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Monitoring for Subclinical Ketosis in Dairy Herds

KEY FACTS

- Subclinical ketosis is associated with decreased milk production, impaired fertility, and displaced abomasum in dairy cows.
- Subclinical ketosis can be detected when the herd is monitored in the first and second weeks after calving in most cows.
- Glucogenic substances can be used to treat cows that test positive for subclinical ketosis.

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ABSTRACT: Ketosis causes economic losses resulting from decreased milk production, impaired fertility, and increased risk of displaced abomasum. On a herd basis, subclinical ketosis is substantially more costly than is clinical ketosis; therefore, greater benefits are to be gained by monitoring cows for subclinical ketosis. More than 90% of subclinical ketosis cases occur in the first and second months after calving. During this period, approximately 40% of all cows are affected by subclinical ketosis at least once, although the prevalence is highest in the first and second weeks after calving. A monitoring program that requires testing each cow for subclinical ketosis in the first and second weeks after calving would identify nearly 90% of the subclinical ketosis cases occurring the first and second months after calving. This monitoring program, including the subsequent treatment of positive cows, may have a cost:benefit ratio of 1:3. This article discusses the profitability of such a monitoring program.

Ketosis causes economic losses due to decreased milk production, impaired fertility, and increased risk of displaced abomasum. Various studies[1–4] have found that ketotic cows produce 1 to 10 L of milk less per day than nonketotic cows. Higher concentrations of milk acetone have also been associated with longer intervals from calving to first service, from first service to conception, and from calving to conception. Higher milk acetone concentrations were also associated with lower first-service conception rates, an increased number of services per conception, and an increased incidence of genital infection and ovarian cysts.[1,5–8] In a recent study,[9] 60% to 80% of the cows had subclinical ketosis before displaced abomasum was diagnosed.

LOSSES CAUSED BY KETOSIS

Subclinical ketosis is more common than is clinical ketosis and causes greater economic losses. On average, 40% of dairy cows are affected by subclinical ketosis at least once during lactation (lactational incidence risk, 40%),[2,10] whereas an average of 5% experience clinical ketosis.[11] One case of subclinical ketosis can result in a loss of $78 because of decreased milk production,[1,2] extended interval

TABLE 1
Estimated Losses Resulting from Subclinical Ketosis in One Cow

Production Losses	*Money Lost*
2 L of milk production less per day for 2 wk ($0.30/L)	$8
Calving-to-conception interval extended for 2 wk[8] ($2/day)	$28
Threefold increased risk of clinical ketosis[2,a]	$22
Threefold increased risk of displaced abomasum[9,b]	$20
Total	$78

[a]Given an average lactational incidence rate of 5% for clinical ketosis[11] and a loss of $145/case,[14] an average clinical ketosis risk would account for $7.25 (5% × $145).
[b]Given an average lactational incidence rate of 2%[11] and a loss of $340/case,[14] an average displaced abomasum risk would account for $6.80 (2% × $340).

from calving to conception,[8] and increased risks of clinical ketosis[2,12] or displaced abomasum.[13] Because of treatment costs, decreased milk production, extended calving-to-conception interval, and increased risks of culling and death,[3,4,7,14] one case of clinical ketosis can cause a loss of $145[14] (Table 1). Therefore, each cow in the herd carries a subclinical ketosis risk of $31/lactation (lactational incidence risk of 40% × losses of $78/case) and a clinical ketosis risk of $7.25/lactation (5% × $145). Thus to prevent losses associated with ketosis, cows should be monitored for subclinical rather than clinical ketosis.

SUBCLINICAL KETOSIS

Defining Thresholds

Threshold values used to define subclinical ketosis should be set at the point at which milk production decreases, fertility deteriorates, or the risks of clinical ketosis or displaced abomasum increase significantly. Several studies revealed that at levels above 100 µmol acetoacetate/L of milk,[15] 250 µmol acetone/L of milk,[16] and 1600 µmol β-hydroxybutyrate (BHB)/L of blood,[2] milk production losses of 1 to 2 L/day can be expected. The calving-to-conception interval was extended by about 12 days when milk acetone concentration had risen to 200 µmol/L.[8] The risk of clinical ketosis was increased when levels were above 100 µmol BHB/L of milk.[12] Cows with more than 1400 µmol BHB/L of blood were at three times greater risk of being subsequently diagnosed with clinical ketosis or displaced abomasum than were cows with lower levels. Therefore, 100 µmol acetoacetate/L of milk, 100 µmol BHB/L of milk, 250 µmol acetone/L of milk, or 1400 µmol BHB/L of blood may be used as threshold values to distinguish between cows with and without subclinical ketosis.

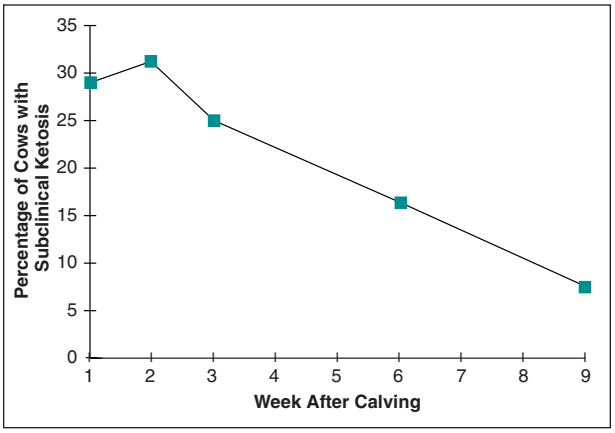

Figure 1—Percentage of cows with subclinical ketosis (greater than 1200 µmol β-hydroxybutyrate/L of blood) in the first 9 weeks after calving.[2]

Incidence

More than 90% of subclinical ketosis cases occur during the first and second months after calving.[1,16] In this period, an average of 36% to 43% of the cows had subclinical ketosis one or more times in German[10] and Canadian[17] studies. The prevalence was highest in the first or second week after calving.[10,16,17] During the first week after calving, 11%,[16] 12%,[18] 16%,[10] or 29%[17] of the cows had subclinical ketosis (Figure 1). Individual cows were often affected only once lasting for a 1- to 2-week period (Figure 2). However, subclinical ketosis may also appear in individual cows several times and can last up to 2 months.[10]

Diagnosis

Milk testing has advantages over urine and blood testing in diagnosing subclinical ketosis because milk is the substance most easily obtained. Cowside milk tests, such as the Ketolac® BHB test strip (distributed by Hoechst, Weisbaden, Germany) or the PINK® milk ketone test (distributed by The Butler Company, Dublin, OH), may be used[18,19] (Table 2). The Ketolac® strip turns pink when BHB concentration in milk exceeds 50 µmol/L; the PINK® liquid turns milk pink when the acetoacetate concentration in milk exceeds 100 µmol/L (Figure 3). Time of day; quarter selected; and sampling before, during, or after milking may not affect ketone body concentration in milk.[5,6,16] Mastitis, however, may affect the test results. When somatic cell count increased by 1 million cells/ml, the Ketolac® strip indicated an increase of 20 µmol BHB/L, whereas the

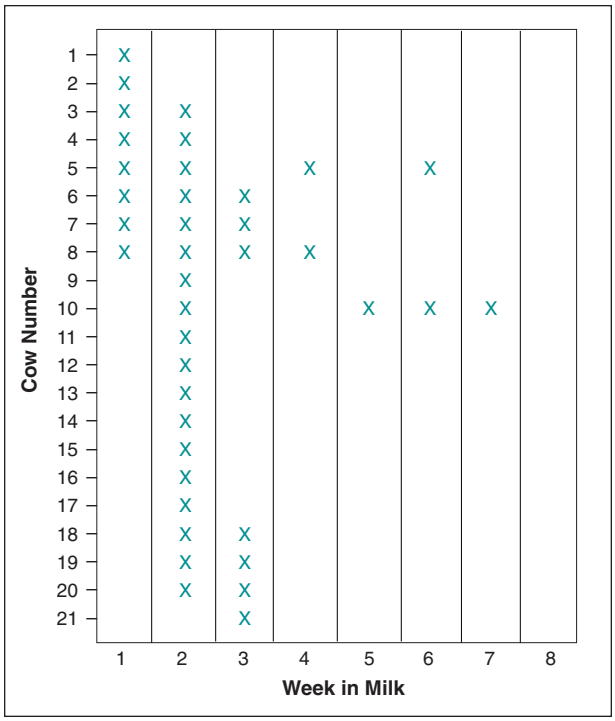

Figure 2—Episodes of subclinical ketosis (greater than 250 µmol acetone/L of milk) during the first 8 weeks of lactation in 21 cows in a herd of 49.[10]

PINK® test indicated an increase of 6 µmol acetoacetate/L.[18] The ingestion of malfermented silage with high butyric acid content may cause an elevated ketone body concentration in milk.[20,21] Elevated ketone body concentration in midlactation cows—not only in early-lactation cows—points toward ingestion of malfermented silage. When cows are test-fed the suspicious silage, they yield elevated milk ketone concentrations.[10]

Monitoring Program

Seventy-nine percent to 95% of the cows that showed subclinical ketosis one or more times during the first and second months of lactation were detected when each cow was tested for this condition in the first and second weeks after calving.[10] This percentage was 69% to 86% when cows were tested in the second week only and 30% to 56% when cows were tested in the first week only.[10] Because displaced abomasum is frequently diagnosed in the first and second weeks after calving[2,22] and subclinical ketosis often precedes displaced abomasum,[9] cows should be tested for subclinical ketosis in the first and second weeks after calving. When tested monthly (e.g., on dairy herd improvement test day), more than 50% of the cows would be tested later than the second week after calving.[23] Thus, in a monitoring program for subclinical ketosis, cows need to be tested more frequently than at monthly dairy herd improvement test dates or biweekly herd health management visits.

Figure 3—The PINK® milk ketone test turns milk slightly pink when more than 100 µmol of acetoacetate is present.

TABLE 2
Sensitivity and Specificity of Ketone Tests When Used with Milk for Subclinical Ketosis
(Defined as greater than 1400 µmol β-hydroxybutyrate/L of blood in dairy cows)

Test (Distributor)	*Sensitivity (%)*	*Specificity (%)*
Ketolac® BHB test strip (Hoechst, Wiesbaden, Germany)[18]	91	56
PINK® milk ketone test (The Butler Company, Dublin, OH)[18]	76	93
Ketocheck™ (Butler, St. Joseph, MO)[19]	39	100
Bioketone (Biopharm, Laval, Quebec)[19]	29	100
Ketostix® (Bayer, Etobicoke, Ontario)[19]	7	100

A practical and workable program would be to test all cows that are in the first and second weeks of lactation on a specific day of the week (e.g., every Monday). Cows diagnosed with subclinical ketosis could be treated to prevent milk production losses, fertility disorders, clinical ketosis, and displaced abomasum; the cows could then be retested the following Monday. We call this the Ketomon program. The herd management program would be used to provide a list of cows to be checked as well as to store the results. In one study,[18] 6% of the milk samples taken in the first week after calving were bloody,[18] which made it difficult to judge test results. Therefore, about 6% of the subclinical ketosis cases in the first week after calving may not be detected when using milk for testing.

Management

Primary ketosis, which can be differentiated from secondary ketosis by clinical examination, may be treated with changes in the feeding program and administration of glucogenic substances. Secondary ketosis will disappear with correction of the primary disease.

Administration of Glucogenic Substances

Sodium propionate was given in quantities of 50 to 150 g[24–29] and propylene glycol in quantities of 125

to 250 g[29–39] twice daily over several days until ketosis had disappeared. Both of these substances can either be mixed with the feeds or administered PO. The distribution of these substances may be more homogenous after spraying than after pouring onto the feeds. Because appetite is often decreased during ketosis and these substances are not very palatable, cows do not always ingest effective quantities; therefore, these substances should be mixed with more palatable feeds for better consumption.[36] When the product is administered PO as a drench from a bottle, liquid solutions may be spilled during adminstration or may enter the lungs and cause aspiration pneumonia.[40,41] Liquid solutions, therefore, are best administered via a ruminal tube. Sodium propionate is also effective in pill form (E-PILL®; distributed by The Butler Company Dublin, OH),[26] which may may be administered using an applicator (balling gun; Figure 4).

Figure 4—Oral administration of sodium propionate may be safer in pill form than as a liquid.

Oral administration of 100 g of sodium propionate provides as much energy as intravenous administration of 100 g glucose.[29] However, administration of large quantities of sodium propionate (500 g twice daily) may cause decreased appetite and milk production and metabolic alkalosis.[29] This blood pH–raising effect of sodium propionate (single dose of 343 g PO) may be used to treat mild metabolic acidosis.[42] If subclinical ketosis occurs in more than 20% of the cows during 2 subsequent weeks, nutritional management should be evaluated and corrected. Ketosis prevalence should decline within several weeks after making corrections to the feeding program. To provide additional energy, glucogenic substances may be added to the feed over several weeks.[16,34,43] However, the addition of glucogenic substances to the feeds without feeding corrections may not always result in a reduction of the ketosis prevalence.[16,34,43] It is often more cost-effective to correct the feeding program than to add glucogenic substances over an extended time.

KETOSIS PREVENTION

Ketosis can be prevented by feeding cows according to their nutritional needs and by genetic selection. Commonly accepted feeding recommendations may be used to prevent ketosis. Cows should neither be too fat nor too thin when entering the dry period and in early lactation. Around calving, cows should already be adapted to the feeds that are offered after calving.[44] After calving, cows should be provided with sufficient energy, predominantly from good-quality silage. Because malfermented silage may cause ketosis, these feeds should not be offered to dairy cows.[20] Breeding programs that select for a persistent lactation curve, high lifetime milk production, and high dry-matter intake capacity may have a long-term effect in reducing the incidence of subclinical ketosis.[45] Oral administration of ionophore monensin 3 weeks precalving has been shown to decrease the incidence of subclinical ketosis by 50% and to lower the incidence of displaced abomasum by 40%.[46]

DOES MONITORING FOR KETOSIS PAY?

One specific scenario for estimation of the cost:benefit ratio of a monitoring program for subclinical ketosis in dairy herds is shown in Table 3. Assume that 40 cows in a herd of 100 are affected by subclinical ketosis at least once during lactation.[10,17] The loss per case of subclinical ketosis was $78 (Table 1). Each cow was tested for subclinical ketosis in both the first and the second weeks after calving. This monitoring program detected 90% of the cows showing subclinical ketosis during early lactation.[10] In order to prevent milk production loss, fertility disorders, clinical ketosis, or displaced abomasum, cows were treated with 100 g sodium propionate or 250 g propylene glycol twice daily over 3 days.

By using this monitoring program, 36 of the 40 cows showing subclinical ketosis at least once during lactation would be detected. The detected loss caused by subclinical ketosis would account for $2808 (36 cows × $78); the actual loss was $3120. Subclinical ketosis that developed in four cows in the third week after calving or later would not be detected because cows are tested in the first and second weeks only. These four cows would cause losses of $312. When using this monitoring program, 200 tests would be performed annually at a cost of $200 ($1/test). Thirty-six cows would be treated for 3 days, costing $360 ($10/cow). A sum of $560 would be invested for tests and treatment, and a loss of $312 would be incurred for undetected cows with subclinical ketosis. Therefore, total costs would be $872. Benefits through prevention of milk production loss, fertility disorders, clinical ketosis, and displaced abomasum would account for $2808. Thus the cost:benefit ratio would be 1:3.2 ($872:$2808). In other words, investing $1 would yield $3.20 (Table 3).

We encourage clinicians to perform their own theoretical scenarios. In our scenario, the cost:benefit ratio drops below 1:2 if the lactational incidence rate of sub-

TABLE 3
Estimation of the Cost:Benefit Ratio of a Monitoring Program for Subclinical Ketosis in Dairy Herds

Independent Variables	*Value*
Number of cows in the herd	100
Lactational incidence rate of subclinical ketosis	40%
Loss caused by subclinical ketosis per case	$78
Testing period	14 days
Testing frequency (tests/testing period)	0.14
Percentage of subclinical ketosis cases that are detected	90%
Cost per test	$1
Cost per treatment	$10
Dependent Variables	
Number of real subclinical ketosis cases per lactation (number of cows × lactational incidence rate)	40
Real loss caused by subclinical ketosis per lactation (number of real cases × loss caused by subclinical ketosis)	$3120
Number of subclinical ketosis cases detected (number of real cases × percentage of cases detected)	36
Detected loss caused by subclinical ketosis per lactation (number of cases detected × loss per case)	$2808
Number of tests per year (number of cows × testing period × testing frequency)	200
Test cost per year (number of tests per year × cost per test)	$200
Treatment cost per year (cost per treatment × number of cases detected)	$360
Loss despite monitoring (number of real cases minus detected cases × loss per case)	$312
Costs of monitoring program (test cost + treatment cost + loss despite monitoring)	$872
Benefits of monitoring program (prevention of losses that are detected)	$2808
Cost:benefit ratio	*3.2*

clinical ketosis is less than 11%, if the percentage of cows detected is less than 77%, if the test costs are higher than $3.80/test, and if treatment costs for each cow exceed $25. The other parameters were kept constant when one variable was changed. Our scenario assumed that the treatment prevented all losses caused by subclinical ketosis, but this theory needs further investigation. Even if the described scenario does not account for all factors that may impact the profitability of a monitoring program for subclinical ketosis in dairy herds, the economic calculations strongly suggest that such a program can be profitable under certain circumstances.

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ARTICLE #6 CE TEST

The article you have read qualifies for 1.5 contact hours of Continuing Education Credit from the Auburn University College of Veterinary Medicine. *Choose the best answer* to each of the following questions; then mark your answers on the postage-paid envelope inserted in *Compendium.*

1. What is the average lactational incidence of subclinical ketosis?
   a. 5%
   b. 11%
   c. 16%
   d. 29%
   e. 40%

2. What is the estimated loss caused by one case of subclinical ketosis?
   a. $7
   b. $31
   c. $40
   d. $78
   e. $145

3. What is the average subclinical ketosis cost per cow per lactaton?
   a. $7
   b. $31
   c. $40
   d. $78
   e. $145

4. What is the average clinical ketosis risk per cow per lactation?
   a. $7
   b. $31
   c. $40
   d. $78
   e. $145

5. Ninety percent of the cows experiencing one or more episodes of subclinical ketosis can be detected when all cows are tested in the
   a. first week after calving.
   b. second week after calving.
   c. third week after calving.
   d. first and second weeks after calving.
   e. second and third weeks after calving.

6. Milk ketone concentration is most likely affected by
   a. time of day.
   b. quarter selected.
   c. sampling before versus after milking.
   d. ingestion of malfermented silage.

7. When a high somatic cell count occurs, the milk ketone concentration
   a. decreases.
   b. increases.
   c. remains unchanged.
   d. is slightly decreased.

8. Subclinical ketosis was defined as greater than
   a. 100 µmol acetoacetate/L of milk.
   b. 100 µmol acetone/L of milk.
   c. 1400 µmol BHB/L of milk.
   d. none of the above

9. The risk of aspiration pneumonia was lowest when liquid treatments were administered
   a. as a drench from a bottle.
   b. via an esophageal tube.
   c. via a ruminal tube.
   d. none of the above

10. A monitoring program for subclinical ketosis is more profitable when _____% of affected cows are detected.
   a. 90
   b. 82
   c. 77
   d. 68