FULL PAPER *Internal Medicine*

The Metabolic Profile Test: Its Practicability in Assessing Feeding Management and Periparturient Diseases in High Yielding Commercial Dairy Herds

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ABSTRACT. The aim of this study was to evaluate the practicability of using the metabolic profile test (MPT) as a preventive tool for periparturient disease of dairy cows. The MPT was assessed in 79 dairy herds with high incidence of periparturient disease and 76 healthy herds of cows producing more than 8,500 kg 305-day milk yield. The changes in metabolic profiles were also assessed in 17 dairy herds at two times, the first at high incidence of periparturient disease and the second after reduced incidence and improved feeding management. In the herds with high incidence of periparturient disease, low blood values of hematocrit, albumin, glucose, cholesterol, calcium and magnesium were observed in the dry period. These values correctly diagnosed malnutrition as the cause of periparturient diseases. Following feeding management changes, there was a low incidence of periparturient disease and the metabolic profiles were normal showing that feeding management had improved. We concluded that the MPT is a useful tool for assessing feeding management and periparturient diseases of dairy cows.

KEY WORDS: dairy cow, metabolic profile test, periparturient disease.

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There were about 550,000 parturient dairy cows in Hokkaido in 1997 [30]. Of these, approximately 65,000 (12%) were treated by veterinarians for periparturient diseases such as milk fever, downer cow syndrome, abomasal displacement, ketosis, fatty liver and retained placenta [11]. Some 8,000 dairy cows died or were culled within a month postpartum [11]. Periparturient disease, culling and death, result in serious economic loss to the dairy farmer through veterinary fees, reduced milk production and reproductive efficiency [8].

Poor management of dairy cows during the dry and early lactation period predisposes them to periparturient diseases. Morrow [18] and Morrow *et al.* [19] described that fat cow syndrome in periparturient cows is caused by faulty feeding management that permits excessive consumption of unbalanced diets during the late lactation and dry period. Shaver [29] reported that the transition period, from two weeks prepartum through two to four weeks postpartum, is the major risk period for the etiology of abomasal displacement, and that it is characterized by a prepartum depression in feed intake, followed by a slow increase in postpartum intake.

The metabolic profile test (MPT) was first established as a tool for assessing metabolic status and helping in the diagnosis of metabolic disorders in dairy herds by Payne *et al.* [25]. Subsequently, many researchers have applied MPT to improve feeding management, detect sub-clinical health problems and prevent production diseases [1, 4, 6, 13, 15–17, 24]. However, as it is not cost effective, MPT is not generally used as a tool for preventive medicine. On the other hand, in conjunction with animal and facility evaluation, body condition scoring and ration evaluation, MPT is an extremely useful tool for nutritional evaluation in dairy herds [31]. MPT has also been used by many commercial dairy herds in Japan [14, 22–23].

The main objective of this study was to evaluate the practicability of MPT as a tool for the prevention of periparturient diseases in dairy cows in Japan. Traits of metabolic profiles in commercial dairy herds with high incidences of periparturient diseases and changes in profiles of herds in which the incidence of periparturient diseases reduced were also assessed.

MATERIALS AND METHODS

The dairy herds: Dairy herds producing more than 8,500 kg of 305-day milk yield on average, were selected from all the herds among which MPT was conducted in various districts of Hokkaido from 1987 to 1996. The feeding and management were different in each herd. Generally all cows were housed indoors and some were on pasture in summer. Feeding systems included continuous feeding of a total mixed ration or separate feeding of forage and concentrates. The MPT was conducted through four seasons.

Depending on the incidence of periparturient diseases—milk fever, downer cow syndrome, abomasal displacement (AD), ketosis, fatty liver and retained placenta—the herds were divided into two groups, high incidence (High group) and low incidence (Low group) of disease (Table 1). The High group consisted of 79 herds in which the incidence of periparturient disease was more than 15% (mean 27%) in a year. These herds particularly had a very high incidence of disease within three months prior to the MPT.

The Low group (control) consisted of 75 herds in which the incidence of periparturient disease was less than 15% (mean 7%) in a year. These herds had a very low incidence of diseases for 3 months prior to the MPT.

Cow selection: Dairy cows included in the study were of various ages with no apparent clinical problems. Though

Table 1. Incidence of periparturient diseases in herds with high and low incidence of disease

	High group[a)]	(%)[d)]	Low group[b)]	(%)
Number of herds	79		75	
Number of cows calved[c)]	4223		3719	
Incidence of diseases				
Milk fever/Downer cow	358	(8.5)	8	(2.1)
Abomasal displacement	189	(4.5)	61	(1.4)
Fatty liver/Ketosis	306	(7.3)	51	(1.2)
Retained placenta	296	(7.0)	66	(1.6)
Total	1149	(27.2)	265	(7.1)

a) Herds with high incidence of periparturient diseases.
b) Herds with very low incidence of periparturient diseases.
c) Total number of cows calved in the year before MPT.
d) Disease incidence (%) for total number of cows calved.

Table 2. Number of cows and milk production in herds with high and low incidence of periparturient diseases

	High group[a)]	Low group[b)]
Total number of cows tested	668	565
Cows in dry period	363	296
Cows in early lactation	305	269
Average number of calvings	2.9	2.9
Average daily milk production[c)]		
Milk (kg)	37.1	38.0
Fat (%)	4.1	4.2
Protein (%)	3.2	3.2

a) Herds with high incidence of periparturient diseases. b) Herds with very low incidence of periparturient diseases. c) Daily milk production of cows in early lactation.

the cows were chosen from all the stages of lactation and dry period at MPT, only cows in the dry period (day of dry-off to calving) and early lactation (calving to 49 days in milk: DIM) were studied, because these cows are at greater risk of periparturient diseases. The number of cows in the dry and early lactation period was 363 and 305 in the High group and 296 and 269 in the Low group, respectively (Table 2). The average number of calvings, milk production and milk components of the cows in each group are also shown in Table 2.

Blood collection, MPT components and analytical methods: Blood samples were collected from the jugular vein in plain vacuum tubes between 09:00 and 11:00 hr, 2 to 3 hr after morning feeding. Blood was analyzed on the farm in a vehicle equipped with automatic biochemical analyzers. Heparinized micro-capillary tubes were immediately filled for determination of hematocrit. Just after blood collection, to avoid depression of glucose, serum was separated by centrifuging (750 g) for 5 min. As fibrin appeared in the serum layer, a small quantity of plastic granules, serum separator (Blut-Z, Tohshin Chemical Co., Ltd.), were then added to the sample tubes which were then centrifuged (1,600 g) again for 5 min.

As shown in Table 3, indicators used for evaluation of protein metabolism were hematocrit (Ht), albumin (Alb), γ-globulin (Glb), and blood urea nitrogen (BUN); for energy metabolism, glucose (Glc), total cholesterol (Cho) and non-esterified fatty acid (NEFA); for liver function, aspartate aminotransferase (AST) and γ-glutamyl transpeptidase (GGT); and for mineral metabolism, calcium (Ca), inorganic phosphorus (iP) and magnesium (Mg).

Within 1–2 hr of collection, blood metabolites were analyzed using an automatic biochemical analyzer (VP-Super, DINABBOTT Co., Ltd. or TBA-40FR, Toshiba Medical Systems Co., Ltd.) and an automated electrophoresis system (CTE-150 or CTE-700, Jokoh Co., Ltd.). Body condition score (BCS) on a scale of 1–5 (1: too thin and 5: obese) with 0.25 intervals [32], was also estimated to assess energy balance at the time of blood sampling.

Metabolic profile in herds with high incidence of periparturient disease: For analysis of MPT, the criterion of diagnosis is illustrated in Fig. 1. The upper and lower limits

Table 3. Metabolic profile components

Indicators	Method of analysis
Protein metabolism	
Hematocrit (Ht)	Micro capillary method
Albumin (Alb)	Electrophoresis method
γ-globulin (Glb)	Electrophoresis method
Blood urea nitrogen (BUN)	Urease-GLDH method
Energy metabolism	
Body condition score (BCS)	1 (too thin) to 5 (obese), 0.25 interval
Glucose (Glc)	HK-G6PDH method
Cholesterol (Cho)	Cholesterol oxidase method
Nonesterified fatty aid (NEFA)	Enzymatic colorimetric method
Liver function	
Aspartate aminotransferase (AST)	MDH UV method
γ-glutamyl transpeptidase (GGT)	Glu-3-CA-4-NA substrate method
Mineral metabolism	
Calcium (Ca)	O-CPC method
Inorganic phosphorus (iP)	Enzymatic UV method
Magnesium (Mg)	Enzymatic UV method

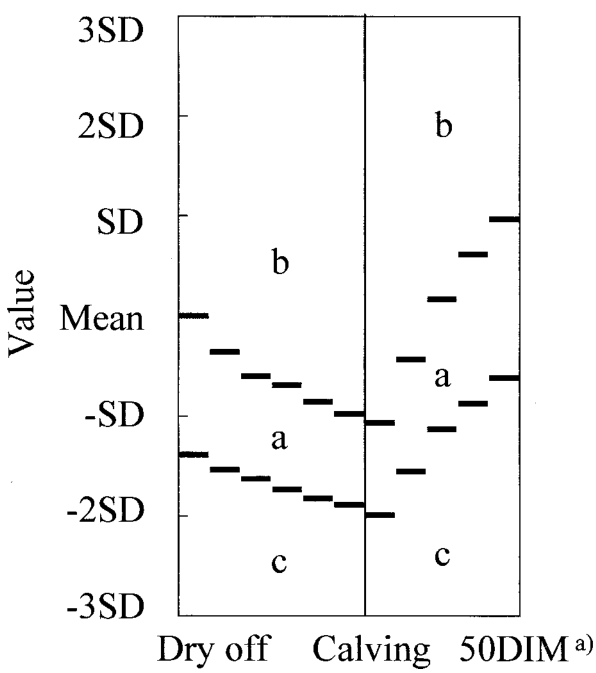

Fig. 1. Diagnosis example by the reference ranges (▬). a: normal. b: deviation above the upper limits. c: deviation below the lower limits. Y axis indicates values of mean ± 3 SD in all stages of criterion. a) Days in milk.

(mean ± 1 SD) of respective reference ranges, established every 10 days after dry off and calving, were used for diagnosis. The blood metabolites and BCS were diagnosed as normal, deviated above the upper limit, or deviated below the lower limit. The incidence of deviation from the upper or lower limits in the dry and early lactation period was calculated as shown below.

Incidence of deviation (%) = 100 × Number of cows with deviated values from reference range / Total number of cows tested

The chi-square test was used to test for the difference in the incidence of deviation between the High and Low groups in each stage.

Changes in metabolic profiles in herds with reduced incidence of periparturient diseases: A second MPT was done among 17 dairy herds of the initial high group among which the incidence of periparturient disease had reduced more than 3 months after the first MPT. Two groups were formed: 150 cows, 81 dry and 69 early lactation at the first MPT, and 151 cows, 93 dry and 58 early lactation at the second MPT. The chi-square test was used to compare the incidence of deviation between the first and second MPT in the dry and early lactation period.

Prior to the MPT, nutrient composition of forage was determined by near infrared reflecting spectroscopy at a commercial laboratory. Nutrient composition of concentrates were taken as shown in the feed composition tables of the Japanese feeding standard [2] or the Nutrient requirements of dairy cattle, NRC [21]. Nutrient ingredients in the diet were calculated as total digestible nutrients (TDN), crude protein (CP), nonfibrous carbohydrate (NFC), and acid detergent fiber (ADF). To investigate the effects of feeding strategies on the levels of blood metabolites, daily total feed intake of peripartum cows was estimated from the amount of feed given and feed bunk management on the day of MPT. Based on NRC [20], the nutrient supply was calculated in far-off dry, 7 days prepartum and 21 days postpartum cows in each herd. Each of the 17 dairy herds were classified into 3 classes of nutrient supply—less than 80%, 80 to 120% and more than 120% of CP and NFC requirements, and the number of herds in each class was compared between the first and second MPT. The nutrient ingredients of diets for cows in early lactation were calculated. Each of the17 dairy herds was then classified into any one of critical nutrient levels—more than 75%, 70 to 75% and less than 70% of TDN, more than 18%, 15 to 18% and less than 15% of CP, more than 40%, 30 to 40% and less than 30% of NFC, and less than 20% of ADF (dry matter basis). The number of dairy herds in which feeding related problems were observed were compared between the first and second MPT.

RESULTS

The incidence of deviation of the blood metabolites and BCS during the dry and early lactation periods in the High and Low groups, are shown in Fig. 2.

Protein metabolism: Incidence of deviation of Ht below the lower limit of the dry period was significantly higher ($p<0.05$) in the High group than in the Low group, as was Alb of the dry ($p<0.01$) and early lactation periods ($p<0.05$). Above the upper limit of early lactation, Alb was significantly lower ($p<0.05$) and Glb significantly higher ($p<0.05$) in the High group than in the Low group.

Energy metabolism: In the High group, there was a significantly higher incidence of deviation of Glc ($p<0.01$) and Cho ($p<0.05$) below the lower limits of the dry period. In early lactation, there was a higher incidence of deviation of Cho below the lower limit ($p<0.05$) and of Glc above the upper limit ($p<0.05$). A relatively higher incidence of deviation of BCS above the upper limit of the dry period was also found.

Liver function: There was no significant difference in the incidence of deviation of AST between the two groups. However, GGT below the lower limit of the dry period was higher in the High group than in the Low group ($p<0.01$).

Mineral metabolism: In the High group, during the dry period, incidence of deviation of Ca was significantly higher below the lower limits ($p<0.01$) and lower above the upper limits ($p<0.05$) than in the Low group, and that of Mg was significantly lower above the upper limits ($p<0.01$). There was no significant difference in iP between the High and Low groups, during both the dry and early lactation periods.

Changes in metabolic profiles of the 17 dairy herds: In the 17 dairy herds in which a second MPT was performed,

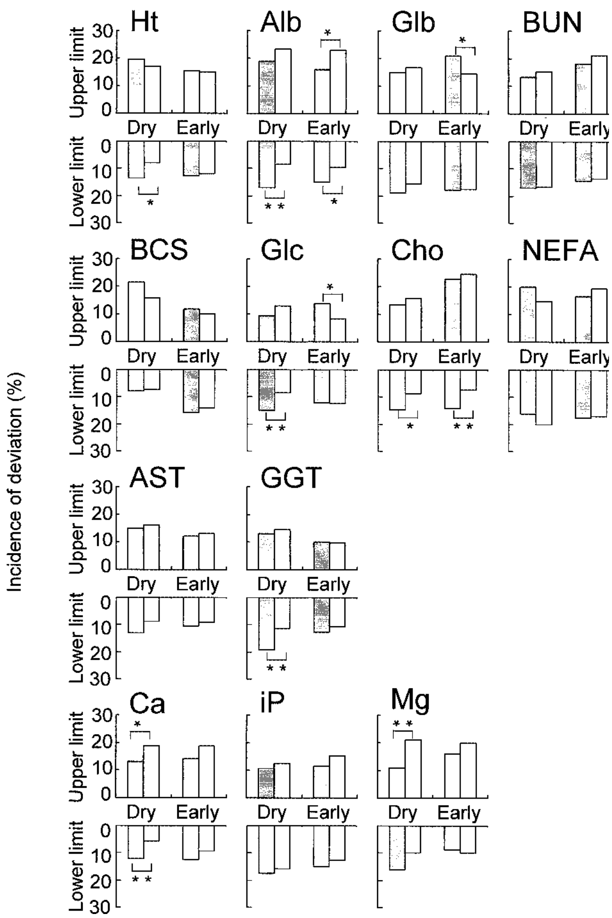

Fig. 2. Incidence of deviation from the reference ranges of MPT components during the dry and early lactation periods in dairy herds with high and very low incidences of periparturient disease. ■ Herds with high incidence of periparturient diseases (High group). □ Herds with very low incidence of periparturient diseases (Low group). Significant difference (*: p<0.05), (**: p<0.01) between groups.

total incidence of milk fever, downer cow syndrome, abomasal displacement, ketosis, fatty liver and retained placenta, decreased from more than 27% in the one year before the first MPT to less than 3% in the three months before the second MPT (Table 4). The incidence of deviation of blood metabolites and BCS from the respective reference ranges is illustrated in Fig. 3.

Regarding protein metabolism, there was significantly lower incidence of deviation above the upper limit of Alb (p<0.05) in early lactation, at the second MPT than at the first, and similarly Glb (p<0.05) in the dry period.

There was no significant difference in the incidence of deviation of the other protein indicators between the first and second MPT. However, incidence of deviation from the lower limit of Ht, Alb, and BUN in early lactation was lower at the second MPT than at the first.

In the indicators of energy metabolism, the incidence of

Table 4. Incidence of periparturient diseases in 17 dairy herds

	Time of MPT			
	1st[a)]	(%)[c)]	2nd[b)]	(%)
Number of cows calved in a year	738			
Incidence of disease[d)]				
Milk fever/Downer cow	69	(9.35)	10	(1.36)
Abomasal displacement	46	(6.64)	5	(0.68)
Fatty liver/Ketosis	47	(6.37)	4	(0.54)
Retained placenta	21	(2.85)	3	(0.41)
Total	186	(27.21)	22	(2.98)

a) Herds at the first MPT. b) Herds at the second MPT. c) Incidence (%) of disease in postpartum cows. d) Disease incidence in the year before the first MPT and 3 months before the second MPT.

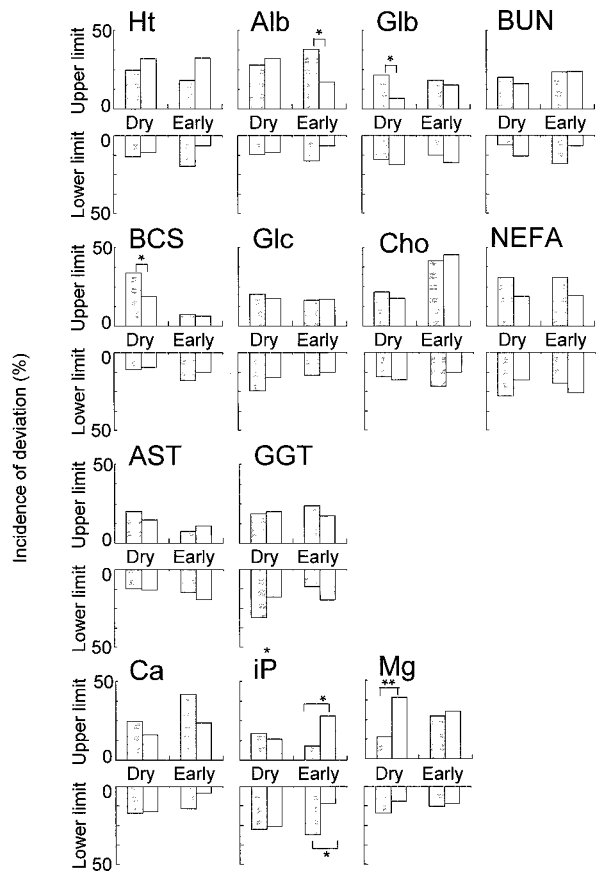

Fig. 3. Changes in incidence of deviation from the reference ranges of MPT components during the dry and early lactation periods in 17 dairy herds at the first and second MPT. ■ Herds at the first MPT. □ Herds at the second MPT. Significant difference (*: p<0.05), (**: p<0.01) between the first and second MPT.

deviation of BCS above the upper limit of the dry period significantly decreased (p<0.05) at the second MPT. There was a relatively lower incidence of deviation of Glc below the lower limit of the dry period at the second MPT, but no difference was found in early lactation between the first and second MPT. Though a relatively lower incidence of deviation of Cho below the lower limit of early lactation was observed at the second MPT, no difference was found from the lower limit of the dry period.

The incidence of deviation of NEFA above the upper limit of the dry and early lactation periods was lower at the second MPT than at the first.

With respect to liver function, there was a relatively lower incidence of deviation of GGT below the lower limit of the dry period at the second MPT.

In the indicators of mineral metabolism, there was a significantly lower incidence below the lower limit ($p<0.05$) and a significantly higher incidence above the upper limit ($p<0.05$) of iP during early lactation at the second MPT. In addition, there was a significantly higher incidence of deviation of Mg ($p<0.01$) above the upper limit of the dry period at the second MPT.

There was no difference in the incidence of deviation of Ca from both limits of the dry period between the first and the second MPT.

Feeding management in the 17 dairy herds: In 5 of the 17 dairy herds, cows were fed a totally mixed ration in free stall barns, while forage and concentrates were fed separately in the rest.

Of the 17 dairy herds, the number of herds in which cows were fed critical levels of nutrients are shown in Table 5. The number of dairy herds in which the far off dry cows were estimated to be fed less than 80% of CP and/or NFC requirements at the first MPT, decreased at the second MPT, from 4 to 1 and 6 to 3, respectively.

In the nutrient ingredients of the diet for early lactation cows 21 days postpartum, the number of herds feeding too high or too low levels of TDN, CP and NFC was lower at the second MPT than at the first. The number of herds feeding too low ADF at the first MPT decreased from 4 to 2 at the second MPT.

Some management problems observed in the 17 dairy herds are also shown in Table 5. At the first MPT, less forage was fed in 8 of the 17 dairy herds where empty feed bunks were observed for 6 hr or more in a day. Depression of the paralumbar fossa was observed in many prepartum cows in these herds. In 6 of the 17 dairy herds, no lead feeding for prepartum cows was carried out. These feeding management problems were resolved in almost all herds by the second MPT.

Table 5. Number of dairy herds of the 17 studied, feeding critical level of nutrients with some management problems

Feeding management	Time of MPT	
	1st[a)]	2nd[b)]
Far off dry cow		
CP[c)] supplied;		
>120% of requirement	2	2
< 80% of requirement	4	1
NFC[d)] supplied;		
>120% of requirement	3	3
<80% of requirement	6	3
Cows 7 days prepartum		
CP supplied;		
<80% of requirement	7	5
NFC supplied;		
<80% of requirement	6	4
Cows 21 days postpartum		
TDN[e)] ingredient;		
>75% of total diet	5	4
<70% of total diet	4	0
CP ingredient;		
>18% of total diet	2	1
<15% of total diet	2	1
NFC ingredient;		
>40% of total diet	2	1
<30% of total diet	3	0
ADF[f)] ingredient;		
<20% of total diet	4	2
Management problems		
Shortage of forage[g)]	8	1
No lead feeding[h)]	6	1
Others[i)]	2	0
No problems observed	0	13

a) Herds at the first MPT. b) Herds at the second MPT. c) Crude protein. d) Nonfibrous carbohydrate. e) Total digestible nutrients. f) Acid detergent fiber. g) Empty feed bunk was observed for 6 hr or more in a day. h) No lead feeding prepartum. i) Overfeeding in late lactation, severe cold stress in winter.

DISCUSSION

Excessive consumption of an unbalanced diet during late lactation and the dry period predisposes periparturient dairy cows to fat cow syndrome [18]. Furthermore, Bertics *et al.* [3] described that dry matter intake is a critical factor influencing the development of fatty liver. In the cow, particularly the obese cow, it is well known that anorexia around calving leads to decreased blood Glc and increased NEFA levels. Dyk *et al.* [10] reported that cows which developed AD had higher plasma NEFA than cows which did not. According to Shaver [29], nutritional risk factors for AD are prepartum intake depression and slow postpartum increase in intake, which lead to low ruminal fill, reduced forage to concentrate ratio, and increased incidence of other postpartum disorders.

The high incidence of deviation of NEFA and BCS from the upper limits, Glc and Cho from the lower limit observed in the High group dry cows in this study, indicate a high risk of energy deficiency and liver dysfunction. Because of increasing milk production postpartum, cows usually have hypoglycemia which reflects an energy deficiency. However, in this study Glc values were also shifted to the lower range of reference values in dry cows of the High group. This showed that there was an energy deficiency in cows of the High group prepartum. This was also supported by a decrease in the number of the herds feeding diet with low NFC after reduction of periparturient disease.

A simultaneous decrease of Alb and BUN indicates chronic shortage of protein in the diet [26]. Dietary protein deficiency also affects the incidence of ketosis and AD [7]. The high incidence of deviation below the lower limit of Ht in the dry period and Alb around calving in the High group, suggests that there was a protein deficiency not only in the dry period but also in late lactation. This protein deficiency in the dry cows was revealed by the feeding evaluation of the 17 dairy herds compared in this study. On the other hand, high levels of Alb in early lactation were observed at the first MPT in the study of these 17 dairy herds. This could be interpreted as dehydration accompanied with indigestion because the postpartum cows were fed a diet with low ADF and had no lead feeding.

Goff and Horst [12] described that three basic physiological functions must be maintained during the periparturient period if diseases are to be avoided: adaptation of the rumen to lactation diets that are high in energy density, maintenance of normocalcemia, and maintenance of a strong immune system. Generally in dairy herds, dry cows are mainly fed grass forage. In 6 of the 17 dairy herds in this study, dry cows were fed grass hay with no concentrates throughout the dry period. This led to NFC and CP deficiency. This kind of feeding may have affected the findings in the High group, which were interpreted as energy and protein deficient. Furthermore, only a few herds practiced 'lead feeding' during the transition period and many empty feed bunks were observed among many herds of the High group. This could have contributed to the high incidence of periparturient disease.

The values of all mineral indicators in the High group shifted to the lower side of the normal range.

Low concentration of Mg, basically indicates decreased dietary intake and absorption in the digestive tract. Low Mg levels are also observed with a low DMI [28]. In this study, there was a significant high incidence of deviation of Mg from the lower limit of the dry period in the High group. This was probably because of depressed DMI. During estimation of BCS, it was observed that many cows had a depressed left paralumbar fossa 2 to 3 hr after feeding. This meant that there was reduced rumen fill. Low levels of Mg may have been caused by a complex combination of factors, i.e. DMI depression due to obesity, feeding of forage with no concentrate, and reduced quantity of ration as evidenced by empty feed bunks.

Since serum Ca concentrations do not reflect dietary Ca intake [28] and about 50% of Ca circulates combined with Alb [5], the hypocalcemia observed in the dry period of the High group cows may have been due to hypoalbuminemia.

When interpreting metabolic profiles, Lee *et al.* [16] suggested that variation due to herd of origin, milk production, stage of lactation, season of year, and dietary intake of nutrients, need to be considered carefully. In herds of different milk yields, Jones *et al.* [13] concluded, that MPT was of limited value in screening such herds for potential problems or deficiencies. On the other hand, Van Saun and Wustenberg [31] described that when blood metabolite analysis is used in conjunction with animal and facility evaluation, body condition scoring and ration evaluation in a team approach, it could be a useful diagnostic tool for evaluating dairy nutritional and health status. At the time of MPT in this study, blood analysis, body condition scoring, ration evaluation, assessment of forage quality were done. Variations in metabolic components in the herds with high incidence of periparturient diseases correctly reflected the occurrence of disease. MPT is a useful tool for helping farmers recognize the importance of good feeding management.

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