Blood Hemoglobin, Plasma Iron, and Tissue Iron in Dams in Late Gestation, at Calving, and in Veal Calves at Delivery and Later

G.A.J. MILTENBURG,1 T. WENSING,1 J.P.M. van VLIET,2 G. SCHUIJT,2 J. van de BROEK,3 and H. J. BREUKINK1
Veterinary Faculty
State University of Utrecht
The Netherlands

ABSTRACT

The effect of 100 ppm of Fe in milk replacer on some hematological and tissue Fe variables was studied during the first 7 wk of the fattening period in two groups of eight calves with low or high initial blood hemoglobin concentrations. Hemoglobin concentration in calves with initially low hemoglobin increased. It decreased in those with initially high hemoglobin, but the difference remained over the experimental period. Higher mean liver Fe concentration, in some cases extremely high, and lower mean total Fe-binding capacity were found throughout the experiment in the group with the initial high hemoglobin. Of all variables, only low muscle Fe concentrations were correlated linearly with plasma Fe.

In another experiment, the relationship of some hematological and tissue Fe variables during late gestation (about 10 d prepartum), at calving in dams, and at delivery in calves was investigated. The calves showed markedly higher liver Fe concentrations at delivery than their dams just before delivery, but these liver Fe concentrations were not correlated between dam and calf. The hematological and tissue Fe variables showed a weak correlation between dams and calves during late gestation or at delivery. However, dams as well as calves were Fe-sufficient.

(Key words: iron, veal calves, dams)

Abbreviation key: Hb = blood hemoglobin concentrations, MCV = mean cell volume, PCV = packed cell volume, PI = plasma iron, TIBC = total iron-binding capacity, TIBC-SAT = saturation of the total iron-binding capacity.

INTRODUCTION

In Fe-deficient veal calves, plasma Fe (PI) concentration and transferrin saturation are low, but total Fe-binding capacity (TIBC) is high. In more severe Fe deficiency, a microcytic anemia develops (20, 28). Hematologic variables during fattening depend not only on dietary Fe supply but also on initial blood hemoglobin concentrations (Hb) and Fe stores in liver, spleen, and bone marrow (23, 28). Body Fe stores in veal calves can be reliably estimated by liver biopsy (1, 27). In veal calves, low muscle Fe concentration at the end of the fattening period is desirable because it is associated with low myoglobin and pale meat color. Muscle biopsies taken during the fattening period give information about the muscle Fe concentration during the fattening period (3, 17). The object of the present experiment was to study the influence of a diet with relatively high Fe concentration on veal calves that were either anemic or not anemic at the beginning of the fattening period. Because extremely high liver Fe concentrations were observed among the calves with normal hemoglobin in the first experiment, a second experiment was conducted to investigate the relationship between calf and dam with respect to hematological and tissue Fe variables.

MATERIALS AND METHODS

Experiment 1

Sixteen clinically normal male crossbred Friesian calves, purchased from an auction
market at about 1 wk of age, were divided into two equal groups based on their initial Hb. The calves of group A had Hb below 6.9 mmol/L (mean, 5.5 mmol/L), and the calves of group B had Hb over 7.5 mmol/L (mean, 8.4 mmol/L). Calves were housed in individual crates with slatted floors and were weighed in wk 1, 4, and 7. The experiment was between wk 1 and 7 of the fattening period. During the experimental period, all calves were fed an increasing but restricted amount of milk replacer divided into two equal feedings (Tentofeed I: 60% dried skim milk, Tentego BV, Mijdrecht, Neth.). The daily amount of milk replacer increased from 300 g at the beginning to 1500 g at the end of the experiment. The composition of the milk replacer was 24.0% protein, 16.5% fat, 42.9% lactose, 2.6% starch, 6.6% minerals and vitamins, .1% fiber, and 7.3% ash. The Fe concentration of the milk replacer was 100 mg of elemental Fe/kg (100 ppm). To achieve this, 460 mg FeSO4·7H2O (Melchemie Holland BV, Amhem, Neth.) were added to 1 kg of milk powder. Feed intake, general physical condition, and abnormalities were recorded twice daily.

During the experimental period, blood was collected weekly for determination of Hb, packed cell volume (PCV), mean corpuscular volume (MCV), PI, TIBC, and saturation of the nBC (TIBC-SAT). All blood samples were obtained between 1000 and 1200 h from the jugular vein. Liver biopsies were taken at wk 2 and 7 and muscle biopsies at wk 2, 4, and 7. Dry weights and Fe concentrations were determined.

**Experiment 2**

In Experiment 2, 53 pregnant crossbred Friesian dairy cows between 2 and 8 yr of age were used. They were purchased from an auction market at different stages of pregnancy. The experiment took place between May and October of 1988 and 1989. During the last trimester of pregnancy, the cows' only diet was pasture. Approximately 2 wk before expected calving, cows were moved to a shed and fed fresh grass, hay, and a maximum of 1.5 kg/d of concentrate. Blood was collected from the jugular vein of all cows 1 to 2 wk before their expected calving date. At the same time, a liver biopsy was taken. At calving, a second blood sample was taken from all 53 cows, and, by means of the puncture method according to Schuit (1990, unpublished data), umbilical cord blood was collected intrauterine from the umbilical vein of their calves. The calves were euthanatized through an injection of 25 ml of sodium pentobarbital into the umbilical vein by means of the same technique. Fetotomy was performed as part of veterinary obstetric education. From each calf, the liver, spleen, and a piece of muscle were collected and weighed. Dry weights and Fe concentrations were determined. In maternal and cord blood PI, TIBC and TIBC-SAT were determined. Because in some cases too little material was collected for all determinations, the number of samples varied between 45 and 53. In the second group (1989), Hb also was measured (23 samples).

**Sample Analysis**

For Hb examination, K2-EDTA was used as an anticoagulant. The Hb, PCV, and MCV were determined with an electronic cell counter (Baker Cell Counter 150® , Deventer, Neth.). The Hb was measured by the cyanmethemoglobin method (11). For the estimation of PI and TIBC, heparinized plasma was used. Plasma samples were stored at -20°C until analyzed. The PI and TIBC were measured spectrophotometrically in duplicate by means of a reagents set (J. T. Baker Chemicals BV, Deventer, Neth.). In an acidic medium, ferric Fe was released from the transferrin complex. Ascorbic acid was used to reduce the ferric Fe to ferrous state. The divalent Fe reacted with ferrozine to form a colored complex, which was measured spectrophotometrically at 560 to 580 nm. An excess of Fe was added to the sample to saturate the available binding sites on transferrin. The unbound Fe was removed by magnesium carbonate adsorption and subsequent centrifugation. The remaining Fe, representing the TIBC, was determined following the PI principle; TIBC-SAT was calculated (28).

In the calves of Experiment 1, liver biopsies were taken percutaneously from the right side just caudal to the 11th rib at about the level of the greater trochanter in calves and just caudal to the 12th rib in the adult cows. An aspiration biopsy instrument was used. The biopsy sam-
piles weighed .5 to 2.0 g. Muscle biopsies of 1.0 to 2.0 g were taken from the triceps brachii muscle of the calves. Lidocaine was administered as a local anesthetic. The complete liver and muscle biopsies were washed in a solution of physiological saline containing sodium heparin (15 IU/ml), blotted dry, and sliced before homogenization. After heating overnight at 110°C, duplicate samples of 25 mg, dry weight, were determined. Dried tissues were transferred to 30-ml teflon tubes with screw-caps (Nalgene® Brand Products, New York, NY) in which the samples were digested overnight at 70°C with 1 ml of nitric acid (70%). The Fe concentrations were measured in a clear solution of nitric acid using atomic absorption spectrophotometry.

Statistical Analysis

In Experiment 1, statistical analysis of changes over time of hematological and muscle Fe data between groups A and B were accomplished with the repeated measurements test. By means of Glim 3.77 (Royal Statistical Society, London, Engl.), transformations that were necessary to meet the statistical assumptions for data testing were selected. For PI and TIBC-SAT, a logarithmic transformation was performed. Statistical analysis of liver Fe data between groups A and B was performed with the Wilcoxon ranked sum test, and analysis of changes in time between the paired liver data was performed with the Wilcoxon signed rank test. Pearson correlations were made for the hematological and tissue Fe means.

In Experiment 2, statistical analysis of the hematological and tissue Fe data between dams and calves or between two sampling times in dams was accomplished with the paired test. Pearson correlations of the hematological and tissue Fe data were made between dam and calf. Significance was declared at P < .05 unless otherwise noted.

RESULTS AND DISCUSSION

Experiment 1

The clinical course during the experimental period was normal with the exception of mild disorders of respiratory or digestive systems between wk 1 and 3. One calf (group A) showed mild diarrhea and drank slowly. Four others, two calves of each group, showed symptoms of respiratory disease: respiratory rate >40/min, coughing, sero-mucous nasal discharge, and rectal temperature between 40.0 and 40.8°C. The mean BW of the calves in groups A and B were the same during the experimental period. Results of Hb and MCV are summarized in Figure 1. Throughout the experiment, the difference in Hb between the two groups remained significant. The changes in Hb during the experimental period, however, were different (P = .06) with an increase in the initial low Hb group and a decrease in the initial high Hb group. The difference between groups A and B almost disappeared at the end of the experimental period. These results are in agreement with previous experiments in which higher initial Hb was associated with a larger decrease during the fattening period (23). Compared with the present experiment, however, these former studies were done with lower Fe concentrations in the milk replacer and were continued to 16 wk. The rate of Hb changes induced by oral Fe supply has been found to be slow (3, 28) and to vary with the degree of anemia: the more severe the anemia, the more rapid the response (28). No difference was found between the MCV of groups A and B; but, in both groups, MCV decreased significantly (P < .01) at the same rate over the 7 wk, demonstrating that the calves developed microcytosis. Bremner and Dalgarno (3) and Katunguka-Rwakishaya et al. (15) also described progressive microcytosis in calves. However, in the experiments of Bremner and Dalgarno (3), microcytosis was observed only in response to diets with less than 40 ppm Fe. Diets with 100 ppm Fe did not result in microcytosis. It is remarkable that in spite of a slight increase in Hb in group A, the MCV in this group showed the same decrease that occurred in group B. In this context, it is important to point out that some investigators (11) considered a decrease in erythrocyte size during the first 3 to 4 mo of life to be normal in calves. It is impossible to determine which part of the decrease of MCV in the present study may be attributable to this physiologic phenomenon and which part was caused by Fe deficiency.

Figure 2 summarizes the course of PI, TIBC, and TIBC-SAT during the experimental

period. Throughout the experiment, no significant difference in PI between the two groups was found. The PI presented an irregular pattern, showing a decrease at the beginning and an increase at the end of the experimental period for both groups. Over the whole experimental period, however, the change in PI was not significant. Changes of PI over the experimental period were different between groups A and B with the mean PI in group B increasing faster than that in group A. The TIBC-SAT showed a pattern similar to PI with a difference between group A and B in the TIBC-SAT values throughout the experimental period. The decrease in PI and TIBC-SAT between wk 1 and 3 may originate, in part, from dilution due to an increase in plasma volume associated with intake of large amounts of liquid diet (14). It may also be due to the inflammatory response to disturbances to several of the calves during this period. One calf (group A) showed mild diarrhea, and four other calves (two of each group) showed mild respiratory disease. In group B, the increases of the mean PI and TIBC-SAT were associated with a decrease in mean Hb. In group A, the increase of PI and TIBC-SAT was slower than in group B and associated with an increase of the mean Hb. This suggests the use of more Fe for an increased rate of Hb synthesis in the calves with the low initial Hb. Calves with the high initial Hb appeared to be unable to increase the rate of Hb synthesis for maintaining the initial Hb level. Throughout the experiment, the TIBC in group A was higher than in group B. After a decrease at wk 2, the TIBC in both groups increased slowly to the end of the experimental period. The decrease of the TIBC in wk 2 associated with the decrease of the PI and TIBC-SAT suggests an inflammatory disease in the calves in that period (24, 28). Higher TIBC in calves with lower blood Hb agrees with earlier observations (15, 27) and is indicative of Fe deficiency (20, 28).

Figures 3 and 4 present the muscle and liver Fe concentrations in wk 2, 4, and 7. There were no differences in muscle Fe concentrations either between groups or among times. The muscle Fe determined in the present study represents mainly that Fe present in myoglobin. In the liver, Fe occurs predominantly as ferritin and hemosiderin. Muscle Fe concentrations were in the same range as described before in young veal calves (3, 17). Liver Fe

Figure 1. The course of mean blood hemoglobin concentration (O, □) and the mean cell volume (□, ○) during the experimental period in eight calves, each with initial blood hemoglobin values <6.9 mmol/L (□) and >7.5 mmol/L (○). Bars represent 1 SD from mean.

Figure 2. The course of the plasma Fe concentration (O, □), the total Fe-binding capacity (□, ○), and the percentage of the total Fe-binding capacity (TIBC-SAT) (O, □) during the experimental period in eight calves, each with initial blood hemoglobin values <6.9 mmol/L (□) and >7.5 mmol/L (○). Bars represent 1 SD from mean.
concentrations in wk 2 differed significantly \((P < .01)\) between group A and B, which was mainly due to two animals (B1 and B2). In both groups, changes in time were identical, namely, a decrease from wk 2 to 7. In group B, the decrease was significant. Figure 4 illustrates the wide variation in liver Fe concentration in group B, 167 to 5174 \(\mu\)g/g of DM (mean, 1404) in wk 2 and 61 to 1802 \(\mu\)g/g of DM (mean, 452) in wk 7. The variation in group A was smaller, 70 to 207 \(\mu\)g/g of DM (mean, 119) in wk 2 and 68 to 146 \(\mu\)g/g of DM (mean, 101) in wk 7. Calves with initially high Hb had higher liver Fe stores, a few of them extremely high, than those with initially low Hb. In all calves, liver Fe concentration decreased during the experiment; in the calves of group B, this decrease was most evident. Possibly, the calves with an initially high Hb could mobilize Fe from their liver Fe stores, thus maintaining their higher Hb more easily. A significant decrease in liver Fe concentration between the onset and end of the fattening period has been described (17). Fitzgerald et al. (6) also described a decrease in liver Fe concentration in calves between 30 and 60 d of age. Our results confirm those of Mevius et al. (17), who found a very wide range of liver Fe concentrations (81 to 2910 \(\mu\)g of Fe/g of DM) in young calves. Johnson et al. (12) found also a wide range of liver Fe concentrations (19 to 1540 ppm wet weight) in perinatal beef calves. Apparently, some young calves have extremely high liver Fe concentrations that decrease during growth. The origin of these high liver Fe concentrations is still unclear.

No significant correlation was found between liver Fe concentration and any of the hematological variables in the corresponding weeks. In wk 4, a high correlation was found between muscle Fe concentration and PI in both groups \(r = .86\) in group A, \(r = .85\) in group B), whereas a high correlation between muscle Fe concentration and Hb was found only in group B \(r = .87\). The mean muscle Fe concentration in the present study was lowest in wk 4 (42 \(\mu\)g/g of DM in group A and 51 \(\mu\)g/g of DM in group B) Only in this week of the fattening period were Hb and PI correlated with muscle Fe concentration. Significant correlations between muscle Fe concentration and the color of the meat \(r = .418\) or PI \(r = .481\) have been described in calves at the end of the fattening period (21 to 23 wk). The muscle Fe concentrations at that time varied from 20 to 50 \(\mu\)g/g of DM (27). Apparently, only at low muscle Fe concentrations does PI give reliable information about muscle Fe status. This may result from the almost complete exhaustion of Fe stores, making mobilization of Fe unlikely and making PI a better reflection of muscle Fe concentration.

Experiment 2

In Table 1, some biochemical variables that provide information about the Fe status in dams and their calves are given. The means for Hb, PI, TIBC, and TIBC-SAT of the calves and dams were within the range of reference values described for female Holstein cattle of
BLOOD AND TISSUE IRON STATUS IN CALF AND DAM

TABLE 1. Some body Fe variables in dams approximately 10 d before delivery and in dams and their calves at delivery.

<table>
<thead>
<tr>
<th></th>
<th>Dam before delivery</th>
<th>Dam at delivery</th>
<th>Calf at delivery</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( \bar{X} )</td>
<td>SD</td>
<td>( \bar{X} )</td>
</tr>
<tr>
<td>Hemoglobin, ( \text{mmol/L} )</td>
<td>7.7(^{b})</td>
<td>.4</td>
<td>8.3(^{a})</td>
</tr>
<tr>
<td>Plasma Fe, ( \mu\text{mol/L} )</td>
<td>21(^{a})</td>
<td>7</td>
<td>16(^{b})</td>
</tr>
<tr>
<td>TIBC, ( \mu\text{mol/L} )</td>
<td>59(^{b})</td>
<td>8</td>
<td>58(^{b})</td>
</tr>
<tr>
<td>TIBC-SAT, %</td>
<td>36(^{a})</td>
<td>12</td>
<td>28(^{b})</td>
</tr>
<tr>
<td>Liver Fe, ( \mu\text{g/g DM} )</td>
<td>253(^{b})</td>
<td>113</td>
<td>ND(^{2})</td>
</tr>
<tr>
<td>Muscle Fe, ( \mu\text{g/g DM} )</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>Spleen Fe, ( \mu\text{g/g DM} )</td>
<td>ND</td>
<td>ND</td>
<td>917</td>
</tr>
</tbody>
</table>

\(^{a,b}\)Means in row with different letters differ (\( P < .01 \)).

\(^{1}\)Hemoglobin samples: \( n = 23 \); all other samples, \( n = 45 \) to 53; TIBC = total Fe-binding capacity; TIBC-SAT = saturation of the total Fe-binding capacity.

\(^{2}\)ND = Not determined.

various ages (16) and male crossbred calves at 5 d after birth (5). A statistically significant difference was found for Hb, PI, and TIBC-SAT (\( P < .01 \)) in the dams between wk 1 and 2 before and at delivery. For humans (25) and also for cows (13), maternal Hb is increased at the time of birth compared with values measured during the last weeks of pregnancy. Physiological changes during pregnancy and the stress of delivery have been mentioned as possible causes for these hematological changes. In cows, from which blood samples were taken every 30 d during pregnancy, the lowest Hb was found at d 240 of gestation and the highest at 3 to 5 h after birth (13). Whether low Hb was due to hemodilution, as has been mentioned in humans around wk 34 of gestation (25), is unknown for cows. The low PI at delivery may be due to incorporation of Fe in the fetus (26).

A difference (\( P < .01 \)) between dams before and calves at delivery was found for Hb, TIBC, and liver Fe concentrations (Table 1). At delivery, however, there was a significant difference between all determined parameters of dams and calves except Hb. At delivery, as well as during late pregnancy, the hematological status of the cow is subject to physiological changes, making it difficult to choose the best time of sampling for comparing blood Fe status in dams and their calves. In the calves, Hb, PI, TIBC, and liver Fe concentration were higher than in their dams before or at delivery (Table 1), suggesting transport of Fe from dam to calf during pregnancy in favor of the calf. The very high liver Fe concentrations found in calves in comparison with their dams is striking. These high liver Fe concentrations with a very wide range are comparable with the liver Fe concentrations found at wk 2 of Experiment 1 in the initial high Hb group calves and the liver Fe concentrations reported in perinatal beef calves (12). The Hb in Experiment 2 were high compared with Experiment 1; the mean Hb was 8.6 mmol/L, and the minimum value was 6.8 mmol/L. Comparable observations of high liver Fe concentrations in fetal livers have been described by Gooneratne and Christensen (7). In that study, fetal liver Fe concentrations during the entire pregnancy were six times higher than the corresponding concentrations in the dam’s liver. The higher values of Hb and PI in the calves compared with those in their dams were in contrast to previous studies (9, 21). This may due to the fact that blood samples in our study were taken from the calves at the moment of calving, whereas in the experiments of Hibbs et al. (9) and Tennant et al. (21) they were taken between 1 and 3 d of age. High Hb, PCV, and PI at birth and an immediate decline with age have been described earlier (10, 11). Already within 4 d after birth, decreases in Hb, PCV, PI, and TIBC-SAT were observed due to expansion of plasma volume by colostrum intake. Decreased PI after birth was suggested to be the result of insufficient Fe intake and slow mobilization of Fe stores (8).

Table 2 presents correlation coefficients illustrating the relationship between some
TABLE 2. Correlation coefficients for relation between some body Fe variables in dams before (Group 1) or at (Group 2) delivery and in their calves at delivery.

<table>
<thead>
<tr>
<th>Dam Group</th>
<th>Hb</th>
<th>PI</th>
<th>TIBC</th>
<th>Liver Fe</th>
<th>Muscle Fe</th>
<th>Spleen Fe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hb₁</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>.12</td>
<td>-.04</td>
<td>.03</td>
<td>-.16</td>
<td>-.04</td>
<td>-.18</td>
</tr>
<tr>
<td>2</td>
<td>.06</td>
<td>.05</td>
<td>-.11</td>
<td>-.16</td>
<td>.02</td>
<td>-.09</td>
</tr>
<tr>
<td>PI</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>.16</td>
<td>.22</td>
<td>-.06</td>
<td>.26</td>
<td>.36*</td>
<td>.12</td>
</tr>
<tr>
<td>2</td>
<td>.16</td>
<td>.33*</td>
<td>.16</td>
<td>.33*</td>
<td>.22</td>
<td>.15</td>
</tr>
<tr>
<td>TIBC</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>-.05</td>
<td>.16</td>
<td>.42*</td>
<td>-.13</td>
<td>-.29*</td>
<td>-1.1</td>
</tr>
<tr>
<td>2</td>
<td>.27</td>
<td>.14</td>
<td>.54*</td>
<td>-.18</td>
<td>-.09</td>
<td>-.13</td>
</tr>
<tr>
<td>TIBC-SAT</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>.28</td>
<td>.14</td>
<td>-.28</td>
<td>.33*</td>
<td>.51*</td>
<td>.18</td>
</tr>
<tr>
<td>2</td>
<td>.05</td>
<td>.36*</td>
<td>.05</td>
<td>.41*</td>
<td>.15</td>
<td>.31*</td>
</tr>
<tr>
<td>Liver Fe</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>.06</td>
<td>.07</td>
<td>.18</td>
<td>.02</td>
<td>.01</td>
<td>.23</td>
</tr>
</tbody>
</table>

*Significant correlation (P < .05).

1Hb = Blood hemoglobin; PI = plasma Fe; TIBC = total Fe-binding capacity; TIBC-SAT = saturation of the total Fe-binding capacity. Hb samples, n = 23; all other samples, n = 45 to 53.

Hematological variables and tissue Fe concentrations found in dams before or at delivery and those found in their calves at delivery. The highest correlations were observed between liver Fe of the calf and TIBC-SAT of the dam before delivery (r = .51) and between TIBC of calf and dam at delivery (r = .54). The normal values of the TIBC in calves and dams associated with normal values for PI and Hb assume Fe sufficiency in calves and dams. On the contrary, in humans the mother is commonly in a state of Fe deficiency at the end of pregnancy, whereas the fetus or neonatal baby is in a state of Fe sufficiency (22, 28). Correlation between TIBC-SAT of the dam around 10 d before delivery and the liver Fe concentration of the calf at delivery may originate from a state of Fe sufficiency in the dam and an efficient Fe transfer from the dam to the liver in the calf during pregnancy. The weak correlations between liver Fe concentrations in dams and calves are remarkable (Table 2). It is possible that the main sites of Fe deposition in the neonatal calf and the dam are not the same. In the calves, Fe stores in the liver were found to be higher than those in the spleen. Blum and Zuber (2) described liver and spleen Fe concentrations in adult cows. They found highest mean Fe concentrations in the spleen: in cows 1 to 3 yr of age, 3067 µg/g of DM; in cows 4 to 6 yr of age, 20,614 µg/g of DM; and in cows 7 to 9 yr of age, 37,040 µg/g of DM. In the liver, they found mean Fe concentrations of 128 µg/g of DM in cows 1 to 3 yr of age, 235 µg/g of DM in cows 4 to 6 yr of age, and 223 µg/g of DM in cows 7 to 9 yr of age. The mean age of the cows in the present study was 4.5 yr. The time of sampling may also have played an important role. The aforementioned physiological changes within dam and fetus around delivery made it difficult to choose the right sampling time. In addition, not much is known about the mechanism of placental Fe transport in the cow. In experiments with rats during pregnancy (22), increased fetal and decreased maternal liver Fe were found. On the basis of that result, it was concluded that in rats Fe was transferred from maternal liver to fetal liver. Differences in placental Fe transport, depending on the hemochorial, endotheliochorial, or epitheliochorial type of placenta, have been described (18). Cows, horses, and pigs have an epitheliochorial type of placenta, whereas rats and humans have a hemochorial type of placenta. From porcine placenta tissue, a progesterone-inducible protein has been isolated. This protein, named uteroferrin, is proposed to have a role in transfer of Fe to the fetal piglet between d 60 and 75 of pregnancy. A uteroferrin-like protein was found in horses (4, 18). These findings imply that a similar mechanism exists in other animals with an epitheliochorial placentalation such as the cow. Also, a special period during pregnancy may be important for placental Fe transport.
CONCLUSIONS

Experiment 1 showed that initial Hb in veal calves is paralleled with TBIC and liver Fe concentration. Differences remained over 7 wk when the calves were fed 100 ppm of Fe. In spite of this relatively high Fe supplementation, initial Hb ≥8.4 mmol/L were not maintained during the 7-wk fattening period. This means that 100 ppm of dietary Fe during the first 6 wk of fattening is insufficient to build adequate Fe stores. However, in calves with an initial Hb ≤5.5 mmol/L, a milk replacer diet with 100 ppm Fe causes an increase in Hb of 1 mmol/L during 7 wk. It may be true that calves with high liver Fe stores primarily use these stores and that calves with low Fe stores primarily use dietary Fe for Hb synthesis.

In veal calves, only low muscle Fe concentrations showed a linear correlation with PI.

The results of Experiment 2 suggest that significant correlations exist between calf and dam with respect to either Hb or Fe status during late gestation or at delivery. The extremely high liver Fe concentrations found in some neonatal or young calves were not related to the liver Fe concentrations in the dams at the end of pregnancy. The variable best correlated with the liver Fe concentration of the neonatal calf was the TIBC-SAT of the dam during the last weeks of pregnancy.

To examine the relation of Fe status between cows and calves, more frequent sampling during pregnancy and around delivery and more knowledge about placental Fe transfer will be required. In our study, no Fe deficiency symptoms were found in the cows or in their calves at delivery.

ACKNOWLEDGMENTS

Thanks are extended to J.J.M. Marx for critical comment and to J. ten Brocke, J. van Dasselar, D. Mevius, L. Overbeek, and A. Westeneng for technical assistance. The project was supported by Tentego BV, animal feed specialties Import/Export, Mijdrecht, Neth.

REFERENCES

plasma iron concentration and liver and muscle iron concentration in veal calves during the fattening period in relation to growth and colour of the meat at slaughter. Page 334 in Proc. 6th Int. Symp. Vet. Lab. Diagnosticians, Amsterdam, Neth.


19 Reference deleted in proof.


