17*	.21**	.16**
F. Birth weights, kg						1.00	.90**	.90**	.41**	.37**	.40**	-.04	.31**	.29**	-.03	-.20**
G. Boar birth weights, kg							1.00	.70**	.36**	.37**	.30**	.02	.32**	.25**	.03	-.12
H. Gilt birth weights, kg								1.00	.39**	.31**	.43**	-.05	.29**	.24**	-.02	-.19**
I. Individual 21-day weaning weights, kg									1.00	.96**	.96**	.46**	.16*	.36**	-.36**	.24**
J. Boar 21-day weaning weights, kg										1.00	.87**	.48**	.19**	.38**	-.37**	.27**
K. Gilt 21-day weaning weights, kg											1.00	.47**	.13	.27**	-.32**	.20**
L. Litter 21-day weaning weights, kg												1.00	.12	.02	.17*	.93**
M. Sows' farrowing weights, kg													1.00	.69**	.30**	.15*
N. Sows' weaning weights, kg														1.00	-.47**	-.06
O. Sows' weight loss, kg															1.00	.30**
P. Sow productivity indices																1.00

*(P / .05)

**(P / .01)

weight loss of the sow during lactation was negatively correlated with the individual pigs 21-day weaning weight ($r = -.36$, $P < .01$). As litter size increased, sow lactation weight loss increased, but individual pig 21-day weight decreased. A negative relationship existed between farrowing interval and sow productivity index ($r = -.30$, $P < .01$) and between farrowing duration and sow productivity index the correlation was .16 ($P < .05$).

The above mentioned values indicated that weight loss of the sow was more dependent on the number of pigs born alive than on birth weight of the pigs. Omtvedt et al. (1965, 1966), as reported by Fahmy and Bernard (1972), found that as litter size increased, there was a tendency for the sow to lose more weight during lactation. A decreased in weight loss of the sow in this study tended to have a corresponding increased in 21-day weaning weight of the litter. Shorter farrowing intervals resulted in more live births, thus sow productivity index increased. Larger litters at birth had longer farrowing duration and the number of pigs born alive is the most important factor in the sow productivity index.

Sex ratio within the litter, state of umbilical cord and its relation to pig mortality

Mean percentage of males born, dead or alive (50.14) slightly exceeded that of females (49.86) in 217 litters. The ratio of males to females was slightly lower than those reported by Bereskin et al. (1974), Friend and Cunningham (1966), and Friend et al. (1962).

Of the 288 pigs born dead, 76.39% had intact umbilical cords. The percentages of male and female pigs born dead with intact umbilical cords were 73.61 and 77.17 respectively. On the other hand, 80.06% of the 1755 pigs born alive had intact umbilical cords. The percentage of the male

pigs born with umbilical cords intact and connected to fetal membrane of the sow's genital tract was 79.99 and that for the female pigs was 79.90. These values were higher than those reported by Jones (1966) and Randall (1972a).

CHAPTER VI

SUMMARY

Effects of season of the year, parents of the litters and sex on pigs' farrowing intervals, birth weights and 21-day weaning weights

Season of the year and sire of the litter did not significantly affect farrowing intervals of either purebred Yorkshire or crossbred pigs. Similarly, sex of the pig had no significant effect on farrowing interval among both groups of pigs. Dam of the litter affected farrowing intervals of purebred ($P < .05$) and crossbred pigs ($P < .01$). No significant difference was found between average farrowing interval for the two groups of pigs.

Over-all, heritability of farrowing interval estimated from the full-sib correlation was .18 and repeatabilities of .01 and .08 were estimated for sire and dam respectively. Heritability of farrowing interval estimated from the paternal half-sib correlation was .05. Heritability estimated from the full-sib correlation for farrowing interval in Yorkshire pigs was .37 with a corresponding repeatability estimates of .19 and 0 for dam and sire, respectively. Estimated heritabilities for farrowing interval from full-sib and paternal half-sib correlations from crossbred pigs were .18 and .14 with estimated repeatabilities of .04 and .05 for sire and dam.

Birth weights of Yorkshire and crossbred pigs were affected significantly by season of the year ($P < .05$) and by dams of the litters ($P < .01$). Sex of the pig significantly affected birth weights of crossbred pigs ($P < .01$) but did not affect birth weights of purebred pigs. No significant difference was found between average birth weights of the two group of pigs.

Season and dam significantly influenced on 21-day weaning weights of both purebred and crossbred pigs ($P < .01$). Sex of the pig significantly affected 21-day weaning weights of crossbreds ($P < .05$) but not the Yorkshires. Sire

of the litter caused no significant differences in 21-day weaning weights in either group of pigs. Purebred pigs were heavier at 21 days than crossbred pigs ($P < .05$).

Mean farrowing interval for 1813 pigs was 16.78 minutes (0 to 432 minutes). Birth order ranged from 1 to 17 and mean birth weight of pigs born (dead or alive) was 1.34 kg ranging from .23 to 2.55 kg and 21-day weaning weights of pigs ranged from 1.80 to 9.36 kg and averaged 4.65 kg.

Correlation coefficients between farrowing interval and birth order and between farrowing interval and 21-day weaning weight were nonsignificant, whereas that between farrowing interval and birth weight was .17 ($P < .01$). Birth order and birth weight were negatively correlated ($r = -.05$, $P < .05$), but the correlation was nonsignificant between birth order and 21-day weaning weight. Birth weight and 21-days weaning weight were positively correlated ($r = .40$, $P < .01$). The partial correlation between birth order and 21-day weaning weight independent of farrowing interval and birth weight was non-significant. Similarly, the partial correlation was nonsignificant between farrowing interval and 21-day weaning weight independent of birth order and birth weight. Farrowing interval and birth order had no significant effect on subsequent pig performance.

Mean farrowing intervals for boars and gilts were 17.29 and 16.42 minutes ranging from 0 to 432 minutes for boars and 0 to 263 minutes for gilts. The ranges of birth order were the same for both sexes. Mean birth weight for boars was 1.37 kg (.23 to 2.54 kg) and for gilts, it was 1.36 kg (.41 to 2.32 kg). The range in 21-day weaning weights for boars was 1.96 to 9.36 kg with a mean of 4.86 and for gilts it was 1.80 to 8.00 kg with a mean of 4.66 kg.

Boars were significantly heavier at birth than gilts ($P < .05$), but in both sexes birth weight was positively correlated to farrowing interval, the

values being .19 and .16, respectively ($P < .01$). A strong positive correlation was calculated between birth weight and 21-day weaning weights for boars and gilts ($r = .40$, $P < .01$). No significant correlations were found between farrowing interval and birth order, between farrowing interval and 21-day weaning weights or between birth order and 21-day weaning weights for both sexes.

Effects of season of the year and sire of the litter on different litter traits

Mean farrowing duration and interval were not affected significantly by season of the year or sire of the litter. Similarly, both factors had no significant effect on farrowing intervals of either boars or gilts within a litter.

Season of the year significantly affected litter birth weight ($P < .01$), but not the number of pigs born alive. Sire of the litter had a significant effect on number of pigs born alive ($P < .05$), but litter birth weight was not affected by the sire of the litter.

Season of the year had a significant effect on average individual pig 21-day weaning weight ($P < .05$), but did not affect 21-day weaning weight or sow productivity index. Sire insignificantly affected individual 21-day weaning weight, litter 21-day weaning weight and sow productivity index. Gilt 21-day weaning weights were significantly affected by season of the year ($P < .01$) but there was no seasonal effect on boar 21-day weaning weights.

Sire of the litter had a significant effect on sow farrowing weight ($P < .01$) but not on sow's weaning weight and weight losses during lactation. Season of the year affected sow farrowing weight ($P < .05$) and sow weaning weight ($P < .01$).

Average number of pigs born alive in 217 litters was 8.00 ranging from 1 to 17. Mean farrowing interval was 18.84 minutes (0 to 85 minutes) and average farrowing duration was 141.51 minutes with a range of 11 to 618 minutes. Mean litter birth weight was 1.37 kg (.82 to 2.24 kg) and 21-day weaning weights ranged from 1.80 to 7.93 kg with a mean of 4.74 kg. Average litter 21-day weaning weight was 254.55 kg and 132.72 kg was the smallest. Weaning weights of the sows ranged from 111.36 to 212.27 kg with an average of 159.93 kg. Mean weight loss during lactation was 24.02 kg (-15.00 to 70.45). Sow productivity indices ranged from 33.30 to 298.70 with an average index of 146.30.

Number of pigs born alive and farrowing intervals were negatively correlated ($r = -.39$, $P < .01$), while the correlation between farrowing duration and number of pigs born alive was .22 ($P < .01$). Litter birth weight was negatively correlated with the number of pigs born alive ($r = -.42$, $P < .01$). Similarly, the relationship between individual 21-day weaning weight and number of pigs born alive was -.25 ($P < .01$). Correlation between farrowing interval and litter birth weight was .25 ($P < .01$) and that between litter birth weight and 21-day weaning weight was .41 ($P < .01$). Sow's weight loss during lactation was affected by number of pigs born alive ($r = .42$, $P < .01$). No significant correlation was found between sow's weight loss and litter birth weight. However, the correlation between weight loss of the sow and individual 21-day weaning weights was -.36 ($P < .01$). Sow productivity index was negatively correlated with farrowing interval ($r = -.30$, $P < .01$), but the relationship between farrowing furation and sow productivity index was positive ($r = .16$, $P < .05$).

Mean percentage of males born, dead and alive, slightly exceeded that of the females in 217 litters (50.14 vs 49.86). Of the 288 pigs born dead, 76.39% had intact umbilical cords. The percentage male and females born dead with

intact umbilical cords were 73.61 and 77.17 respectively. On the other hand, 80.06% of the 1755 pigs born alive had intact umbilical cords. The percentage of the males born with intact umbilical cords was 79.99 and that of the females was 79.70.

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FARROWING DURATION AND ITS EFFECTS ON PIG PERFORMANCE

by

MARIO SAMBILE SUBA

B. S., CENTRAL LUZON STATE UNIVERSITY, 1978
PHILIPPINES

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Two hundred seventeen litters were farrowed by 80 purebred Yorkshire sows and 125 Yorkshire x Duroc crossbred dams between October, 1979 and August, 1982. Time of birth, birth order, sex, birth weight and state of umbilical cord of 2,156 pigs were recorded and analyzed. Farrowing duration and interval, adjusted 21-day weaning weights of pigs, individual sow productivity index and weight loss of the sow were calculated. Estimates of heritabilities and repeatabilities of farrowing interval were obtained. Relationships between pigs and litter traits were determined using simple and partial correlation coefficients. Effects of season of the year, parents of the litters and sex on farrowing interval, birth weight and adjusted 21-day weaning weights of pigs and different litter traits were analyzed using mixed effects models.

Season of the year, sire of the litter and sex of the pig did not significantly affect farrowing intervals and duration of either purebred or crossbred pigs. Dam of the litter affected ($P < .05$) farrowing intervals of Yorkshire and crossbred pigs ($P < .01$). No significant difference was found between farrowing intervals for the two groups of pigs.

Over-all, heritability of farrowing interval estimated from full-sib correlation was .18 and repeatabilities of .01 and .08 were estimated for sire and dam, respectively. Over-all heritability of farrowing interval estimated from the paternal half-sib correlation was .05 and that estimated only for Yorkshire pigs was .37 with corresponding repeatability estimates of 0 and .19 for the Yorkshire's sire and dam, respectively. Estimated repeatabilities for farrowing interval from full-sib and half-sib correlations for crossbred pigs was .18 and .14 with estimated repeatabilities of

.04 and .05 for sire and dam.

Birth weights of Yorkshire and crossbred pigs were affected significantly by the season of the year ($P < .05$). Dam of the litter affected birth weights for both group of pigs ($P < .01$). Sire of the litter significantly influenced the number of pigs born alive ($P < .05$), but not litter birth weight. Sex of the pig affected birth weight of crossbred pigs ($P < .01$) but did not affect birth weight of purebred pigs. No significant difference was found between average birth weights of the two groups of pigs.

Season and dam influenced individual 21-day weaning weights of purebred and crossbred pigs ($P < .01$) but not litter 21-day weaning weights and sow productivity index. Gilt 21-day weaning weights but not boars 21-day weaning weights, were affected ($P < .01$) by season of the year. Sex significantly affected 21-day weaning weights of crossbreds ($P < .05$), but not the 21-day weaning weights of Yorkshires. Sire of the litter caused no significant difference for these traits in either group of pigs. Yorkshires were heavier at 21 days than crossbreds ($P < .01$).

Sire of the litter affected sow farrowing weight ($P < .01$) but not sow's weaning weight and weight losses during lactation. Season of the year affected sow farrowing weight ($P < .05$), sow weaning weight and weight loss ($P < .01$).

Mean farrowing interval for 1813 pigs was 16.78 minutes. Birth order ranged from 1 to 17. Average birth weight and 21-day weaning weight were 1.34 and 4.65 kg, respectively. Correlation coefficients between farrowing interval and 21-day weaning weights and between farrowing interval and birth order were nonsignificant. Birth order and birth weight were

negatively correlated ($P < .05$) but a nonsignificant correlation was found between birth order and 21-day weaning weight. Birth weight was positively correlated ($P < .01$) with 21-day weaning weight. Farrowing interval and birth order did not significantly affect subsequent pig performance.

Mean farrowing interval, birth weight and 21-day weaning weights for boars and gilts were also calculated. Range of birth order were the same for both sexes. Boars were heavier at birth than gilts ($P < .05$). Correlation coefficients were also estimated between the above mentioned traits.

Means, standard deviations and ranges for different litter traits such as the number of pigs born alive, farrowing interval and duration, birth weight, individual 21-day weaning weight, litter 21-day weaning weight, sows' farrowing and weaning weights, sow's weight loss during lactation and sow productivity indices were calculated.

Number of pigs born alive was negatively correlated with farrowing intervals, litter birth weight and individual 21-day weaning weight. Farrowing duration was positively correlated with number of pigs born alive. Similarly, positive correlation existed between farrowing interval and litter birth weight and between litter birth weight and individual 21-day weaning weight. Sow's weight loss during lactation was positively correlated with number of pigs born alive but was independent of litter birth weight. However, a negative correlation was obtained between sow's weight loss and individual 21-day weaning weight. Sow productivity index was negatively correlated with farrowing interval and positively related to farrowing duration.

Mean percentage of males slightly exceeded that of females. Almost 80% of all pigs born, dead or alive had intact umbilical cords.