In recent decades, genetic advancement has improved milk production and composition but at the cost of fertility and life span.

At the beginning of lactation, cows have high energy requirements due to an increase in milk production. When a cow is unable to consume enough energy, excessive body fat mobilization will occur, resulting in loss of body condition, indicating a negative energy balance. As a result, products of body fat degradation find their way to the udder and the liver. In the udder, these free fatty acids increase the fat-to-protein ratio. In the liver, free fatty acid accumulation alters metabolism, causing increased ketone production and lack of available energy.

Negative energy balance as express by body condition score (BCS) loss is related to reduced serum progesterone concentrations during the breeding period and lower pregnancy rates; in addition, conception rate decreases about 10 percent per 0.5 unit BCS loss from calving to insemination.

The physiological condition of any animal is reflected in the components of its body fluids, such as milk in a dairy cow. Using an optic sensor, we can measure milk composition (fat, protein, lactose and blood) for each cow during every milking. By proper interpretation of daily milk fat and protein percentages, this sensor can identify cows in negative energy balance and ketosis.

The association between negative energy balance, milk’s fat-to-protein ratio and ketosis

A shortage of available energy followed by excessive fat mobilization results in increased fat and decreased protein content in milk. The rise in milkfat stems from the increased amount of free fatty acids in the blood, while decreased milk protein results from a delay in the protein production processes due to a shortage of energy.

Ketosis is another biochemical expression of negative energy balance characterized by an increase of ketones in the blood. This increase is caused by disturbances in the liver’s glucose production process that result from a shortage of volatile fatty acids from the rumen and the accumulation of free fatty acids in the liver cells. The timing and amount of ketones released to body tissues and secreted in urine or milk are influenced by feeding time and ration composition. Therefore, ketones are not necessarily found in the various body fluids of cows at the same time. Consequently, ketone levels are not always compatible with high fat-to-protein ratios, meaning, for example, negative energy balance.

In 1986, researchers suggested that an increased fat-to-protein ratio of milk indicates negative energy balance and ketosis.

Economics and negative energy balance

In a study of 20,816 lactations in 59 Israeli herds calving in 2009 to 2011, rates of diagnosed ketosis and fat-to-protein ratio greater than 1.4 in the first four to 45 days in milk (DIM) were 17.34 percent and 17.52 percent, respectively. The estimates of losses of production in the first 180 days of the lactation and in selected fertility variables are presented in Table 1. The population means of milk, fat and protein (pounds per 180 days) and that of conception rate (CR) to first A.I. service and cows open greater than 150 DIM were 7,706 pounds, 265.8 pounds, 236.4 pounds, 34.6 percent and 36.8 percent, respectively.

In view of the different payment formulas for milk solids, giving different weights to the different milk

### Table 1

<table>
<thead>
<tr>
<th>Diagnosed ketosis</th>
<th>Rate</th>
<th>Milk, lbs</th>
<th>Fat, lbs</th>
<th>Protein, lbs</th>
<th>CR to 1st Al</th>
<th>open&gt;150 DIM</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>17.3%</td>
<td>-58.6</td>
<td>7.15**</td>
<td>-9.96**</td>
<td>-3.8%**</td>
<td>8.6%**</td>
</tr>
<tr>
<td>Fat-to-protein ratio&gt;1.4</td>
<td>17.5%</td>
<td>-253.9**</td>
<td>41.25**</td>
<td>-10.62**</td>
<td>-1.0%</td>
<td>3.0%**</td>
</tr>
</tbody>
</table>

*

**p<0.01; *Least Square Mean (LSMeans) allowed for the effects of herd, parity and month of calving.

**
components, the associations among milk solids and the two measures of negative energy balance (diagnosed ketosis and fat-to-protein ratio) in our sample are of interest (see Figure 1).

It can be concluded from Table 1 and Figure 1 that in our sample herds, cows with a fat-to-protein ratio greater than 1.4 produced less milk and protein but more fat while cows with diagnosed ketosis produced less protein, a little more fat and the same amount of milk than cows without the traits; the higher the contribution of fat to the price formula, cows in negative energy balance will be paid more for their milk; the higher the contribution of protein to the price formula, cows in negative energy balance will be paid less; and fertility of cows with negative energy balance is lower after diagnosed with ketosis.

The cost of a ketosis event is estimated to be $102 to $232.

Researchers in 2013 reported that cows with negative energy balance or subclinical ketosis had about 1,000 pounds less milk estimated in 305 DIM and were 14 to 18 percent less likely to get pregnant. It can be confidently assumed that the ability to diagnose cows with negative energy balance and treat them promptly could be greatly improved by using a continuous monitoring of the fat-to-protein ratio in milk.

The distribution of negative energy balance and ketosis in different lactations and dairy farms

In cows, the timing and duration of the period after calving in which the fat-to-protein ratio is high indicates an increased mobility of body fat. This differs between different lactations, both among herds and within the same herd. To efficiently treat and reduce damages, daily monitoring during the high-risk period (to about 60 DIM) is required.

Figure 2 shows an example of a herd in which cows in the first and third or later lactation are in negative energy balance at the beginning of the lactation (until 30 DIM), while cows in the second lactation are influenced mostly at a later stage (30 to 45 DIM).

Diagnosing and treating ketosis

In diagnosing ketosis on the dairy farm, ketone levels in the blood, milk or urine are normally checked. Ketone tests are advantageous in diagnosing ketosis because they consist of direct measurements of ketone concentrations in body fluids. However, these are discrete measurements conducted at specific times, usually during a veterinarian’s visit. In diagnosing a ketosis event, the day and time of examinations affect test results, as increased ketone concentrations in body fluids depend on their release from the liver.

In a study conducted at a northern Israeli dairy herd, the blood ketone concentrations of 18 cows (five to 45 DIM) were measured three times a day. According to the acceptable threshold for diagnosing ketosis (levels of BHBA higher than 1.4 mmol/L), we diagnosed two cows with ketosis in the morning, while during the afternoon and evening hours, the number of cows with ketosis rose to five and six, respectively (see Figure 3). On the same day, we diagnosed a total of seven ketotic cows. No single

continued on page 50
and diagnosing ketosis and negative energy balance in dairy cows. Can milk tests help diagnose ketosis consistently?

Diagnosis of ketosis according to daily fat-to-protein value monitoring is a challenge because fat-to-protein ratio is a continuous variable in need of a clear threshold for diagnosis. Moreover, reproducibility and repeatability are not constant due to variations in biologic values. Various thresholds of fat-to-protein ratio in milk and BHBA have been suggested for the diagnosis of clinical and subclinical ketosis.

Between 2006 and 2012, we conducted four field studies on different commercial Israeli dairy farms. Diagnosis was based on the fat-to-protein ratio in milk as measured by our milking equipment at every milking. In these studies, cows’ blood ketone levels were examined three to four times a week for periods ranging between one to 10 weeks.

In a preliminary study (2006), we found that an increase in BHBA in blood and that of milk’s fat-to-protein ratio are not completely synchronized. We found that the delay in BHBA increase could be up to three days after the increase in fat-to-protein ratio. To overcome the synchronization problem and the sensitivity/specificity conflict, we introduced “simultaneous testing” in which the gold standard for identification (a serum BHBA greater than 1.4 mmol/L) would be compared with the timing of a fat-to-protein ratio increase. A true-positive was registered if a serum BHBA increase indicated above occurred on the same day of a fat-to-protein increase, one day prior to increase or one day after increase.

The combined model that was developed based on these studies enables the diagnosis of ketotic cows at a respective specificity and sensitivity of 85 percent. As dairy practitioners, we prefer treating as many of the ketotic cows (by the 85 percent sensitivity model) but many herd managers choose treating only the cows that are truly ketotic (by the 85 percent specificity model). In the milking equipment’s software, sensitivity and specificity can be adjusted to a specific farm’s needs.

Along with the models, we developed a special toolbox in our dairy management software. These tools could improve decision-making regarding the treatment and prevention of energy imbalances in the herd. Every day, the system turns out an updated list of potential cows that require treatment according to the dairy’s defined protocol.

Our findings, based on academic research, can be summarized as follows: different herds have different metabolic patterns influenced by feeding and management; ketone levels in different body fluids increase at different times within two days before or after the rise in ketone bodies; there is no definite time for effective ketone measurement during the day; and direct ketone testing is costly, requires manual labor and produces additional stress for postpartum animals.

The advantage of our system is that it combines highly specific and sensitive parameters in relation to ketosis (milk fat-to-protein ratio) together with continuous monitoring capability. This enables ongoing...
The financial impact of minimizing the effects of negative energy balance

The loss of profits caused by negative energy balance stems from three main elements: reduction in milk production, poor fertility performance and increased involuntary culling of cows. In an examination of 42,355 lactations in 132 Israeli dairy farms between 2009 and 2011, we found the average annual economic damage from negative energy balance to be about $28 per cow. In different dairies, the economic damage may be twice or even three times as great.

An examination of a dairy using the BHBA and fat-to-protein ratio monitoring protocol described herein to diagnose and treat cows with negative energy balance and ketosis showed very low economic damage—about $4.20 per cow per year. This was due only to lost reproductive efficiency from open days (see Figure 4).

Summary

The way cows get through the transition period influences production, fertility and survival in subsequent lactations. As a consequence of the high-energy requirements involved in producing milk, many cows suffer from negative energy balance after calving at different times and for varying durations. Monitoring, diagnosis and the early treatment of cows are critical to the herd’s future and to optimize production and fertility.

The fat-to-protein ratio in milk is an efficient parameter in diagnosing cows suffering from negative energy balance and ketosis. Daily measurements of milk composition allow for effective monitoring during the risk period, early diagnosis and preemptive treatment. The use of these measurements can enable diagnosis and early treatment of cows, which will lead to improved dairy revenues.

References omitted due to space but are available upon request.