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THE RELATIONSHIPS BETWEEN PLASMA PROGESTERONE AND LH AND THE NUMBERS OF CORPORA LUTEA AND EMBRYOS IN PUREBRED AND CROSSBRED GILTS^{1,2}

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Summary

Relationships between plasma progesterone and luteinizing hormone (LH) and the numbers of corpora lutea and embryos were determined in 133 8-month-old purebred Duroc, Hampshire and Yorkshire gilts and two-breed crosses among the three breeds. The numbers of corpora lutea and normal embryos were determined at slaughter on day $30.8 \pm .2$ of pregnancy, and progesterone and LH were quantified in plasma obtained the previous day. Progesterone concentrations in plasma were influenced by sire ($P < .10$), breed of dam ($P < .05$) and breed of sire \times breed of dam ($P < .05$). Hampshire gilts had higher concentrations of progesterone in plasma than did Durocs ($P < .05$) and Yorkshires ($P < .01$). None of the effects in the model was significant for LH. Plasma progesterone and LH had heritability estimates of $.48 \pm .41$ and $.29 \pm .40$, respectively. Most genetic and phenotypic correlations of plasma progesterone and LH with other traits were small. These data indicate that progesterone concentrations in plasma at 30 days of pregnancy are not a satisfactory predictor of the numbers of corpora lutea and embryos. The differences in plasma progesterone between breeds illustrate the need to consider the breed of gilts when selecting animals for the

study of luteal function or physiological factors that may influence progesterone concentrations in plasma.

(Key Words: Corpora Lutea, Embryonic Survival, Genetic Correlations, Heritability, Progesterone, Reproduction.)

Introduction

The mean number of live embryos expressed as a percentage of the number of corpora lutea at 30 days after breeding ranges from 75 to 85% in different breeds of gilts (Johnson and Omtvedt, 1973). Studies to determine the effects of exogenous progesterone on embryonic survival are not conclusive (Day *et al.*, 1959; Spies *et al.*, 1959; Schultz *et al.*, 1966; Wildt *et al.*, 1976). Studies of the relationship between plasma progesterone concentrations or progesterone metabolites in the urine and embryo numbers have yielded inconsistent results (Mayer *et al.*, 1961; Tillson and Erb, 1970; Edgerton *et al.*, 1971; Rampacek and Ulberg, 1973). However, by altering the endogenous progesterone concentrations and embryo numbers, Webel *et al.* (1975) demonstrated that plasma progesterone does not influence embryo survival in gilts during the first 30 days of pregnancy.

Progesterone concentrations in plasma are a good indicator of the number of ovulations in prepuberal gilts when induced ovulation results in a large range in the number of corpora lutea and when blood progesterone is determined at a precise time after ovulation (Dziuk *et al.*, 1972). Progesterone concentrations in plasma of gilts are also related to the numbers of corpora lutea during the first 25 days of pregnancy (Guthrie *et al.*, 1974; Webel *et al.*, 1975).

Ovulation rate can be improved through selection (Zimmerman and Cunningham, 1975), but the increase does not have a major effect on litter size (England *et al.*, 1977). Young *et al.* (1976) found significant differences between

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breeds in ovulation rate and embryonic survival, but differences in plasma progesterone and luteinizing hormone (LH) have not been documented.

The objectives of this study were to estimate the relationships of plasma progesterone and LH with the numbers of corpora lutea and embryos at day 30 of pregnancy in gilts and to determine the effect of breed on plasma progesterone and LH concentrations at day 30 of pregnancy.

Materials and Methods

One-hundred and thirty-three purebred and two-breed cross gilts of Duroc, Hampshire and Yorkshire breeding were used. Management and performance of the gilts have been described (Young *et al.*, 1976). Gilts were bred by natural service on the first and second days of estrus during a 56-day breeding period. Approximately 30 days postbreeding, the gilts were slaughtered on a weekly basis. The experiment was replicated and gilts were slaughtered in July of 2 consecutive years. Replicate 1 included both purebreds and crossbreds, while replicate 2 involved purebred gilts only.

At slaughter, the reproductive tract of each gilt was removed and the numbers of corpora lutea and normal embryos were recorded. Embryo length (Johnson and Omtvedt, 1973) was the criterion used to determine embryo normality. On the day before slaughter ($29.8 \pm .2$ days of pregnancy), blood was collected by puncture of the vena cava. Each blood sample (1 ml) was placed in a 50-ml centrifuge tube containing 32 mg oxalic acid, cooled to 5 C and centrifuged ($5,000 \times g$ for 10 min) within 30 min to remove cells. The plasma was decanted and stored at -15 C. Progesterone and LH in the plasma were quantified by the radioimmunoassay procedures described by Hallford *et al.* (1975).

Data were analyzed within replication by least-squares mixed model procedures (Harvey, 1972). The model for replication 1 (purebred and crossbred gilts) included the effects of breed of sire of gilts, sire within breed of sire, breed of dam and breed of sire \times breed of dam interactions. The model for replication 2 (purebreds) included the effects of breed of gilt and sire within breed of gilt. Sire and residual degrees of freedom and sums of squares from the two analyses were pooled, and the sire component of variance was used to estimate the

heritability of each trait and the genetic correlations among traits. The genetic causal components of the sire and residual variance components were assumed to be equal for each replication. Theoretical expectations are different for crossbreds and purebreds. But, the difference is probably small and these data were not extensive enough to test the hypothesis. A total of 36 sires was used, six of which were represented in each replication. This design caused the sire degrees of freedom to be increased by 6 but did not bias the sire mean square. Standard errors of estimates of heritability and genetic correlations were calculated by the methods of Swiger *et al.* (1964) and Tallis (1959), respectively.

Results and Discussion

Results of the analyses of variance for numbers of corpora lutea and embryos are presented in table 1. None of the effects of the model was significant for number of corpora lutea, but the effects of breed of gilts in replication 2 and breed of dam of gilt in replication 1 approached significance ($P < .10$) for number of embryos. Duroc and Yorkshire gilts had similar numbers of embryos at 30 days of pregnancy (table 2). Duroc gilts had $2.72 \pm .82$ more embryos than Hampshire gilts ($P < .01$), and Yorkshire gilts had $2.71 \pm .82$ more embryos than Hampshire gilts ($P < .01$). Crossbred gilts had $1.29 \pm .52$ more ($P < .05$) embryos than did purebred gilts.

From the pooled analysis of variance, the effect of sire was significant ($P < .10$) for percentage of live embryos, and breed of dam also influenced percentage of live embryos. Duroc and Yorkshire gilts had similar percentages of live embryos and averaged $20.03 \pm 5.90\%$ and $21.91 \pm 5.64\%$, greater ($P < .01$) embryo survival than did Hampshire gilts. The relatively large breed of sire \times breed of dam interaction indicates heterosis for percentage live embryos. Crossbred gilts had $10.83 \pm 3.73\%$ more ($P < .01$) live embryos than did purebred gilts. These results are similar to those reported by Johnson and Omtvedt (1973).

Analysis of variance (table 1) indicates that concentration of progesterone in plasma was influenced by sires ($P < .10$), breed of dam ($P < .05$) and breed of sires \times breed of dam ($P < .05$). Purebred Duroc and Yorkshire gilts had similar progesterone concentrations in plasma (table 2). Averaged over replications,

TABLE 1. MEAN SQUARES AND DEGREES OF FREEDOM FOR NUMBERS OF CORPORA LUTEA AND EMBRYOS, PERCENTAGE LIVE EMBRYOS OF CORPORA LUTEA AND PLASMA PROGESTERONE AND LH FOR GILTS SLAUGHTERED AT 30 DAYS OF PREGNANCY

| Source ^a | df | No. of corpora lutea | No. of embryos | % live embryos of corpora lutea | Plasma, ng/ml | |
|-----------------------------|----|----------------------|----------------|---------------------------------|---------------|------|
| | | | | | Progesterone | LH |
| Breed/Rep 2 | 2 | 3.19 | 24.54+ | 1,046.63 | 39.71 | 1.64 |
| BOS/Rep 1 | 2 | 15.31 | 13.90 | 51.89 | 19.16 | 1.05 |
| Sires (pooled) ^b | 36 | 8.35 | 8.36 | 548.87+ | 39.66+ | 2.27 |
| BOD/Rep 1 | 2 | 6.12 | 27.94+ | 1,070.01+ | 115.68* | .22 |
| BOS × BOD/Rep 1 | 4 | 4.84 | 9.89 | 998.51* | 88.47* | 1.18 |
| Residual (pooled) | 85 | 6.20 | 9.93 | 354.06 | 27.43 | 1.80 |

^aReplication 1 involved purebred and crossbred gilts produced from a complete diallel mating of Duroc, Hampshire and Yorkshire pigs. Replication 2 involved purebred gilts of Duroc, Hampshire and Yorkshire breeding.

^bError term used to test breed/replication 2 and breed of sire/replication 1 effects.

+P<.10.

*P<.05.

Hampshire gilts had 4.09 ± 1.67 ng/ml ($P<.05$) more progesterone than Duroc and 4.64 ± 1.63 ng/ml more ($P<.01$) than Yorkshire gilts. Yorkshire × Duroc cross gilts had 5.16 ± 1.81 ng/ml more progesterone than purebred Durocs and Yorkshires; however, the heterosis expressed by all crosses was not consistent, so average overall heterosis for concentration of progesterone in plasma was not significant. These differences between breeds in plasma progesterone concentrations demonstrate the need to consider the breed of gilts when selecting animals for the study of luteal function or physiological factors that may influence plasma progesterone concentrations.

None of the effects in the model was significant ($P<.10$) for plasma LH concentrations (table 1). Spies *et al.* (1967) demonstrated that treatment of pregnant gilts with antibodies to LH caused atrophy of corpora lutea and loss of embryos. Thus, LH may exert only a permissive role on progesterone synthesis since variations in plasma LH are not directly related to reproductive performance.

Numbers of observations were not adequate to provide precise estimates of genetic parameters. Little information is available, however, on the genetic relationships of hormone concentrations with ovulation rate and embryo survival. Estimates of these parameters are necessary before consideration can be given to indirect selection for ovulation rate and embryo survival by measurement of plasma progesterone and(or) LH concentrations.

terone and(or) LH concentrations.

Estimates of heritability and phenotypic and genetic correlations among traits are presented in table 3. The heritability estimate of $.41 \pm .41$ for number of corpora lutea agrees closely with previous estimates (Zimmerman and Cunningham, 1975; Young *et al.*, 1977). The heritability estimate for number of embryos was negative, but the estimate for percentage live embryos of corpora lutea was $.57 \pm .41$. Heritability estimates for progesterone and LH concentration in plasma were $.48 \pm .41$ and $.29 \pm .40$, respectively.

Number of corpora lutea was negatively correlated with number of live embryos when the latter was expressed as a percentage of the number of corpora lutea, both genetically ($-1.45 \pm .73$) and phenotypically ($-.33$). In general, correlations of plasma progesterone and LH with other traits were small. Plasma progesterone was positively correlated both genetically ($.17 \pm .69$) and phenotypically ($.45$), with number of corpora lutea, but correlations with number of embryos and percentage live embryos of corpora lutea were small. Similarly, Webel *et al.* (1975) found that plasma progesterone was correlated with the number of corpora lutea in pregnant gilts but was not influenced by the number of embryos on days 14, 19 and 25 of pregnancy. Guthrie *et al.* (1974) observed that when some of the gilts they studied were superovulated, plasma progesterone concentrations at day 24 of

TABLE 2. LEAST-SQUARES MEANS AND STANDARD ERRORS AND SPECIFIC COMPARISONS AMONG MEANS FOR NUMBERS OF CORPORA LUTEA AND EMBRYOS, PERCENTAGE LIVE EMBRYOS OF CORPORA LUTEA, PLASMA PROGESTERONE AND LH

| Breeding of gilt ^a | No. | No. of corpora lutea | No. of embryos | % live embryos of corpora lutea | Plasma progesterone, ng/ml | LH ^b ng/ml |
|--|-----|----------------------|----------------|---------------------------------|----------------------------|-----------------------|
| Rep 1 | | | | | | |
| D X D | 15 | 13.20 ± .75 | 11.00 ± .75 | 85.05 ± 6.05 | 16.06 ± 1.63 | 1.93 ± .39 |
| D X H | 11 | 13.86 ± .87 | 12.06 ± .87 | 89.66 ± 7.06 | 20.98 ± 1.90 | 2.15 ± .45 |
| D X Y | 8 | 15.55 ± 1.02 | 12.65 ± 1.02 | 85.23 ± 8.28 | 24.38 ± 2.23 | 1.86 ± .53 |
| H X D | 7 | 12.17 ± 1.09 | 11.44 ± 1.09 | 94.77 ± 8.85 | 15.24 ± 2.38 | 2.36 ± .57 |
| H X H | 19 | 13.85 ± .66 | 8.26 ± .66 | 60.54 ± 5.37 | 24.91 ± 1.44 | 1.85 ± .35 |
| H X Y | 7 | 13.16 ± 1.09 | 12.80 ± 1.09 | 96.92 ± 8.85 | 16.49 ± 2.38 | 2.77 ± .57 |
| Y X D | 11 | 13.12 ± .87 | 10.74 ± .87 | 84.72 ± 7.06 | 20.68 ± 1.90 | 2.67 ± .45 |
| Y X H | 10 | 12.14 ± .91 | 9.70 ± .91 | 81.52 ± 7.41 | 20.65 ± 1.99 | 2.33 ± .48 |
| Y X Y | 11 | 13.55 ± .87 | 11.58 ± .87 | 88.34 ± 7.06 | 18.69 ± 1.90 | 1.81 ± .45 |
| Rep 2 | | | | | | |
| D X D | 9 | 14.56 ± .96 | 11.89 ± .96 | 83.26 ± 7.80 | 22.36 ± 2.10 | 2.13 ± .50 |
| H X H | 15 | 13.87 ± .75 | 9.20 ± .75 | 67.71 ± 6.05 | 21.69 ± 1.63 | 1.84 ± .39 |
| Y X Y | 10 | 13.40 ± .91 | 11.30 ± .91 | 83.73 ± 7.41 | 18.64 ± 1.99 | 1.32 ± .48 |
| Comparison of purebred gilts (Data averaged over reps) | | | | | | |
| D - H | | .02 ± .82 | 2.72 ± .82** | 20.03 ± 5.90** | -4.09 ± 1.67* | .19 ± .48 |
| D - Y | | .41 ± .89 | .01 ± .89 | -1.88 ± 6.31 | .55 ± 1.78 | .47 ± .52 |
| H - Y | | .39 ± .82 | -2.71 ± .82** | -21.91 ± 5.64** | 4.64 ± 1.63** | .28 ± .49 |
| Comparison of purebred vs crossbred gilts (Rep 1 only) | | | | | | |
| [(DH+HD) - (DD+HH)]/2 | | -.51 ± .89 | 2.12 ± .89* | 19.42 ± 6.52** | -2.38 ± 1.83 | .37 ± .51 |
| [(DY+YD) - (DD+YY)]/2 | | .96 ± .90 | .41 ± .90 | -1.72 ± 6.37 | 5.16 ± 1.81** | .40 ± .52 |
| [(HV+YH) - (HH+YY)]/2 | | -1.05 ± .91 | 1.33 ± .91 | 14.78 ± 6.50* | -3.23 ± 1.84+ | .72 ± .53 |
| Crossbreds-purebreds | | -.20 ± .52 | 1.29 ± .52* | 10.83 ± 3.73** | -1.15 ± 1.05 | .50 ± .30 |

^aFirst letter represents breed of sire of gilts and second letter, breed of dam: D = Duroc, H = Hampshire, Y = Yorkshire.

^bLH standard was NIH-LH-S₁₈.

*P<.10.

**P<.05.

***P<.01.

TABLE 3. STANDARD DEVIATIONS, HERITABILITIES AND GENETIC AND PHENOTYPIC CORRELATIONS FOR NUMBERS OF CORPORA LUTEA AND EMBRYOS, PERCENTAGE LIVE EMBRYOS OF CORPORA LUTEA, PLASMA PROGESTERONE AND LH^a

| | op | (1) | (2) | (3) | (4) | (5) |
|-----|---------------------------------|------|-----------|------------|-----------|------------|
| (1) | No. of corpora lutea | 2.64 | .41 ± .41 | | | |
| (2) | No. of embryos | 3.06 | .36 | | .17 ± .69 | -.04 ± .91 |
| (3) | % live embryos of corpora lutea | 20.6 | -.33 | -.21 ± .37 | + | +.25 ± .75 |
| (4) | Plasma progesterone, ng/ml | 5.64 | .45 | .57 ± .41 | .22 ± .67 | .14 ± .86 |
| (5) | Plasma LH, ng/ml | 1.40 | .01 | -.15 | .48 ± .41 | .29 ± .40 |
| | | | .17 | .20 | -.03 | |

^aHeritabilities on the diagonal, genetic correlations above and phenotypic correlations below the diagonal.

pregnancy were correlated with ovulation rate and embryo numbers. Plasma progesterone concentration becomes a better indicator of numbers of corpora lutea and embryos when superovulation results in a large range in these values.

We conclude that although plasma progesterone concentration is phenotypically correlated with the number of corpora lutea at 30 days of pregnancy, neither plasma progesterone nor LH is a satisfactory predictor of the numbers of corpora lutea or embryos in gilts. Furthermore, breed of gilt should be considered when animals are selected for the study of factors that influence luteal function or plasma progesterone concentration in swine.

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