**Project: Ketosis in Nursing Sows**  
**Team: Paul Luimes, Ph.D., Greg Simpson, M.Sc., and Greg Wideman, DVM.**

**Introduction**
Off-feed events are detrimental to a sow during lactation. They not only affect her litter, but also have a negative effect on subsequent reproductive performance. The relationship between voluntary feed intake during lactation on piglet performance and subsequent reproductive performance is well documented (Revell et al., 1998a,b; Koketsu et al. 1996c). It has been well established that overfeeding during gestation results in fatter sows which leads to lower voluntary feed intake in sows (Trottier and Johnston, 2001). Other factors, such as environmental temperature, humidity (Trottier and Johnston, 2001) and other stresses can “tip” the scale and cause a sow to go off feed. The cause and effect of off-feed events in sows is reminiscent of ketoacidosis in dairy cattle.

New technology, available for human diabetics, can measure blood β-hydroxybutyrate (BHBA) with a handheld monitor. This type of monitor has also shown considerable promise in research into bovine ketosis (Ken Leslie, personal communication). The unit is similar to the blood glucose testers many diabetics are familiar with except that it measures β-hydroxybutyrate. Unpublished results show the unit provides accurate blood BHBA measurements for dairy cattle (Leslie, personal communication). It should be possible to measure BHBA in other body fluids using this monitor (ie. milk, saliva, etc.). However, testing on milk from dairy cattle provided inconsistent results (Leslie, personal communication). Testing of saliva in swine may be possible but in cattle the effect of ruminal fermentation would confound results.

**Literature Review**
Ketosis is the normal process by which ketones are formed as a result of fatty acid degradation in the liver. When the body is in negative energy balance, because of specific requirement of many tissues for glucose, the liver switches its energy cycling mechanism to one of glucose synthesis (Table 1). In so doing, fatty acids can no longer enter the energy cycle and must be converted to ketones. Glucose is predominantly made in the liver so other tissues can still use the energy cycle to consume glucose and ketones. However, if liver ketone synthesis exceeds the body’s
ability to catabolize them, they will accumulate, causing a state of ketoacidosis (the lowering of blood pH). If the net rate of ketone accumulation is not brought under control, the blood pH can drop severely causing death. Compounding the problem, an animal suffering from ketoacidosis usually decreases feed intake, causing a more negative energy balance and making the situation worse. The animal will also attempt to decrease energy utilization to attempt to bring itself back into a manageable energy balance. For lactating animals this means a decrease in milk production and a negative impact on any suckling young.

Ketoacidosis is a well-known and common metabolic disorder in dairy cattle, there has been a major effort into the investigation of this disease in dairy cattle. There is a scarcity of data on this disorder in swine, specifically sows. This is despite the fact that a lactating sow secretes equal amounts of milk energy, on a metabolic body weight basis, as a dairy cow (Table 2).

<table>
<thead>
<tr>
<th>Table 2. Comparison of milk energy output by sows and cows.</th>
</tr>
</thead>
<tbody>
<tr>
<td>body weight (kg)</td>
</tr>
<tr>
<td>metabolic body weight (kg(^{0.75}))</td>
</tr>
<tr>
<td>milk production (kg/d) (^a)</td>
</tr>
<tr>
<td>fat, protein &amp; lactose (%)</td>
</tr>
<tr>
<td>energy in milk (Mcal/kg(^{0.75}))/d)</td>
</tr>
</tbody>
</table>

\(^a\)Productions considering following assumptions: sow with 10 piglets each gaining 250 g/d; cow producing 11,000 kg per lactation.

There have been a few studies involving lactating sows that have investigated the relationship between the ketone bodies and metabolic status. Kveragas et al. (1986) reported serum bHBA concentrations at days -22, -19, -4 and 5 days relative to parturition in sows. With only two measurements taken near parturition, it is difficult to gain accurate knowledge of ketosis during this time. Extrapolating from figure 2 from Kveragas et al. (1986), serum bHBA concentration increased to approximately 220 µmol/L from 175 µmol/L in sows five days post-farrowing in comparison to sows 4 days pre-farrowing (Kveragas et al., 1986). While there is little data on ketoacidosis in sows, an additional issue may be that a sow cannot use ketones in the mammary
gland as well as a ruminant, thereby potentially having a lowered ability to decrease blood ketone levels (Spincer et al., 1969; Jones and Parker, 1978).

Alsop et al. (1994) reported a case of ketosis in a sow around farrowing. They noted the over-condition of the sow and increased stress during late gestation may have had an impact on the sow’s metabolic condition (Alsop et al., 1994). Upon necropsy they found classic symptoms of ketoacidosis such as liver damage, including fatty liver (Alsop et al., 1994).

Ultimately, it would be valuable to understand the degree of ketosis sows are subject to during lactation and to develop methods to alleviate this metabolic disease through interventions such as glucose supplementation in water, etc.

The purpose of this trial was to determine the accuracy (how close values are to the laboratory results) and precision (how much variation between the values) of the Precision Xtra® blood BHBA analyzer monitor. As it will be difficult to predict which sows are likely to be in a healthy, subclinical or clinical situation of ketosis, we attempted to develop a scenario that might influence metabolic status by making sows work at three different levels of production (7, 10 and 13 piglets). Even with differing production demands it was possible that none of the sows would experience clinical or sub-clinical levels of ketosis. We hoped that by increasing production levels we would be able to demonstrate a range of ketone levels in the blood, thereby giving us a range to test the accuracy and precision of the monitor.

Objectives
1. Can the Precision Xtra® monitor accurately predict BHBA levels in lactating sows from blood, milk or saliva samples?
2. Establish a time course for BHBA over lactation at days -5, 6 and 8 relative to farrowing.

Materials and Methods
**Layout & Treatments.** Sixty-three Yorkshire sows were used for this experiment. Each sow was randomly assigned to one of 3 treatments over 3 consecutive parities with treatment groups balanced for parity. There were three sow groups used such that there were nine periods (3 parities x 3 sow groups). As some sows were culled or were not bred in time to continue in the experiment a total of 122 sow periods were completed. The three treatments used were based on three litter sizes (7, 10 and 13 piglets) in order to have different levels of milk production, or metabolic stress, and were established by cross-fostering.

**Animals & Diets.** Gestating sows were fed approximately 2 kg of a gestating sow ration daily from breeding until day 110 (Table 3). Sows were moved to farrowing crates at day 110 of gestation. Upon entry into the farrowing facilities, sows were fed a lactating ration at restricted levels (1.8 kg/d) until farrowing when they were fed on an increasing scale up to *ad libitum* (Table3). In period 2, sows were fed *ad libitum* from farrowing day onward. Daily feed intakes (kg feed offered – kg refusals) were recorded. Cross-fostering was done after initial colostrum intake was completed (within 24 hr) in order to obtain the litter sizes required. All procedures conducted on animals were authorized by the University of Guelph Animal Care committee.

**Table 3. Diets offered sows.**

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>Dry Sows&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Nursing Sows&lt;sup&gt;b&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn</td>
<td>77.6%</td>
<td>69.6%</td>
</tr>
<tr>
<td>Soybean meal</td>
<td>14.6%</td>
<td>22.3%</td>
</tr>
<tr>
<td>Wheat bran</td>
<td>3.7%</td>
<td>3.7%</td>
</tr>
<tr>
<td>Animal/vegetable fat blend</td>
<td>1.0%</td>
<td>1.0%</td>
</tr>
<tr>
<td>Vitamin/mineral premix</td>
<td>3.1%</td>
<td>3.5%</td>
</tr>
</tbody>
</table>

<sup>a</sup>Fed to sows to day 110 of gestation.

<sup>b</sup>Fed to sows from day 110 of gestation through lactation.

**Experimental procedures.** In order to validate the Precision Xtra® monitor for use with swine, two 5cc samples of blood were taken from each sow over each parity for a total of 242 samples (two samples were missed from the 122 sow periods). Elevations in BHBA were expected either with increasing parity, prior to parturition (as in sheep) or shortly after parturition during early
lactation (as in cattle). Thus a minimum of 2 samples per sow across multiple parities was desired. A simple Pearson Correlation coefficient was used to calculate the correlation between the Precision Xtra® monitor and the laboratory serum BHBA. The sensitivity and specificity of the Precision Xtra® monitor was compared to laboratory serum BHBA with an appropriate threshold separating normal BHBA.

Sampling dates were established as follows: When the median sow in a group reached day 109 of gestation (approximately day -5 from farrowing) all the sows in that group were blood sampled. This provided a range of days around which ketosis may be significant during late gestation. A second sample was taken on half of the sows in the group on day 6 of lactation for the median sow. The other half of the sows had their second blood sample when the median sow reached day 8 of lactation. The reason for two days of sampling during the lactation period was to spread the demand of sampling on staff resources and stress on the sows out, plus to get a wider range of samples around the time when research shows sows are likely to go off feed and more ketosis may be expected.

Additionally, if a value was observed from the blood sample saliva was also tested using the Precision Xtra® monitor. On group one (18 sows), two strips were used for each sample (in order to measure precision) but for each other block only one strip was used for each sample. Blood samples were allowed to clot at room temperature for 30 minutes and then centrifuged and serum was separated and frozen for further analysis. Serum samples were evaluated for blood concentrations of BHBA by the AHL. In addition, sow weights were measured on days -4 and 28 and back fat thickness (by ultrasound) was recorded on days -4, 0, 7, 14, 21 and 28. Piglet performance such as pre-weaned mortality (daily) and weights (weekly) were recorded as well.

Analyses. Blood and salivary β-hydroxybutyrate analyses from the Precision Xtra® monitor were recorded. Serum samples were sent for analysis to the Animal Health Laboratory, Laboratory Services (AHL), University of Guelph to be analyzed on the Cobas 6000 c501 for β-hydroxybutyrate. Validation of the Precision Xtra® monitor was conducted and differences between treatments were analyzed using SAS®. Pearson correlations between the Precision Xtra® data and the AHL values were calculated. Intra-class correlation coefficients were
measured on the repeated Precision Xtra® samples as an indication of precision. Potential associations between back fat thickness changes, piglets per sow and BHBA were investigated.

**Results and Discussion**

There was a feed intake effect due to treatment where the sows with 7 piglets consumed less feed than the sows with 10 or 13 piglets (P < 0.05, see Figure 1). We had very few cases of sows going off feed on this trial. Of the total of 4155 sow days from the trial, there were only 25 sow days where a sow did not consume any feed. Of those 25 sow days, there were only 2 sows that had more than one day of consuming no feed.

Figure 1. Feed intake from day -8 to 28 relative to farrowing for sows with either 7, 10 or 13 piglets per litter, plus two sows that exhibited off-feed events.

We observed a total of six incidences where elevated blood BHBA was detected with the handheld monitor (which has a minimum detection of 100 μmol/L). Of those, two samples were detected higher than 1,000 μmol/L (1,200 and 3,000 μmol/L). BHBA was not detected in the saliva on any sow. The first higher level of serum BHBA was related to one of the sows that
consistently showed poor feed intake. If any BHBA was detected, further daily measurements were taken until the levels dropped below the level of detection. In one incidence of a significant reduction in feed intake (6 days), the BHBA levels remained elevated for 5 days. Of the two regularly scheduled samples that were elevated, the sample that was measured at 3,000 μmol/L using the monitor was measured at 11 μmol/L from the laboratory and the sample that was measured at 1,200 μmol/L using the monitor was measured at 1,161 μmol/L from the laboratory. In short, the frequency of high BHBA was exceptionally low, as was the incidences of large reductions in feed intake.

The average serum BHBA level for this trial was 29 +/- 10 μmol/L and 27 +/- 10 μmol/L for the pre-farrowing and post-farrowing periods, respectively. The BHBA levels recorded during this trial were considerably lower than the levels seen by Kveragas et al. (1986), where they detected levels of 175 μmol/L and 220 μmol/L for the pre-farrowing and post-farrowing periods, respectively. It is not clear what may have caused our data to be much lower. Kveragas et al. (1986) reported that their dry sow diet supplied 7,000 kcal ME/d compared to approximately 6000 kcal ME/d in our trial. They did not report the energy supply for the nursing diet (Kveragas et al. 1986), but ours was 19,800 kcal ME/d. Two possibilities that may address the differences are that the project by Kveragas et al. (1986) took place in a warmer climate (Georgia, U.S.A.) vs. our project here in Ontario and the other is that their project was more intensive (injections, sampling, etc.) both of which may have led to more stress for the sows.

Blood samples sent for laboratory analysis spanned most days between day -11 before farrowing to day 12 after farrowing. For any day that was represented by at least 10 sows there was at least one sow that had a reading of 0 μmol/L. Serum BHBA levels were affected by litter size and day relative to farrowing (P < 0.05), but when multiple comparison tests were completed, it was clear the only differences were for two days, both because of single high samples (Figure 2). As shown in Figure 2, average BHBA levels, were slightly elevated from days -11 to -5 and days 5 to 9 from farrowing. These elevated averages, however, are mostly due to individual cases of elevated BHBA. Using the laboratory analysis, there were seven cases of blood BHBA being greater than 100 μmol/L, at which the monitor should have been able to detect the level. Of the samples were taken around parturition, the monitor detected 4 increased levels of BHBA. As a
result there was no correlation between the laboratory and handheld monitor with these results ($R^2 = 0.02$, $P = 0.90$).

Figure 2. Serum BHBA levels by day for the average, lowest and highest sample at each day.

Conclude

With so few incidences of sows going off-feed and/or experiencing ketosis making any conclusions about their relationship is impossible. Certainly 13 piglets per litter did not impose enough of a metabolic stress on the sows to raise serum BHBA levels. In normal situations where a sow is consuming adequate feed, it seems apparent that the levels of BHBA were relatively low during the periparturient time (28 $\mu$mol/L).

Unfortunately we did not see much in the way of off-feed events for the sows on this trial. We could not establish if there is a relationship between a sow not consuming feed and serum BHBA levels. Again, with few incidences, we did see some evidence of sows going off feed and higher BHBA levels on an on-farm investigation that was completed. In terms of a time course for BHBA over the -5 to +8 days around parturition, it appears that on most sows the levels remain low and only a few isolated situations of high BHBA occurred. The normal stress of increased
fetal growth or milk production demands did not affect BHBA levels on most sows such that, except for a few cases, the BHBA levels remained low around the time of parturition.

Based on these data, we would recommend to a producer, nutritionist or veterinarian that, at least in situations where sows are generally consuming well that ketosis is not a major issue for lactating sows. Whether or not ketosis becomes a confounding issue during incidences of significant reductions in feed intake cannot be concluded from this trial. Nevertheless, as similar remedies would be used to alleviate symptoms of ketosis and an incidence of significant reductions in feed intake, it could be generally recommended that practices to encourage feed intake (availability of fresh, palatable feed and water, etc.) should be encouraged.

The data from this trial will be merged with data from some on farm observational studies conducted last summer to investigate correlations between sow and piglet production and performance parameters.

**Cited Literature**


Revell, D.K., Williams, I.H., Mullan, B.P., Ranford, J.L. and Smits, R.J. (1998b) Body composition at farrowing and nutrition during lactation affect the performance of

