FLUSHING AND ALTRENOGEST AFFECT LITTER 
TRAITS IN GILTS1,2

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ABSTRACT

Gilts (n = 267) were allotted to flushing (1.55 kg/d additional grain sorghum), altrenogest (15 mg·gilt−1·d−1) and control treatments in a 2 × 2 factorial arrangement. Altrenogest was fed for 14 d. Flushing began on d 9 of the altrenogest treatment and continued until first observed estrus; 209 gilts (78%) were detected in estrus. The interval from the last day of altrenogest feeding to estrus was shorter (P < .05) with the altrenogest + flushing treatment (6.6 ± .2 d) than with flushing alone (7.6 ± .3 d). Ovulation rates (no. of corpora lutea) were higher (P < .05) in all flushed gilts (14.5 ± .4 vs 13.4 ± .4), whether or not they received altrenogest. Flushing also increased the total number of pigs farrowed (.9 pigs/litter; P = .06) and total litter weight (1.43 kg/litter; P = .01), independent of altrenogest treatment. Number of pigs born alive and weight of live pigs were higher for gilts treated with altrenogest + flushing and inseminated at their pubertal estrus than for gilts in all other treatment combinations. In contrast, gilts receiving only altrenogest had greater live litter weight and more live pigs born when inseminated at a postpubertal estrus than when inseminated at pubertal estrus. We conclude that flushing increased litter size and litter weight, particularly for gilts that were inseminated at their pubertal estrus. Increased litter size resulted from increased ovulation rates, which, in nonflushed gilts, limited litter size at first farrowing.

Key Words: Flushing, Synthetic Progestogens, Ovulation Rate, Litter Size, Puberty


Introduction

Efficient pork production requires management techniques that increase the rate of reproduction. One such technique may be increasing feed intake of gilts during the prebreeding period (flushing). Flushing increases the number of ovulations in gilts (Anderson and Melampy, 1971) and thereby, may increase the number of pigs farrowed.

However, studies of flushing generally have been terminated in early gestation. Furthermore, information on ovulation rate and litter size at farrowing in the same gilt is not available.

Increasing ovulation rate would be expected to increase litter size only to the limit imposed by the capacity of the uterus to support additional fetuses. Davis et al. (1987) demonstrated that flushing increased litter size for gilts inseminated at puberty but not for gilts inseminated at a postpubertal estrus. The effect of flushing on litter size of pubertal gilts may have been related to a lower ovulation rate for nonflushed pubertal gilts than for the postpubertal gilts. Ovulation rate, however, was not determined in that study. Furthermore, response to flushing has varied (Anderson and Melampy, 1971) due to different amounts of "control" vs "flush" diets, the duration of flushing, and the time when flushing was discontinued relative to the onset of estrus.
Synchronization of estrus with altrenogest might allow more precise timing of the flushing effect and thereby produce more consistent responses to flushing.

The objectives of the present experiment were to determine the influence of flushing in combination with altrenogest on ovulation rate and litter size in gilts of known pubertal status.

**Materials and Methods**

*Treatments and Experimental Design.* Gilts of Yorkshire × Duroc (Trials 1, 2, and 3) and Chester White × Yorkshire × Duroc (Trials 4, 5, and 6) breeding (n = 267; average BW = 106 ± .6 kg) were utilized in the study. Gilts (29 to 58 per trial) were moved from a modified open-front finishing barn to outside pens adjacent to two mature (> 1 yr old) boars to achieve some synchronization of first estrus. Gilts were fed daily 1.82 kg of a sorghum grain-soybean meal diet (Table 1) that met or exceeded NRC (1979) estimated requirements. After 3 to 6 d, gilts were moved to individual stalls (.5 × 1.7 m) in a gestation barn, weighed, and assigned randomly to treatments. One-half of the gilts were fed 15 mg altrenogest (allyl trenbolone or RU-2267; 17β-hydroxy-17-(2-propenyl)estra-4,9,11-trien-3-one) in the first .45 kg of the daily feed for 14 d. One-half of the gilts in both the altrenogest and control groups were fed an additional 1.55 kg (5.0 Mcal metabolizable energy) ground sorghum grain (flushing treatment) beginning on d 9 of altrenogest treatment. The flushing treatment for each gilt was discontinued when estrus was detected. The resulting four factorial treatments were: control (n = 66), altrenogest (n = 67), flushing (n = 66) and altrenogest plus flushing (n = 68). Blood was collected by puncture of the anterior vena cava at the beginning of altrenogest treatment and again 10 d later. Concentrations of progesterone in serum were determined by radioimmunoassay (Davis et al., 1985). Concentrations of progesterone exceeding 2 ng/ml indicated ovulation, and gilts were classified retrospectively as postpubertal. Otherwise, gilts were considered to have been prepubertal during the treatment period and were referred to as pubertal if they were detected in estrus after treatment.

*General Procedures.* The experiment consisted of six trials. Gilts in Trials 1 and 2 were inseminated in August and September, Trials 3, 4, and 5 in May, June and July and Trial 6 in December. Gilts were immunized against parvovirus and five strains of leptospirosis before breeding. Daily observations for estrus (0800 and 1600) began at 4 d after the last daily feeding of altrenogest, and continued for 10 d. During estrus detection, gilts were moved to a pen and exposed to a boar. Because the same 10-d breeding period was used for both altrenogest- and nonaltrenogest-treated gilts, interval to estrus was calculated by designating the last feeding of altrenogest as d 0 in each trial.

Artificial insemination (AI) utilized semen from at least two Chester White (Trials 1 and 2) or Yorkshire (Trials 3, 4, 5 and 6) boars. Both AI doses contained at least 3 × 10⁹ motile spermatozoa extended to 100 ml in Beltsville thaw solution (Pursel and Johnson, 1975). Semen was stored no longer than 24 h at 15 to 18°C. Insemination occurred first at 8 to 16 h after the first estrus and again at 24 h. Ovulation rate was determined for a subgroup (n = 81) of gilts selected at random in Trials 1, 2, 4 and 5. Gilts were anesthetized with thiamylal sodium i.v., followed by inhalation of methoxyflurane in oxygen. The ovaries were exposed through a midventral incision, and corpora lutea (CL) were counted. Prenatal survival is defined as live + dead pigs/CL.

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**TABLE 1. DIET COMPOSITION**

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>%</th>
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<tbody>
<tr>
<td>Sorghum grain</td>
<td>80.85</td>
</tr>
<tr>
<td>Soybean meal</td>
<td>15.00</td>
</tr>
<tr>
<td>Dicalcium phosphate</td>
<td>2.20</td>
</tr>
<tr>
<td>Limestone</td>
<td>1.10</td>
</tr>
<tr>
<td>Salt</td>
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</tr>
<tr>
<td>Trace mineral premix&lt;sup&gt;a&lt;/sup&gt;</td>
<td>.10</td>
</tr>
<tr>
<td>Vitamin premix&lt;sup&gt;b&lt;/sup&gt;</td>
<td>.25</td>
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</table>

<sup>a</sup>Calculated to contain 3.067 Mcal ME/kg.

<sup>b</sup>Provided the following mg/kg of complete diet: Mn, 50; Zn, 100; Fe, 100; Cu, 10; I, 3; and Co, 1.

<sup>c</sup>Provided the following per kg of complete diet: vitamin A, 8,800 USP; vitamin D₃, 660 USP; vitamin E, 44 IU; riboflavin, 9.9 mg; menadione, 3.4 mg; d-pantothenic acid, 26.4 mg; niacin, 55 mg; choline chloride, 1,014.2 mg; vitamin B₁₂, 48.4 μg.
gilts in the flushing only treatment. Overall, the interaction of treatment with
had shorter (P<.05) following the last day of altrenogest feeding
breeding periods (Table 2). More (P<.05) were observed in estrus. The interval to estrus
was related to treatments (P<.05), pubertal status at breeding (P<.01), trial (P<.05), and
the interaction of treatment with trial (P<.05).

Gilts in the altrenogest + flushing treatment had shorter (P<.05) intervals to estrus than
gilts in the flushing only treatment. Overall, gilts that had experienced at least one estrus
before insemination had shorter (P<.05) intervals to estrus (6.7 ± .2 d) than gilts
inseminated at their pubertal estrus (7.5 ± .2 d).

Farrowing Traits. Similar percentages of
gilts farrowed that were prepubertal (84%) or
pubertal (75%) before treatment. Farrowing
rate also was unaffected by altrenogest or
flushing (Table 2). The total number of pigs
farrowed increased (P=.06) approximately
one pig/litter as a result of flushing, but neither
altrenogest nor the flushing × altrenogest
interaction affected total number of pigs
farrowed (Table 2). The interaction of flushing
× pubertal status at breastfeeding affected (P=.05)
total number of pigs farrowed. This interaction
occurred because flushing increased (P=.05)
the total number of pigs farrowed by gilts
inseminated at their pubertal estrus, but it had
no effect on litter size for gilts bred at a
postpubertal estrus (Figure 1a). The interaction of flushing × pubertal status at
breeding tended to be related (P<.10) to total litter weight
because postpubertal gilts and flushed-pubertal
gilts farrowed heavier litters than nonflushed,
pubertal gilts (Figure 2b). Total litter weight
farrowed was greater (P=.01) for gilts that

<table>
<thead>
<tr>
<th>Treatment</th>
<th>No. gilts in estrus (%)</th>
<th>Interval to estrus, d</th>
<th>No. gilts farrowed (%)</th>
<th>No. of total pigs</th>
<th>Total litter wt, kg</th>
<th>No. of live pigs</th>
<th>Live litter wt, kg</th>
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</thead>
<tbody>
<tr>
<td>Altrenogest</td>
<td></td>
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<td></td>
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<tr>
<td>+</td>
<td>66 (77)</td>
<td>6.8 ± .5</td>
<td>32 (76)</td>
<td>8.9 ± .6</td>
<td>10.4 ± .6</td>
<td>8.0 ± .5</td>
<td>9.9 ± .7</td>
</tr>
<tr>
<td>-</td>
<td>50 (67)</td>
<td>7.4 ± .3</td>
<td>35 (76)</td>
<td>10.3 ± .5</td>
<td>12.2 ± .6</td>
<td>9.0 ± .5</td>
<td>11.1 ± .6</td>
</tr>
<tr>
<td>No flushing</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flushing</td>
<td>134 (70)</td>
<td>7.2 ± 2</td>
<td>79 (84)</td>
<td>9.3 ± 8h</td>
<td>9.5 ± .4</td>
<td>8.6 ± .4</td>
<td>10.3 ± .5</td>
</tr>
<tr>
<td>No altrenogest</td>
<td>130 (78)</td>
<td>7.4 ± 2</td>
<td>82 (79)</td>
<td>9.6 ± 4</td>
<td>11.3 ± 4</td>
<td>8.4 ± .4</td>
<td>10.5 ± .5</td>
</tr>
<tr>
<td>Altrenogest</td>
<td>135 (67)</td>
<td>7.0 ± 2</td>
<td>96 (79)</td>
<td>9.7 ± 3</td>
<td>11.8 ± 4</td>
<td>8.8 ± 3</td>
<td>10.9 ± .4</td>
</tr>
<tr>
<td>Cyclic statusf</td>
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<tr>
<td>Pubertal</td>
<td>106 (75)</td>
<td>7.5 ± 2</td>
<td>63 (84)</td>
<td>9.3 ± .4</td>
<td>11.2 ± .5</td>
<td>8.4 ± .4</td>
<td>10.4 ± .5</td>
</tr>
<tr>
<td>Postpubertal</td>
<td>161 (83)</td>
<td>6.7 ± 2</td>
<td>100 (75)</td>
<td>10.0 ± 3</td>
<td>11.9 ± 4</td>
<td>8.9 ± 3</td>
<td>10.9 ± .4</td>
</tr>
</tbody>
</table>

4Percentage of estrous gilts.
3Altrenogest effect (P<.05).
2Pubertal status effect (P<.05).
1Means with different superscripts differ (P<.05).
5Pubertal status categorized retrospectively according to concentrations of progesterone in serum assessed on d 0 and
10 of altrenogest feeding.
6Flushing effect (P<.05).
7Flushing effect (P<.01).

Statistical Analysis. Data were analyzed as
a 2 × 2 factorial using GLM procedures of the
Statistical Analysis System (SAS, 1982). Independent variables were treatment, trial, pubertal
status at AI, and their two-way interactions.
When F-tests (Type III sums of squares) were
significant (P<.05), means were compared
using Scheffe’s procedure in SAS (1982).
Categorical data were evaluated using chi-
square and procedure FREQ in SAS. Regression
equations were generated using procedure
STEPWISE of SAS.

Results

Estrus Traits. Two hundred nine gilts (78%)
were detected in estrus during the 10-d
breeding periods (Table 2). More (P<.05)
postpubertal than pubertal and more (P<.05)
altrenogest- than nonaltrenogest-treated gilts
were observed in estrus. The interval to estrus
following the last day of altrenogest feeding
was related to treatments (P<.05), pubertal
status at breeding (P<.01), trial (P<.05), and
the interaction of treatment with trial (P<.05).

TABLE 2. ESTROUS AND LITTER TRAITS FOR FLUSHED AND ALTRENOGEST-TREATED GILTS
FLUSHING AND ALTRENOGEST FOR GILTS

Figure 1. Number of total pigs farrowed (P = .05; 1a) and total litter wt (P < .10; 1b) was influenced by the flushing × pubertal status interaction.

were flushed than for gilts not flushed (Table 2).

Number of live pigs and litter weight of live pigs at farrowing were influenced by the interaction of treatment × pubertal status (P < .05; Figure 2). The largest pubertal-status effects occurred for altrenogest and altrenogest + flushing. Among pubertal gilts, those receiving altrenogest + flushing farrowed the most live pigs and had the heaviest live litter weights, but altrenogest-treated, nonflushed gilts were lowest for these traits. Relative rank for altrenogest-treated gilts increased from lowest to highest for pubertal vs postpubertal gilts for both live pigs and live litter weight, whereas the altrenogest + flushing gilts inseminated at a postpubertal estrus farrowed fewer live pigs and lighter live litter weights than all but control gilts.

Number of mummified fetuses at farrowing was altered (P < .05) by a flushing × altrenogest interaction. Flushing tended to decrease the number of mummies when altrenogest was fed (.12 ± .08 vs .23 ± .08 for flushed and nonflushed gilts fed altrenogest, respectively) and increase the number of mummies when altrenogest was not fed (.31 ± .10 vs .06 ± .10 for flushed and nonflushed gilts not fed altrenogest, respectively).

Flushing (P < .05), trial (P < .001) and altrenogest × trial interaction (P = .06) influenced ovulation rate. Flushing increased ovulation rate approximately 1.1 CL (Table 3). Ovulation rates were greater (P < .05) in Trials 4 and 5 (16.1 ± .6 and 15.6 ± .7, respectively) than in Trials 1 and 2 (12.2 ± .5 and 12.2 ± .5, respectively). In Trials 1 and 2, ovulation rates for altrenogest- (11.7 ± .7) and nonaltrenogest- (12.5 ± .7) treated gilts were similar, whereas in Trials 3 and 4 altrenogest-treated gilts ovulated more (P < .05) eggs than nonaltrenogest-treated gilts (16.6 ± .7 vs 14.6 ± .7, respectively).

The relationship between ovulation rate and litter size (R² = .35) is presented in Figure 3.
Two gilts had ovulation rates in excess of 19 and were excluded from this analysis. The linear model ($R^2 = .35; P < .001$) is depicted in Figure 3. Neither covariate nor regression analysis provided evidence that prenatal survival was affected by ovulation rate ($P > .20$).

**Discussion**

This study confirmed our previous observation (Davis et al., 1987) that flushing increased the total number of pigs farrowed by gilts inseminated at puberty. In a summary of 40 experiments, Anderson and Melampy (1971) suggested that an increase of 1.57 CL is a realistic expectation for flushing treatments. In contrast, we observed an increase of only 1.1 CL from flushing in the present experiment. Anderson and Melampy (1971) determined that the optimal duration of feeding (flushing period) was 11 to 14 d, and the optimal feeding level to increase ovulation rate was 6.0 to 8.0 additional Mcal ME/d. In the present experiment, gilts in flushing and altrenogest + flushing treatments were fed the extra grain for 13.6 ± 3 and 12.6 ± .2 d, respectively, which provided an additional 4.973 Mcal ME/d. Therefore, the ME content of our flushing treatment might not have produced a maximal response. The response of ovulation rate to flushing among postpubertal gilts was not significant. This may explain why flushing postpubertal gilts failed to increase litter size, because our data (Figure 3) indicate a linear relationship between litter size and ovulation rate. Further work will be required to resolve this question. Robertson et al. (1951) also reported a smaller increase in ovulation rate for flushing gilts bred at their second rather than at their pubertal estrus (1.1 vs 1.8 CL, respectively).

In another study (Kirkwood et al., 1988), flushing did not increase litter size for gilts

![Figure 3. Relationship between ovulation rate and the total pigs farrowed. Individual means ± SE are presented for each ovulation rate and the regression line is plotted (n = 58).](image)

### Table 3. Least Squares Means for Ovulation Rate and Embryo Survival After Altrenogest and Flushing

<table>
<thead>
<tr>
<th>Item</th>
<th>Altrenogest</th>
<th>Flushing</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>−</td>
<td>+</td>
</tr>
<tr>
<td>All gilts</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CL</td>
<td>13.7 ± .4 (41)b</td>
<td>14.2 ± .4 (40)</td>
</tr>
<tr>
<td>Pigs/litter</td>
<td>9.5 ± .6 (29)</td>
<td>9.8 ± .5 (31)</td>
</tr>
<tr>
<td>Pigs/CL</td>
<td>.67 ± .04</td>
<td>.70 ± .03</td>
</tr>
<tr>
<td>Pubertal gilts</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CL</td>
<td>13.6 ± .5 (14)</td>
<td>14.0 ± .5 (17)</td>
</tr>
<tr>
<td>Pigs/litter</td>
<td>8.7 ± .9 (110)</td>
<td>9.0 ± 1.1 (14)</td>
</tr>
<tr>
<td>Pigs/CL</td>
<td>.64 ± .06</td>
<td>.64 ± .07</td>
</tr>
<tr>
<td>Postpubertal gilts</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CL</td>
<td>13.8 ± .5 (27)</td>
<td>14.8 ± .6 (23)</td>
</tr>
<tr>
<td>Pigs/litter</td>
<td>9.9 ± .8 (19)</td>
<td>10.4 ± .8 (17)</td>
</tr>
<tr>
<td>Pigs/CL</td>
<td>.69 ± .05</td>
<td>.72 ± .05</td>
</tr>
</tbody>
</table>

*aCorpora lutea.
bNumber of gilts.
cFlushing effect ($P < .05$).
dFlushing effect ($P = .10$).
mated at puberty. Pubertal gilts in that study were younger (165 d) than those in our study and that of Davis et al. (1987) (195 to 245 d). Age at puberty may explain the different response to flushing if younger pubertal gilts have lower embryo survival. George and England (1974) and Archibong et al. (1987) reported that gilts mated at puberty had reduced embryo survival. However, Knott et al. (1984) observed no effects on embryo survival when gilts were mated at first vs third estrus. The latter authors used gilts that were 217 d old and 117 kg at puberty, compared with gilts that were 84.5 kg at puberty used by Archibong et al. (1987). We observed no effects of pubertal status on prenatal survival.

Altrenogest also tended to increase ovulation rate, but its effect differed from effects of flushing, as indicated by an altrenogest-trial interaction. Variation in ovulation response to altrenogest among trials may explain the inability of altrenogest to increase litter size. Reports of the effects of altrenogest on ovulation rate in gilts demonstrate this variation in response. Davis et al. (1979) observed an increase in ovulation rate following altrenogest treatment in two experiments. Others (O’Reilly et al., 1979; Boland and Gordon, 1981; Redmer and Day, 1981a) reported slight increases, whereas Redmer and Day (1981b) reported a slight decrease in the ovulation rate of altrenogest-treated gilts.

Reasons for the effects of trial on ovulation rate and for the altrenogest-trial interaction cannot be determined. Gilts in Trials 1 and 2 were treated in the fall and were of Duroc × Yorkshire breeding; treatments in Trials 4 and 5 occurred during late summer and gilts were of Chester White × Duroc × Yorkshire breeding. Perhaps these variables contributed to the interaction effects of trial and ovulation rate.

The relationship between ovulation rate and litter size was described equally well by linear (R² = .35, MSE = 6.21) and quadratic (R² = .35, MSE = 6.25) equations. Only two gilts had ovulation rates exceeding 19 (20 and 21 CL) and had relatively low prenatal survivals (45 and 48%, respectively). Data for the latter two gilts markedly altered prediction equations. Therefore, the range in CL was restricted to less than 20. Sasaki and Johnson (unpublished observations cited by Johnson et al., 1985) also observed a linear relationship between litter size and number of CL, but with less slope (y = 9.01 + .061x). That report also indicated a decrease in embryo survival as ovulation rate increased. In contrast, we observed no relationship between ovulation rate and prenatal survival.

Because our treatments were applied before AI, they most likely exerted effects on litter traits by altering ovulation rate. However, there was one indication of a postinsemination effect. Altrenogest treatment decreased the number of mummified fetuses observed for flushed gilts, but it had little effect among litters of nonflushed gilts. Except for random chance, we know of no explanation for this effect.

Implications

Gilts in our experiment were 7 to 8 mo old at AI, similar to the age at breeding on many farms. In commercial swine production, it is unusual to know the pubertal status of gilts. Gilts in our experiment were handled in a manner to allow breeding at second estrus, but 40% were inseminated at puberty. Pubertal gilts responded to flushing by farrowing more pigs. Therefore, flushing should increase litter size under the conditions of commercial pork production. Providing feed in excess of the 3.3 kg diet we used, also could increase litter size for postpubertal gilts.

Literature Cited


