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# Sexual maturation and morphological development of the reproductive tract in Large White and prolific Chinese Meishan pigs

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**Summary.** Body weight of Large White gilts was greater at birth, weaning, 5 months of age and at slaughter; however, Meishan gilts reached puberty at an earlier age ($91 \pm 2$ *vs* $192 \pm 3$ days, $P < 0{\cdot}01$), had longer periods of oestrus ($60 \pm 2$ *vs* $49 \pm 2$ h, $P < 0{\cdot}01$) and experienced more oestrous cycles ($7 \pm 0{\cdot}4$ *vs* $4 \pm 0{\cdot}4$, $P < 0{\cdot}01$) before slaughter. The interoestrous interval was longer ($P < 0{\cdot}01$) for Large White gilts ($19{\cdot}8 \pm 0{\cdot}2$ *vs* $19{\cdot}1 \pm 0{\cdot}2$ days). At slaughter, uterine length ($P < 0{\cdot}05$), uterine weight, width of uterine horns, endometrial surface area, endometrial weight and percentage of uterine weight represented by endometrium was greater ($P < 0{\cdot}01$) for Large White gilts. However, breed differences were not significant when slaughter weight was included in analyses as a covariate. This indicated that development of the reproductive tract was proportionate to body weight at slaughter for each breed. When body weight at slaughter was included as a covariate, effects of day of the oestrous cycle and pregnancy on uterine width, uterine weight, endometrial surface area and endometrial weight were detected ($P < 0{\cdot}01$) and for uterine length there was a day-by-status interaction ($P < 0{\cdot}01$). Total number of CL ($P < 0{\cdot}05$) and total ovarian weight ($P < 0{\cdot}05$) were also greater for Large White gilts independent of body weight at slaughter. There were more CL in left ovaries for Meishan ($8{\cdot}1 \pm 0{\cdot}4$ *vs* $6{\cdot}6 \pm 0{\cdot}4$) and Large White ($8{\cdot}4 \pm 0{\cdot}4$ *vs* $7{\cdot}9 \pm 0{\cdot}5$) gilts. These results indicate that the more prolific Meishan gilts: (1) reach puberty at an earlier age and at a lighter body weight; (2) express oestrus longer and have slightly shorter oestrous cycles; (3) have morphologically smaller uteri; and (4) have lower numbers of CL in ovaries that are smaller than those of Large White gilts.

*Keywords:* pig; uterus; ovary; development

## Introduction

The People's Republic of China has a history of domestication of pigs dating back 6000–7000 years and possibly 10 000 years based on recent discoveries (Peilieu, 1984). In the lower Changjiang River Basin three types of pigs among the Taihu breed are exceptionally prolific, attain sexual maturity at an early age and have 16–20 mammary glands. These breeds are the Meishan, Fengjing and Jiaxing Black. In November 1979, the government of France imported, for experimental purposes, three breeding pigs, 2 females and 1 male, of each of the Meishan, Jiaxing and Jinhua breeds from the People's Republic of China. Bidanel & Legault (1986) reported results of extensive breeding studies in which they compared reproductive traits of two breeds of pigs commonly used in France, the Large White and French Landrace, with the Meishan, Jiaxing and Jinhua breeds. Their data and

**Table 1.** Comparison of reproductive efficiency of Large White and Chinese breeds of pigs

| Genotype of dam* | No. | Piglets born | | Age at puberty (days) | No. of mammary glands | Ovulation rate | Conceptus mortality (%)§ |
|---|---|---|---|---|---|---|---|
| | | Total | Alive | | | | |
| LW | 132 | 12·4 ± 0·04 | 11·5 ± 0·4 | 227 ± 9 | ‡ | 17·6 ± 0·8 | 26 ± 7 |
| MS | 305 | 15·6 ± 0·3 | 14·5 ± 0·3 | 81 ± 9 | 16·1 ± 1·4 | 17·2 ± 1·2 | 16 ± 9 |
| JX | 173 | 11·9 ± 0·4 | 11·3 ± 0·3 | 91 ± 10 | 18·8 ± 1·9 | –† | –† |
| JH | 44 | 12·1 ± 0·6 | 11·6 ± 0·6 | 109 ± 15 | 15·9 ± 0·9 | –† | –† |
| MS × LW | 70 | 16·0 ± 0·5 | 15·2 ± 0·5 | 87 ± 11 | 14·7 ± 1·4 | –† | –† |
| JX × LW | 19 | 16·1 ± 1·0 | 15·4 ± 0·9 | 93 ± 13 | 16·2 ± 1·4 | –† | –† |
| JH × LW | 11 | 12·5 ± 1·2 | 11·6 ± 1·2 | 96 ± 14 | 15·1 ± 1·4 | –† | –† |
| MS × $LW_h$ | 72 | 17·4 ± 0·6 | 16·4 ± 0·5 | –† | ‡ | –† | –† |
| $LH_h$ | 17 | 13·1 ± 1·3 | –† | 229 ± 9 | ‡ | 22·9 ± 1·0 | 41 ± 7 |

*LW = Large White; $LW_h$ = Large White Hyperprolific; MS = Meishan; JX = Jiaxing; JH = Jinhua.
†Data not available.
‡The numbers of mammary glands for LW and $LW_h$ vary from 12 to 14.
§Calculated as no. of live piglets divided by no. of CL and expressed as a percentage.

data from Bolet *et al.* (1986) for Large White Hyperprolific sows, summarized in Table 1, confirm that the Meishan breed was most prolific and provided an excellent model for study of determinants of prolificacy in pigs. Bolet *et al.* (1986) also found that Meishan gilts were more prolific than Large White and Large White Hyperprolific gilts. Litter size at birth has changed little in the commonly used breeds of pigs since the classic studies of Hammond (1914, 1921) established the relationships between ovulation rate, embryonic death losses and litter size. Ovulation rate and extent of morphological development of the uterus have been considered primary factors regulating litter size in pigs (see Wrathall, 1971). The objectives of this study were: (1) to characterize sexual maturation of Meishan and Large White gilts under common management conditions in France and (2) to compare morphological development of the ovaries and uteri of Meishan and Large White gilts to examine whether they are primary determinants of prolificacy in pigs.

## Materials and Methods

As shown in Table 2, 82 gilts (43 Meishan and 39 Large White) were used in this study. Body weight was measured at birth, at 28 days of age when weaned and at slaughter. After 70 (Meishan) and 150 (Large White) days of age gilts were observed daily for oestrus in the presence of boars to determine age at puberty, defined as the age at which gilts first exhibited behavioural oestrus, i.e. the lordosis response. During this period Meishan and Large White gilts were fed 1·5 and 2·2 kg per day of a standard corn–soybean meal ration supplemented with minerals and vitamins. Gilts were observed for oestrus at 07:00 and 17:00 h daily from puberty until slaughter to provide estimates of length of the

**Table 2.** Assignment of Chinese Meishan (MS) and Large White (LW) gilts to day of the oestrous cycle (cyclic) and pregnancy

| | Days after onset of oestrus | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 8 | | 10 | | 11 | | 12 | | 14 | |
| Status | MS | LW | MS | LW | MS | LW | MS | LW | MS | LW |
| Cyclic | 4 | 4 | 3 | 4 | 4 | 3 | 4 | 4 | 5 | 4 |
| Pregnant | 4 | 4 | 4 | 4 | 5 | 4 | 6 | 4 | 4 | 4 |

oestrous cycle and length of oestrus. The experiment began after all gilts had experienced at least 3 oestrous cycles. Gilts assigned to be mated were inseminated artificially at 12 and 24 h (Large White) and 24 and 36 h (Meishan) after onset of oestrus. Meishan gilts ovulate about 12 h later than do Large White gilts (F. Martinat-Botte, unpublished data).

The reproductive tracts were recovered from each gilt immediately after slaughter. Ovarian weight, number of corpora lutea (CL) per ovary and total weight of CL per ovary were determined. Uterine length was measured and uteri were weighed on an analytical balance. Uterine width was measured, after the uterus had been dissected open along the mesometrial border, at points about 10 cm above the uterine body, 10 cm below the utero-tubal junction and at the middle of the uterine horn. The average width of each uterine horn was determined and that figure was multiplied by uterine length to give an estimate of endometrial surface area. Sections of uterine horn were then taken at about the same positions as those for measuring uterine width. Each section was weighed, then the endometrium was dissected from the myometrium and serosa. The endometrium was then weighed and endometrial weight divided by total weight of the corresponding uterine section to determine percentage of uterine weight represented by endometrium. That percentage was multiplied by total uterine weight to estimate total endometrial weight.

Gilts were assigned randomly to Days 8, 10, 11, 12 and 14 of the oestrous cycle and pregnancy and slaughtered at those times. The presence of apparently normal conceptuses in uterine flushings confirmed that inseminated gilts were pregnant. Data from inseminated gilts that were not pregnant are not included in the analyses. Data were analysed by least squares analysis of variance to detect effects of breed, day, status (cyclic *vs* pregnant) and interactions. None of the variables measured was affected by day, status, or interactions between those main effects. Therefore, the main effect of breed, which was significant for many of these variables, will be discussed. In addition, analyses were carried out with body weight at slaughter as the covariate to determine whether differences among classes for these effects were related to age at slaughter.

## Results

Body weights for Meishan gilts were lower ($P < 0{\cdot}01$) at birth, weaning and at slaughter, indicating that they were smaller at birth, grew at a slower rate, and remained smaller throughout the experimental period (see Table 3). However, age at puberty was about 100 days earlier for Meishan gilts ($P < 0{\cdot}01$) and these gilts had longer ($P < 0{\cdot}01$) periods of oestrus. The interoestrous interval was shorter ($P < 0{\cdot}01$) by about 0·7 days for Meishan gilts. Age at slaughter and the mean number of oestrous cycles experienced before slaughter for Meishan and Large White gilts are summarized in Table 3.

**Table 3.** Body weight measurements and indices of maturation for Meishan and Large White gilts at selected times

| | Breed | |
|---|---|---|
| | Meishan | Large White |
| No. of observations | 51 | 46 |
| Birth wt (kg) | 1·0 ± 0·04 | 1·4 ± 0·04** |
| Weaning wt (kg) | 5·5 ± 0·2 | 6·7 ± 0·2** |
| 5 month wt (kg) | 36·3 ± 3·8 | 55·3 ± 4·1** |
| Slaughter wt (kg) | 79·4 ± 3·1 | 148·0 ± 3·4** |
| Age at puberty (days) | 91 ± 2 | 192 ± 3** |
| Length of oestrus (h) | 60 ± 2 | 49 ± 2** |
| No. of oestrous periods | 7 ± 0·4 | 4 ± 0·4** |
| Age at slaughter (days) | 218 ± 7 | 264 ± 8** |

Values are mean ± s.e.m.
**$P < 0{\cdot}01$ compared with Meishan pigs.

Morphological development of the reproductive tract was not greater for the more prolific Meishan gilts (Table 4). All the measures were greater for Large White gilts when differences in weight at slaughter between breeds were not considered in the statistical model. However, when

**Table 4.** Overall differences in development of the reproductive tract in Meishan and Large White gilts between Days 8 and 14 of the oestrous cycle and pregnancy

| | Breed | |
|---|---|---|
| | Meishan | Large White |
| No. of observations | 43 | 39 |
| No. corpora lutea | 14·9 ± 0·4 | 16·2 ± 0·5* |
| Total ovarian wt (g) | 12·7 ± 0·7 | 15·0 ± 0·8* |
| Uterine width (cm) | 2·7 ± 0·1 | 3·3 ± 0·1** |
| Total uterine wt (g) | 414 ± 17 | 640 ± 18** |
| Total uterine length (cm) | 199 ± 6 | 281 ± 7** |
| Total uterine surface area ($cm^2$) | 547 ± 30 | 938 ± 33** |
| Total endometrial wt (g) | 210 ± 10 | 329 ± 11** |

Values are mean ± s.e.m.
*$P < 0·05$; **$P < 0·01$ compared with Meishan pigs.

**Table 5.** Indices of uterine development in Large White (LW) and Chinese Meishan (MS) gilts between 8 and 14 days after onset of the oestrous cycle (C) and pregnancy (P)*

| | Days after onset of oestrus | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 8 | | 10 | | 11 | | 12 | | 14 | |
| | C | P | C | P | C | P | C | P | C | P |
| Uterine weight (g)†‡ | | | | | | | | | | |
| LW | 529 | 531 | 567 | 569 | 568 | 630 | 692 | 773 | 835 | 708 |
| MS | 261 | 313 | 378 | 398 | 380 | 424 | 500 | 566 | 407 | 513 |
| Uterine length (cm)†§ | | | | | | | | | | |
| LW | 289 | 254 | 327 | 251 | 278 | 279 | 255 | 304 | 263 | 315 |
| MS | 178 | 177 | 203 | 206 | 200 | 209 | 207 | 226 | 152 | 226 |
| Uterine width (cm)†‡ | | | | | | | | | | |
| LW | 2·8 | 3·3 | 2·6 | 2·8 | 3·3 | 3·4 | 3·4 | 3·7 | 4·5 | 3·6 |
| MS | 2·4 | 2·4 | 2·5 | 2·5 | 3·0 | 2·9 | 3·0 | 3·7 | 2·9 | 3·2 |
| Endometrial surface area/uterine horn (cm)†‡ | | | | | | | | | | |
| LW | 802 | 826 | 858 | 692 | 909 | 974 | 865 | 1122 | 1184 | 1140 |
| MS | 417 | 422 | 498 | 516 | 604 | 611 | 620 | 609 | 443 | 727 |
| Endometrial weight/horn (g)†‡ | | | | | | | | | | |
| LW | 282 | 278 | 265 | 293 | 277 | 325 | 360 | 424 | 423 | 361 |
| MW | 124 | 154 | 189 | 192 | 177 | 226 | 269 | 294 | 213 | 260 |

Overall standard errors for MS and LW gilts were, respectively: uterine weight, 17 and 18; uterine length, 6 and 7; uterine width, 0·08 and 0·09; endometrial surface area, 30 and 33; endometrial weight, 10 and 11.
*Body weight at slaughter utilized as covariate.
†Breed effects significant ($P < 0·01$) when body weight at slaughter was not included as covariate.
‡Day effects ($P < 0·01$).
§Day-by-status effect ($P < 0·01$).

body weight at slaughter was included as a covariate in the statistical model, only differences in ovarian weight and number of CL remained higher for Large White gilts. The inclusion of body weight at slaughter in the statistical model allowed detection of differences in uterine development due to day, status and day-by-status interaction (Table 5).

Uterine width increased between Days 8 and 14 for both breeds ($P < 0.01$), as did uterine weight ($P < 0.01$) and total uterine surface area ($P < 0.01$). A day-by-status interaction ($P < 0.01$) indicated that uterine length increased between Days 8 and 10–12 and either maintained this length or decreased by Day 14 of the cycle, in contrast to a continuous increase in uterine length between Days 8 and 14 of pregnancy. Total endometrial weight was affected by day ($P < 0.01$) and generally increased between Days 8 and 14 in cyclic and pregnant gilts.

## Discussion

One of the determinants of prolificacy, which has received considerable attention, is that of morphological development of the uterus (see Dziuk, 1985). Attempts to assess the significance of differences in uterine development on prolificacy in our commonly used breeds of pigs lead into a circular argument because it is not possible to establish whether litter size in an individual gilt or sow is large because the uterus was morphologically large or if the uterus was morphologically large because it contained a large litter of conceptuses which provided stimuli to induce uterine development. By using unilaterally hysterectomized–ovariectomized gilts, litter size per uterine horn can be increased to twice that normally found until about Day 30 of gestation, but after Day 30 of pregnancy conceptus deaths reduce litter size in unilaterally pregnant gilts to about the same numbers per uterine horn as found in intact gilts and sows (Knight *et al.*, 1977). Similarly, gilts and sows induced to superovulate by injection of exogenous gonadotrophins have significantly larger litters early in gestation, i.e. to about Day 30, but at term differences in litter size are generally not significant (see Bazer & First, 1983). Since Meishan gilts are more prolific than Large White gilts due to low rates of conceptus death (Bolet *et al.*, 1986), differences in sexual maturation and morphological development of the reproductive system were studied to determine whether they are primary determinants of prolificacy.

The Meishan gilts were smaller at birth and grew at a slower rate until slaughter, but they attained puberty at an earlier age, had longer periods of oestrus and shorter oestrous cycles than did Large White gilts. These data are consistent with previous reports (Bolet *et al.*, 1986). Ovarian weight at slaughter was greater for Large White gilts because they had higher numbers of CL and total weight of CL. This difference in ovulation rate was not detected by Bidanel & Legault (1986) when Meishan and Large White multiparous sows were studied, but differences in ovulation rate favouring Large White pigs were detected by Bolet *et al.* (1986) for gilts.

Data on morphological development of the uterus in pigs during the oestrous cycle and early pregnancy are very limited. Perry & Rowlands (1962) reported that length of the uterine horns increased throughout the first 18 days of gestation, but increased most rapidly between Days 2 and 6. Changes in uterine length and uterine weight were positively correlated ($r = 0.74$). The extent of uterine development has been considered important since inadequate surface area available for placental attachment may determine whether or not individual conceptuses survive (Wrathall, 1971). Dziuk (1985) supports the view that each conceptus requires a minimum of about 20 cm linear endometrial space if it is to survive to term in our common breeds of pigs. Therefore, one would expect greater morphological development of the uterus if that were a primary determinant of prolificacy in Meishan pigs. No evidence for this relationship was obtained for Meishan gilts from this study. In fact, actual weight, length and width of the uterine horns as well as endometrial surface area and weight were all greater for the less prolific Large White gilts. When weight at slaughter was used as a covariate in the statistical model, breed effects on uterine development were not significant. This indicated that uterine development was proportionate to body weight in sexually mature gilts. Because of extreme differences in body weight between breeds, effects of day and status as well as their interaction were not detected until body weight at slaughter was included as a covariate. The effects of day of the oestrous cycle and pregnancy on uterine development were as expected and indicated that, during the luteal phase of the oestrous cycle, there was, in general, an increase in width and weight of the uterus as well as total endometrial surface area and weight. Only for uterine length was there a significant day-by-status interaction due to the fact that uterine length increased continuously between Days 8 and 14 for pregnant gilts, but increased only between Days 8 and 10 of the oestrous cycle.

This study allowed comparison of sexual maturation and morphological development of the reproductive tract in Large White and Meishan pigs maintained under the same management conditions. Sexual maturity was attained at an earlier age for Meishan gilts and ovulation rate was less than that for Large White gilts. There was no evidence that ovulation rate was a factor limiting litter size in pigs of either breed. Furthermore, unadjusted mean values for all indices of uterine development indicated that the reproductive organs were smaller for the prolific Meishan pigs. It is concluded that ovulation rate and morphological development of the uterus are not primary determinants of prolificacy for Meishan pigs.

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