Effects of Energy Source in the Diet on Reproductive Hormones and Insulin During Lactation and Subsequent Estrus in Multiparous Sows

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ABSTRACT: Two experiments were performed. The first experiment was done to study the effects of dietary energy source on plasma insulin concentration using five gilts in a Latin square design with two diets over two periods. The diets contained either 200 g/kg of cornstarch (Starch) or soybean oil (Fat) as energy sources. Results indicate that insulin response was greater in the Starch-fed than in the Fat-fed gilts. A second experiment was performed in which 18 multiparous sows were fed one of the two experimental diets from farrowing until slaughter at d 35 of subsequent pregnancy. All sows nursed nine pigs. Blood samples were taken from a permanent jugular vein catheter every 12 min during a 12-h period on d 109 ± 1 of pregnancy, on d 7 ± 1, 14 ± 1, and 21 ± 1 of lactation, and on the day of weaning (d 22 ± 1). From 48 h after weaning, blood samples were taken every 4 h until 24 h after ovulation. After that, blood samples were taken at 12-h intervals until d 10 after ovulation. Differences between diets in insulin response were not significant. In Starch-fed sows, LH pulsatility at d 7 of lactation was greater (P < .05), the preovulatory LH surge was greater (P < .05), and progesterone production was greater (P < .05) from 108 h until 256 h after the LH surge than in the Fat-fed sows. Results indicate that feeding Starch-rich diets to multiparous sows compared with Fat-rich diets, on an isocaloric basis, increases LH pulsatility during early lactation, the preovulatory LH surge, and progesterone production after the LH surge.

Key Words: Sows, Progesterone, LH, Dietary Carbohydrate, Dietary Fat

Introduction

The effect of added fat in sow diets on lactation performance has been reviewed (Moser and Lewis, 1980; Pettigrew, 1981; Drochner, 1989; Babinszky, 1992). Adding fat to sow diets during lactation seems to increase the fat content in the milk. Effects on total milk yield, weight loss of the sow during lactation, and weaning weight of the litter seem to be small or absent. Effects of fat-rich vs carbohydrate-rich diets on reproductive performance have hardly been investigated in sows. Insulin may have a key role in restoration of reproduction during and after lactation (Tokach et al., 1992), and energy source may affect insulin secretion. The first experiment in this study was designed to investigate the effect of a carbohydrate-rich vs a fat-rich diet on insulin production in gilts. The second experiment was performed to investigate the effects of a carbohydrate-rich vs a fat-rich diet on LH release during lactation, the interval between weaning and ovulation, reproductive hormones around estrus, ovulation rate, and embryonic mortality in multiparous sows.

Materials and Methods

Experiment 1

Five commercial gilts (Great Yorkshire × Dutch Landrace) were housed individually in crates and surgically fitted with a jugular vein catheter (Soede et al., 1994) at approximately 6 mo of age. From 8 mo of age onward, the gilts were used in a Latin-square design experiment with two diets in two periods of 3 wk each. The carbohydrate-rich diet (Starch) contained 20 weight units of cornstarch. In the fat-rich diet (Fat), 6.4 weight units of soybean oil were used to replace the cornstarch and produce isocaloric diets. The composition of the diets is shown in Table 1. The
Table 1. Composition of the diets

<table>
<thead>
<tr>
<th>Item</th>
<th>Starch, g</th>
<th>Fat, g</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barley</td>
<td>56</td>
<td>56</td>
</tr>
<tr>
<td>Wheat middling</td>
<td>42</td>
<td>42</td>
</tr>
<tr>
<td>Toasted soybeans</td>
<td>48</td>
<td>48</td>
</tr>
<tr>
<td>Solvent-extracted soybean meal</td>
<td>97</td>
<td>97</td>
</tr>
<tr>
<td>Sunflower meal</td>
<td>150</td>
<td>150</td>
</tr>
<tr>
<td>Rapeseed meal</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>Meat meal tankage</td>
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<td>40</td>
</tr>
<tr>
<td>Alfalfa meal</td>
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<td>2</td>
</tr>
<tr>
<td>Tapioca</td>
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<td>258</td>
</tr>
<tr>
<td>Cane molasses</td>
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</tr>
<tr>
<td>Soybean oil</td>
<td>10</td>
<td>74</td>
</tr>
<tr>
<td>Monocalcium phosphate</td>
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<td>6</td>
</tr>
<tr>
<td>Chalk</td>
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<td>7</td>
</tr>
<tr>
<td>Salt</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>DL-Lysine</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>DL-Methionine</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Vitamin-mineral premix</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Maize starch</td>
<td>200</td>
<td>864</td>
</tr>
<tr>
<td>Total, g&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1,000</td>
<td></td>
</tr>
<tr>
<td>Nutrient content</td>
<td></td>
<td></td>
</tr>
<tr>
<td>As analyzed — g&lt;sub&gt;1,000&lt;/sub&gt; g —</td>
<td>— g&lt;sub&gt;864&lt;/sub&gt; g —</td>
<td></td>
</tr>
<tr>
<td>Crude Protein</td>
<td>171.9</td>
<td>171.1</td>
</tr>
<tr>
<td>Crude Fat</td>
<td>36.5</td>
<td>100.2</td>
</tr>
<tr>
<td>Starch</td>
<td>403.2</td>
<td>228.8</td>
</tr>
<tr>
<td>As calculated</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Net energy for swine&lt;sup&gt;b&lt;/sup&gt;</td>
<td>9.179</td>
<td>9.171</td>
</tr>
<tr>
<td>MJ NE</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Digestible lysine&lt;sup&gt;c&lt;/sup&gt;</td>
<td>6.9</td>
<td>6.9</td>
</tr>
</tbody>
</table>

<sup>a</sup>1,000 g of the Starch diet and 864 g of the Fat diet are isocaloric.
<sup>b</sup>According to the Rostock net energy system: Centraal Veevoederbureau (CVB, 1988).
<sup>c</sup>Fecal digestibility (CVB, 1988).

The sows were fed 21.3 MJ of NE daily in two equal portions at 0800 and 2000. Water was available for ad libitum consumption. During the first 3-wk period, two gilts were assigned to the Starch diet and three to the Fat diet. During the subsequent period, gilts were assigned to the other diet. At the start and end of the experiment, gilts were weighed.

At d 14 and 21 of each 3-wk period, blood samples were taken at −24, −12, 0, 12, 24, 36, 60, 84, 120, 156, 228, 300, and 372 min relative to the 0800 feeding. Blood samples were collected in ice-cooled polypropylene tubes containing 100 μL of EDTA-solution (144 mg/mL of saline; Titriplex® II, Merck Nederland BV, The Netherlands), placed on ice, and then centrifuged at 2,000 × g for 10 min at 4°C. Plasma was collected and stored at −20°C until hormone analyses were performed.

Experiment 2

Eighteen commercial crossbred sows (Great Yorkshire × Dutch Landrace) of second to sixth parity were on approximately d 90 of their next pregnancy at arrival on the experimental farm. Sows were fitted surgically with a jugular vein catheter (Soede et al., 1994), placed in farrowing crates, and tethered by a neck collar. Until farrowing, all sows were fed the same commercial diet to receive 28.14 MJ of NE/d; the daily diet was given in two equal portions at 0800 and 2000. At birth, litter size was standardized to nine pigs. The sows received one of the two diets, as described in Exp. 1, at 0800 and 2000 daily from farrowing onward. Sows were allotted to treatments based on parity. At d 1 of lactation the total amount fed was 18.3 MJ of NE. Subsequently, the total amount fed was increased daily by increments of 9.2 MJ of NE/d to 45.7 MJ of NE on d 5 and was kept at this level until d 21 of lactation. The pigs were weaned at 0800 on d 21 ± 1 of lactation. After the lactation period, the sows were relocated to individual crates and fitted with a neck collar. No feed was given on the day of weaning. Between weaning and the day of ovulation, 27.4 MJ of NE/d was given. From the day of ovulation to slaughter on d 35 after AI, 18.3 MJ of NE/d was given. During the experimental period just before the next feeding, feed residues from the last feeding were weighed. Sows were checked for estrus at 4-h intervals from 48 h after weaning onward and inseminated artificially with diluted, chilled semen (3 × 10⁹ sperm cells). A boar was used to detect estrus. Time of onset of estrus was defined as 2 h before the first time a sow showed a standing response to a back-pressure test in the presence of a boar. The time of the end of estrus was defined as 2 h after the last time the sow showed a standing response to the back pressure test.

Ovulation was assessed by transrectal ultrasonography at 4-h intervals beginning 18 h after onset of estrus (Soede et al., 1994). The time of ovulation was defined as the first time that follicle count was zero minus 2 h. When follicle count was not zero, but consistently less than before, ovulation was assumed to have just started (t = 0). Ovulation was confirmed by one additional scan 4 h later.

Sows that did not return to estrus after AI were slaughtered on d 35 after ovulation. The reproductive tract was removed, and the numbers of corpora lutea and normal and degenerating embryos were counted. Embryonal survival was calculated as the percentage of corpora lutea represented by normal embryos.

Weight and backfat thickness (determined ultrasonically, similar to Verstegen et al., 1979) of the sows were measured within 24 h after farrowing and at weaning. Blood samples were taken from the sows every 12 min from 0830 until 2030 on d 109 ± 1 of pregnancy, on d 7 ± 1, 14 ± 1, and 21 ± 1 of lactation, and on the day of weaning (d 22 ± 1). From 48 h after weaning, blood samples were collected every 4 h, at 0730, 1130, 1530, 1930, 2330, and 0330. From 24 h after detected ovulation, blood samples were drawn at 12-h intervals, at 0800 and 2000, until 10 d after ovulation. Blood sampling procedures and sample handling were similar to those in Exp. 1.
Hormone Assays

Insulin. Insulin was quantified in all plasma samples from Exp. 1 and in samples taken at -24, -12, 0, 12, 24, 36, 60, 84, 120, 156, 228, 300, and 372 min relative to the 0800 feeding on d 109 of pregnancy, on d 7, 14, and 21 of lactation, and on the day of weaning from Exp. 2. A commercial RIA kit (Coat-a-Count Insulin; DPC, Los Angeles, CA) was used. Maximum binding for [125I] insulin was 62%. The sensitivity was 9.9 μU/mL at 80% binding. The interassay CV was 5.9%, and the intraassay CV was 5.6%.

Luteinizing Hormone. Plasma concentrations of LH were measured with a double-antibody RIA (Niswender et al., 1970). Porcine LH (pLH iodination grade; batch 004/3; potency .85× NIH LH-S19; UCB, Brussels, Belgium) was used as standard and for radioiodination (specific activity, 35 μCi/μg). Anti-porcine LH (batch 004 from UCB) was used in a 1:384,000 final dilution; this gave an initial binding of the labeled hormone of approximately 40%. Sac-cel was used as second antibody (donkey antirabbit IgG; Wellcome Reagents, Beckenham, U.K.). The sensitivity of the assay was .5 ng/mL at the 80% B/Bo concentration. The minimal detectable dose at the 90% B/Bo concentration was .13 ng/mL. The interassay CV was 13.8%, and the intraassay CV was 10.6%.

Progesterone. Plasma concentrations of progesterone were measured with a RIA (Helmond et al., 1986). A specific rabbit antiserum raised against a 4-pregnene-6β,8-ol-3,20-dione-hemisuccinate-BSA-conjugate was used in a final dilution of 1:75,000. Progesterone (code P-9776; Sigma Chemical, St. Louis, MO) was used as standard and [1,2,6,7-3H]progesterone as the tracer (code NET 381; specific activity 93.5 Ci/mmol; NEN Chemicals, ’s Hertogenbosch, The Netherlands). The sensitivity of the assay was .2 ng/mL at the 80% B/Bo concentration. The minimum detectable dose at the 90% B/Bo concentration was .15 ng/mL. The interassay CV was 14%, and the intraassay CV was 7.6%. The main crossreacting steroids were pregnenolone (98%), corticosterone (2.7%), 17α-hydroxyprogesterone (1.5%), and 20α-hydroxy-4-pregnen-3-one, cortisol, estrone, estradiol-17β, estradiol-17α, estradiol, androstenedione, dehydroandrosterone, and testosterone (all < .2%).

Estradiol. Estradiol-17β was measured, after extraction and column chromatography, with a RIA, using a modification of the method described by Helmond et al. (1980). Plasma samples of 100 μL were diluted in 900 μL of phosphate buffer containing .1% BSA and mixed with 1 mL of acetate buffer (.15 M, pH 4.1). The samples were added to SPE C18 columns (Baker, Deventer, The Netherlands) and extracted with methanol; 500 cpm of [2,4,6,7-3H]estradiol (NEN Chemicals) was added to each column to estimate procedural losses. The methanol in the extracts was evaporated under a stream of nitrogen, and the residues were dissolved in 250 μL of toluene:methanol (9:1, vol/vol) and applied to columns (8.0 cm × .7 cm) packed with Sephadex LH-20 (Pharmacia, Uppsalan, Sweden; eluting solvent, toluene:methanol 9:1, vol/vol). The first 5-mL fraction was discarded, and estradiol was eluted in a final 3-mL fraction. The estradiol fraction was dried under a stream of nitrogen and dissolved in 500 μL of ethanol. An aliquot of 150 μL was taken to determine the recovery of [3H]estradiol (62%). Estradiol concentrations were measured in duplicate (2 aliquots of 150 μL). The RIA used a specific rabbit antiserum against 6-keto-estrone 6-CMO-BSA. The main crossreacting steroids were estrone (1.49%) and estradiol (.21%). The antiserum was used in a final dilution of 1:125,000. Estradiol-17β (code E1132; Sigma) was used as standard and [2,4,6,7-3H]estradiol (code NET 317; specific activity 95.4 Ci/mmol, NEN Chemicals) as tracer. The sensitivity of the assay was 20 pg/mL at the 80% B/Bo concentration. The minimal detectable dose at the 90% B/Bo concentration was 8 pg/mL. The interassay CV was 17.4%, and the intraassay cv was 12.4%. The amount of estradiol was expressed in picograms/milliliter after correction for procedural losses.

Statistical Analyses

The GLM procedure of SAS (1990) was used to analyze the data.

Insulin. Basal insulin concentrations were calculated per sow per day as the mean insulin value 24 and 12 min before feeding. The area under the curve (insulin concentration × time) during the sampling period was calculated as the area corrected for preprandial insulin concentrations. In Exp. 1, data for basal insulin concentration during the sampling period and area under the insulin curve (total area and area under the curve from 0 to 36 min after feeding) per sow per week were analyzed using a model that accounted for the variance associated with sow, diet, and period. In Exp. 2, basal insulin concentration and area under the curve per sampling period per sow were analyzed using a model that included diet and the covariate, percentage of maximum energy intake at the 0800 feeding during the sampling period. In Exp. 2, to describe differences in insulin between treatments within a sampling period, plasma insulin concentrations per sow per sampling time (ranging from 24 min before the 0800 feeding to 372 min after feeding) were analyzed separately for each sampling day (d 109 of pregnancy, d 7, 14, and 21 of lactation, and day of weaning) using split-plot-time ANOVA that included diet, sow nested within diet, the diet×time interaction, and time.

Luteinizing Hormone. The 12-min samples collected during the 12-h sampling periods on d 109 of pregnancy, d 7, 14, and 21 of lactation, and the day of weaning were analyzed for effects of treatment on mean LH concentrations and number of LH peaks using Cluster Analyses (Urban et al., 1989), in which
an LH peak was defined when a minimum of three consecutive LH values were greater ($P < .05$) than the mean LH value. The CV was set at 10% during lactation and 5% for the day of weaning. Data on the number of LH peaks per 12-h period and mean LH production per 12-h period per sow were analyzed separately for each sampling period using a model that included diet and the covariate, percentage of maximum feed intake during lactation. To evaluate the effect of sampling period on mean LH release and number of LH peaks, a model was used that included sow and sampling period as sources of variation.

Blood samples taken every 4 h, from 48 h after weaning to 24 h after ovulation, were used to measure the preovulatory LH surge. The onset and end of the preovulatory LH surge were determined as the first and last time at which the LH concentration was greater than the mean basal LH concentration plus its standard deviation. Basal LH concentration is the mean LH concentration in blood samples taken at 4-h intervals between 48 h after weaning and the onset of the LH surge. The LH peak values were defined as the maximum LH value during the LH surge. Peak values were analyzed with a model that included diet.

Progestosterone and Estradiol. Blood samples taken every 4 h, from 48 h after weaning to 24 h after ovulation, were used for analyses of estradiol data. The time after which estradiol concentrations show a consistent decrease was defined as the time of peak estradiol; the concentration of estradiol at that time was defined as the peak concentration of estradiol. Peak concentration of estradiol were evaluated with a model that included diet. Data were plotted per sow relative to the LH peak and per 4-h interval before or after the LH peak, estradiol values were evaluated with a model that included diet. Blood samples taken after the LH peak were used to evaluate progesterone. Data were plotted per sow relative to the LH peak and evaluated per sampling time with a model that included diet.

Other Variables. Body and backfat loss during lactation and the interval from weaning to ovulation (Exp. 2) were evaluated with a model that included diet and the covariate, mean feed intake (as a percentage of the daily allowance).

The effect of diet on mean feed intake, time of onset of estrus, ovulation, LH peak, estradiol peak, and progesterone increase after weaning, duration of estrus, ovulation rate, and embryonal mortality were evaluated with one-way ANOVA. The data are expressed as least squares means and standard error.

Results

Experiment 1

Weight Gain. Gilts weighed 197 ± 6 kg at the start of the experiment and 203 ± 5 kg at the end of the experiment 6 wk later.

Insulin. Insulin concentrations after feeding for the two diets are shown in Figure 1. Plasma insulin concentration increased sooner when gilts were fed the Starch diet than when they were fed the Fat diet; this caused the insulin response to differ ($P < .05$) 12 min after feeding. Basal insulin concentrations were comparable (Fat vs Starch, 29.6 ± 5.6 vs 28.0 ± 3.6 μIU/mL), and area under the entire insulin curve tended ($P = .15$) to be greater for the Starch diet (15,163 ± 2,262 vs 8,562 ± 3,538 μIU/6.6 h). The area under the insulin curve from 0 to 36 min after feeding was greater ($P < .01$) for the Starch diet than for the Fat diet (2,197 ± 2.64 vs -64 ± 413 μIU/h).

Experiment 2

Feed Intake, Body Weight, and Backfat Loss During Lactation. Weight of the sows at 24 h after farrowing (Fat vs Starch, 216 ± 9 vs 218 ± 9 kg) and backfat thickness (19 ± 1 vs 19 ± 2 mm) were similar for the treatment groups. During lactation, there were no significant differences between treatment groups in mean feed intake, expressed as percentages of daily allowance (Fat vs Starch, 89.9 ± 5.5 vs 87.8 ± 4.0%), weight loss (27.4 ± 2.0 vs 28.0 ± 3.0 kg), or backfat loss (3.9 ± 0.3 vs 3.8 ± 0.5 mm).

Plasma Insulin During Pregnancy and Lactation and at Weaning. Figure 2 shows the insulin response curves for the different periods. Basal insulin concentrations and area under the curve did not differ between diets in any of the periods.

Luteinizing Hormone Concentrations on Day 109 of Pregnancy, During Lactation, and at Weaning. One sow on the Starch diet seemed to have ovulated during lactation; she had corpora lutea on d 2 after weaning and returned to estrus 19 d after weaning. The data for this sow were excluded from the analyses. Plasma LH concentrations are shown in Table 2 for both diets for d 109 of pregnancy, d 7, 14, and 21 of lactation,
Figure 2. Least squares means for plasma insulin concentrations for the Starch (---) and Fat (----) dietary groups after feeding in Exp. 2: (A) d 109 of pregnancy, (B) d 7 of lactation, (C) d 14 of lactation, (D) d 21 of lactation.

and at weaning. On d 7 of lactation the number of LH pulses was greater (P < .01; 2.01 ± .35 vs .55 ± .33) for sows on the Starch diet. The mean LH release in all periods and the number of LH pulses during pregnancy, at weaning, and on d 14 and 21 of lactation did not differ between the diets. The LH pulse pattern and mean concentration were influenced by sampling day. On d 109 of pregnancy, 2.41 ± .37 LH pulses per 12 h were detected, and mean LH concentration was .85 ± .03 ng/mL. On d 7 and 14 of lactation, the number of LH pulses decreased to approximately 1.23 ± .37 and 1.12 ± .37 pulses per 12 h, respectively. Mean LH release was less (P < .05) on d 7 (.68 ± .03 ng/mL) and 14 (.60 ± .03 ng/mL) of lactation than on d 109 of pregnancy. On d 21 of lactation, the number of LH pulses increased slightly, but significantly, to 1.71 ± .37 pulses per 12 h, and mean LH release (.63 ± .03) was comparable to that on d 7 and 14 of lactation. At weaning, typical high-frequency, low-amplitude pulses were detected. A mean of 9.94 ± .37 LH peaks were detected during a 12-h period. Also, mean LH release (.84 ± .08 ng/mL) was increased (P < .05) compared with lactation values.

Periestrus Reproduction Characteristics. One sow in the Starch group lost her blood sampling catheter at 100 h after weaning. The remaining seven sows in the Starch group and nine sows in the Fat group were used for further analyses on periestrus reproduction characteristics.

No effect of diet was detected for onset of estrus after weaning (Starch vs Fat, 116 ± 8 vs 119 ± 9 h), duration of estrus (58 ± 5 vs 50 ± 6 h), or the time of ovulation after weaning (157 ± 8 vs 154 ± 11 h).

In Figure 3A, the mean preovulatory LH surge is shown for the two diets. The LH peak was detected at
127 ± 9 and 124 ± 12 h after weaning for the Starch and Fat groups, respectively. Sows on the Starch diet had a greater (P < .01; 6.97 ± 2.61 ng) LH surge than the sows on the Fat diet (4.64 ± 1.6 ng).

In Figure 3B, concentrations of estradiol relative to the time of the LH peak are shown for the two diets. Peak estradiol concentrations were detected at 11 ± 1 and 10 ± 2 h before the LH peak for the Starch and Fat diets, respectively. The mean peak was 19.4 ± 2.1 pg/mL for the Starch diet and 33.2 ± 7.0 pg/mL for the Fat diet, but the differences were not significant (P > .05).

In Figure 3C, progesterone concentrations are shown relative to the time of the LH peak. Progesterone was 1 ng/mL greater than basal from 43 h after the LH surge for both diets (Starch SE = 1.5; Fat SE = 1.2). From 108 until 256 h after peak LH, progesterone concentrations in sows on the Starch diet were greater (P < .01) than those for sows on the Fat diet.

Ovary Rate and Embryonal Survival. None of the sows had returned to estrus by d 21 after AI. In the Starch group, one sow aborted on d 28, and the uterus of another sow contained three degenerating embryos. In the remaining five sows, the number of corpora lutea was 20.3 ± .9, and embryonal survival was 68.7 ± 7.9%. In the Fat group, one sow aborted on d 34, and another sow had inactive ovaries and no embryos. In the remaining seven sows, the number of corpora lutea was 19.4 ± .7, and embryonal survival was 69.7 ± 5.3%. Numbers of corpora lutea and embryonal survival did not differ among sows fed different diets.

**Discussion**

**Dietary-Induced Insulin Production**

The aim of the experiments was to investigate the effect of dietary energy source on insulin production (Exp. 1) and reproductive hormones and reproductive characteristics of multiparous sows (Exp. 2). In a previous experiment with Meishan gilts (Kemp et al., 1993), insulin production could be stimulated by feeding dextrose as a dietary energy source to replace soybean oil. For the present experiments, gilts and sows were fed a basic diet to which an isocaloric amount of either soybean oil (Fat diet) or cornstarch (Starch diet) was added. To test differences in insulin response to these diets, a Latin-square design was chosen for Exp. 1 because insulin response to a diet is quite variable among animals. The first experiment confirmed a large variation in insulin response between animals. However, on the Starch diet a greater insulin response was detected immediately after feeding. The second experiment indicated that the responses in lactating sows are less clear. Only on d 7 of lactation did insulin concentrations after feeding tend to be greater in the Starch group. A negative energy balance results in suppressed insulin production, as was shown in lactating sows by Mullan and Close (1991). One might speculate that a negative energy balance due to lactation suppresses the effects of diet on insulin production.

**Luteinizing Hormone Production During Lactation and at the Time of Ovulation**

The LH concentration and pulse frequency were gradually restored during lactation in primiparous
sows (Tokach et al., 1992). In that study, sows with a prolonged interval between weaning and estrus (>15 d) had decreased mean plasma LH concentrations on d 14, 21, and 28 of lactation. In our study with multiparous sows, all sows ovulated within 190 h (8 d) after weaning, indicating that there were no prolonged intervals. In multiparous sows, prolonged intervals are not common, as they are in primiparous sows (for review, see Hughes, 1989). In our study, there were no effects of diet on LH release on d 14 and 21 of lactation or at weaning, and diet did not affect the interval from weaning to ovulation. However, on d 7 of lactation, LH pulsatility seemed to be stimulated more by the Starch diet. It remains to be determined whether a Starch diet would be more effective in restoring LH pulsatility in primiparous sows and effectively preventing prolonged intervals from weaning to ovulation.

Ovulation Rate, Luteinizing Hormone Surge Characteristics, and Progesterone Increases

In our experiment, sows on both diets had approximately 20 corpora lutea at slaughter. Cox et al. (1987) and Matamoros et al. (1991) reported positive effects of insulin administration on ovulation rate, but only in gilts. Furthermore, nutritional “flushing” during the preovulatory period to increase ovulation rate seems to be effective only in gilts (see Hughes, 1989). Therefore, the absence of a stimulatory effect of the insulin-stimulating diet (Starch) on ovulation rate may be explained by the fact that multiparous sows were used in our experiments and by the relatively small number of sows used per treatment group.

In this experiment, the Starch diet caused a 52% greater LH surge and greater progesterone concentrations after the LH surge than those elicited by the Fat diet. Kirkwood et al. (1987) found smaller LH peaks, reduced progesterone concentrations, and a greater incidence of embryonal mortality in second-parity sows fed restricted diets during lactation. They reported that GnRH injection at the estrus after weaning increased progesterone production after the LH surge. Einarsson and Rojkittikhun (1993) suggested that a suboptimal LH surge results in inadequate luteinization of corpora lutea and results in reduced plasma progesterone and increased embryonal mortality. Ashworth (1991) reported a positive effect of postmaturing progesterone supplementation on embryonal survival in gilts fed enhanced energy diets prematuring. In the present study, the increased plasma progesterone concentrations induced by treatment were not related to embryonal mortality; however, the number of sows was small. The absence of effects of treatment on ovulation rate or embryonal mortality could also indicate that the changes in endocrinology due to feeding a Starch diet were not sufficient to influence physiological aspects associated with reproductive events after weaning.

This research indicates that dietary energy source can influence insulin production in gilts, and it can stimulate LH release and progesterone production in sows. Literature on the addition of fat to sow diets (see Introduction) claims positive effects on milk yield and fat content of the milk. Increased dietary fat may even improve pig survival after parturition (Pet-tigrew, 1981). Because of the reduced metabolic rate of sows fed a fat-rich diet (Babinszki, 1992), energy intake at high ambient temperature may be improved by feeding fat, and this may improve reproductive performance. However, results on improving energy intake by addition of fat remain contradictory. The results of the present experiments indicated beneficial effects of the Starch diet on reproductive hormones. Effects might have been clearer if primiparous sows had been used. In this experiment, we chose to keep sows on the same experimental diets from farrowing onward. Therefore, it is unclear whether the effects on reproductive hormones during the periestrus period are a result of dietary difference during lactation or during the periestrus period itself. Ramirez et al. (1994) reported an enhancement of litter size in sows by insulin administration before breeding. This may indicate a direct effect of insulin stimulation on the LH surge and progesterone. More research is therefore, needed to further substantiate the discussion on starch or fat as an energy source for lactating sows.
Implications

The experiments performed indicate a positive effect of starch in the diet (vs fat) on LH release and progesterone production after ovulation in multiparous sows. This may indicate that starch-rich diets during lactation could be more beneficial for minimizing the weaning to estrus interval and for postweaning reproductive characteristics than are fat-rich diets.

Literature Cited


