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Original article

Evaluation of venous blood gas levels, blood chemistry and haemocytometric parameters in milk fed veal calves at different periods of livestock cycle

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Abstract

An evaluation of blood chemistry profile in relation to specific stages of livestock cycle can help better understand variations in physiological conditions in order to adjust management systems to animal needs. In addition to basal hematological investigation, the acid-base balance and blood gases are essential tools in evaluating metabolism in calves. The relationship between blood gas parameters, diet and growth should be further investigated.

The aim of this study was to evaluate changes in acid-base status, blood gases, serum chemistry and hematological parameters in veal calves at different periods of livestock cycle.

One hundred twenty-eight healthy cross breeding calves were enrolled in a farm in North-East Italy. Blood samplings were carried out from the jugular vein on day 1 (t1), 60 (t2) and 150 (t3) after arrival. Blood gas analysis was performed and hematological parameters were evaluated. One-way ANOVA and Tukey-Kramer post-hoc test were performed to assess differences between blood parameter values at the different periods.

The main differences in blood gas parameter levels during the livestock cycle concerned pH, Base Excess and HCO_3 with higher values recorded in t3. Urea, creatinine, gamma-glutamyl transpeptidase and bilirubin mean values were significantly higher in t1 than in t2 and t3. Aspartate aminotransferase increased from t1 to t2 and t3. Alkaline Phosphatase was higher in t2. Fe levels severely dropped in t2 and in t3, and the decrease led to a restrained but significant reduction in haemoglobin values. A correspondent decrease in the other haemocytometric parameters was found.

Key words: breeding, blood gas analysis, calf, hematology

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Introduction

Veal calves are raised in small groups within closed barns with wooden fully slatted floors to ensure animal welfare (Cozzi et al. 2009). Animals are bucket-fed with milk replacers throughout the entire livestock cycle. European Council Directive 97/2/EC states that calves are provided with increasing amounts of fibrous feed from 50 g/head/d at 8 weeks of age to 250 g/head/d at 20 weeks. A low iron concentration feeding plan is provided to the calves in order to confer the characteristic pale pink color to meat due to low concentration of myoglobin in muscle. Because of the feeding plan administered to calves, the most common sub-clinical condition in milk-fed veal calves is iron deficiency anemia (Lindt and Blum 1994). Iron restriction can impair welfare and cause the onset of diseases due to reduced cell-mediated immune reactions and increased infection rates (Gygax et al. 1993). Iron deficiency can cause an increase in lactate formation (Lindt and Blum 1993) and a decrease in average daily gain due to a reduction in feed intake (Völker et al. 1996). Moreover, other consequences of marked iron deficiency are reduced O_2 transport (by hemoglobin), O_2 storage (by myoglobin), and O_2 utilization (by enzymes of the respiratory chain) (Lindt and Blum 1993). In this regard, European Council Directive 2008/119/EC states that calf food must contain sufficient iron to ensure an average blood hemoglobin level of at least 4.5 mmol/L (7.3 g/dL).

Bovines are susceptible to blood acid-base imbalance caused by addition, subtraction or retention of acids and bases, which may lead to metabolic or respiratory acidosis or alkalosis. Metabolic acidosis is usually due to the increase of fixed acids secreted by kidneys or to a loss of bicarbonate. A decrease in fixed acids or an excessive administration of alkaline salts may cause metabolic alkalosis. Respiratory acidosis and alkalosis are instead caused by hypo- or hyper-ventilation, respectively (Dirksen et al. 2004). Furthermore the high presence of carbohydrates (lactose > 5.0%) in milk replacer diet may lead to metabolic acidosis (Dirksen et al. 2004).

The evaluation of blood gas parameters represents a valid tool to assess metabolic and respiratory status in animals. Arterial sampling could be technically difficult to realize in field (Fisher et al. 1980, Gökel et al. 2000), so venous sampling is often preferred. Reliable values can be obtained for blood pH, base deficit, HCO_3 and pCO_2 in venous blood compared to the corresponding values in arterial blood in healthy calves (Pickel et al. 1989, Gunes and Atalan 2006). As regards values of pO_2 there is a significant difference between levels of pO_2 in venous and in arterial blood (Nagy et al. 1994).

During the life cycle of veal calves, changes in diet, age, body growth, occurrence of diseases and the administration of alkalinizing substances could affect normal blood acid-base balance and blood parameter levels. An extended survey on hematological profile could be useful to monitor the physiological response on the risk of anemia and metabolic acidosis in the breeding of milk-fed veal calves. The aim of this study was to evaluate changes in acid-base status, blood gases, serum and hematological parameters in veal calves at different time points of livestock cycle.

Materials and Methods

Animals

One hundred twenty-eight healthy cross breeding calves (43 Holstein Friesian x Brown Swiss; 40 Holstein Friesian x Belgian Blue; 45 Holstein Friesian x Chairolaise) were enrolled in a farm in North-East Italy. The animals were housed in a single barn after transportation from different districts of Veneto.

The mean age (± SD) of calves was 29 ± 10 days and the mean weight (± SD) was 72.95 ± 3.72 kg upon arrival at the farm. Livestock cycle lasted 150-

Table 1. Feeding plan and chemical composition of diets used in the farm during livestock cycle of milk fed veal calves.

	t1	t2	t3
Milk (L/Meal)	3	6	8
CP (% DM)	23	19.9	19.9
Fats (% DM)	20	18.6	18.6
Cellulose (% DM)	9	0.17	0.17
Ash (% DM)	0.8	7.3	7.3
Vitamine A (kIU/Kg)	25	25	25
Vitamine D3 (kIU/Kg)	4.00	3.5	3.5
Vitamine E (kIU/Kg)	119.2	114.1	114.0
$NaHCO_3$ (% DM)	0	3	5
Fibrous feed (Kg/day)		0.2	0.7
Composition:			
Corn (% total)	–	63.1	63.1
Straw (% total)	–	29.1	29.1
Glycerol (% total)	–	2.9	2.9
Barley (% total)	–	1.9	1.9
Commercial vitamins and minerals complex (%t otal)	–	3	3
Analysis:			
Proteins (% DM)	–	8.67	8.67
Fats (% DM)	–	3.54	3.54
Cellulose (% DM)	–	6.39	6.39
Ash (% DM)	–	3.99	3.99
Na (% DM)	–	0.912	0.912
Vitamine E (mg/Kg)	–	150	150
Urea (mg/Kg)	–	4224	4224

DM: dry matter.

-160 days. Mean weight before slaughter was 261.21 ± 26.74 kg. All the animals were fed milk replacers twice a day throughout the livestock cycle. The amount of milk provided was gradually increased from 3 to 8 L/meal. Three different milk formulas were administered depending on the stage of the livestock cycle. Based on European Council Directive 2008/119/EC fibrous feed was also administered (Table 1).

Three surveys were carried out on day 1 (t1), 60 (t2) and 150 (t3) after arrival.

Health status was monitored in each period. The faeces status was evaluated in order to exclude the occurrence of diarrhea. Auscultation of the abdomen was performed to verify the incidence of rumen drinking. Rectal temperatures were recorded too.

Blood gas analysis

During each survey (tl, t2, t3), blood samplings were carried out from the jugular vein. Heparinized syringe 3cc and 23G x 1'' needles were used. Syringes containing blood samples were immediately plugged, put in iced water and transported to the laboratory within 10 minutes. The syringes were removed from ice water immediately before analysis, rolled between the palms for 5s, and turned three times upside-down to ensure adequate mixing. Seventy µL of blood samples were aspirated from the blood gas analyzer directly from the syringes by means of a special adapter. Blood gas analysis was performed using Stat Profile® pHOx® (Nova Biomedical, Waltham, MA) analyzer. The pH, pCO_2, pO_2, HCO_3, Base Excess in the extracellular fluid (BEecf), Ca^{++}, Na^+, K^+ and Lactate were analyzed. The pH, pCO_2 and pO_2 measured values were corrected for rectal temperature (pH Tc, pCO_2 Tc, pO_2 Tc).

Blood chemistry and haemocytometric analysis

In each period (tl, t2, t3), blood samples were taken from the jugular vein with 20G needles and collected into 10 ml tubes (VACUETTE®) for biochemical investigation, and into 10 ml dry tubes (VACUETTE®) containing K_3EDTA (Tripotassium Ethylene Diamine Tetra-acetic Acid) for haemocytometric analysis. Blood samples in dry tubes were allowed to clot at room temperature and then centrifuged at 3000 g for 10' for serum separation. Serum was transferred into plastic 1.5 ml tubes and stored at -20°C until analysis. Blood chemistry investigation was carried out by means of the automated Clinical Chemistry Analyzer's Konelab 60I (Thermo Electron Corporation). Aspartate aminotransferase (AST), gamma-glutamyl transpeptidase (GGT), alkaline phosphatase (ALP), conjugated and total bilirubin, urea, creatinine, Ca, P, Mg, Fe, total proteins (TP) and Glucose were analyzed.

Blood samples with anticoagulant were carried to the laboratory at a temperature of + 4°C and immediately analyzed. Red blood cells (RBC), hemoglobin concentration (HGB), hematocrit (HCT), mean corpuscular volume (MCV) and mean corpuscular haemoglobin (MCH) were measured. Haemocytometric analyses were performed by means of an automated cell counter with veterinary software Cell-Dyn 3700 (Abbott Laboratories, Abbott Park, Illinois, USA).

Statistical analysis

All statistical analyses were performed using SigmaStat 3.5 (Statsoft) software. Normality of data distribution was assessed by Kolmogorov-Smirnov test. Repeated-Measures Two-Way Analysis of Variance (ANOVA) followed by multiple comparison Tukey-Kramer post-hoc test was performed to assess the effects of breed and period on blood parameters. A probability level of $p<0.05$ was considered significant.

Results

No signs of disease were found in the veal calves. Calves faeces status indicated that the animals had no diarrhea and auscultation of the abdomen excluded the occurrence of rumen drinking.

Mean values for rectal temperatures were 39.19 ± 0.57°C in t1, 39.13 ± 0.67°C in t2 and 39.01 ± 0.58°C in t3.

No significant differences were found between the three breeds in the blood gas and hematological parameters investigated.

Table 2 summarizes the mean values (± SD) of blood gas parameters obtained in the veal calves at different periods of breeding cycle. The main differences in blood gas parameter levels during the livestock cycle concerned pH, BEecf and HCO_3. The pH and BEecf mean values were normal in all the periods according to reference ranges, although a significant increase ($p<0.001$) was highlighted as the livestock cycle went ahead. As regards HCO_3 a significant effect was found between the periods. Levels of HCO_3 were in the normal range in t1 and t2 but higher values were recorded in t3 ($p<0.001$).

Table 2. Blood gas parameter values (Mean ± Standard Deviation) in milk fed veal calves at different periods of livestock cycle.

Blood gas parameters	t1	t2	t3	p[1]
pH Tc	7.41 ± 0.02^{A}	7.43 ± 0.03^{B}	7.44 ± 0.02^{B}	***
HCO_3 (mmol/L)	30.28 ± 1.97^{A}	32.65 ± 3.02^{B}	34.62 ± 5.12^{C}	***
BEecf (mmol/L)	5.90 ± 2.15^{A}	8.47 ± 2.94^{B}	10.67 ± 3.12^{C}	***
pCO_2 Tc (kPa)	6.49 ± 0.42	6.63 ± 0.31	6.77 ± 1.00	ns
pO_2 Tc (kPa)	5.67 ± 0.85	5.51 ± 0.62	5.39 ± 0.47	ns
Na^+ (mmol/L)	135.01 ± 1.80	133.92 ± 1.93	136.99 ± 1.62	ns
K^+ (mmol/L)	4.70 ± 0.44^{A}	4.22 ± 0.32^{B}	3.97 ± 0.21^{C}	***
Ca^{++} (mmol/L)	1.26 ± 0.05	1.29 ± 0.04	1.30 ± 0.04	ns
Lactate (mmol/L)	1.24 ± 0.32	1.20 ± 0.48	1.18 ± 0.48	ns

[a] Differences among periods according to ANOVA are shown in p column. *p<0.05, **p<0.01, ***p<0.001, ns = non-significant. [A, B, C] different letters in the same line show significant differences among periods according to post-hoc Tukey-Kramer test (p<0.05).

Table 3. Blood chemistry parameter values (Mean±Standard Deviation) in milk fed veal calves at different periods of livestock cycle.

Blood chemistry parameters	t1	t2	t3	p[1]
Ca (mmol/L)	2.53 ± 0.47	2.69 ± 0.25	2.58 ± 0.3	ns
P (mmol/L)	2.88 ± 0.70	3.09 ± 0.56	2.9 ± 0.46	ns
Mg (mmol/L)	0.86 ± 0.18	0.85 ± 0.6	0.77 ± 0.12	ns
Fe (µmol/L)	21.24 ± 12.00^{A}	11.46 ± 6.15^{B}	6.11 ± 2.76^{C}	***
Urea (mmol/L)	7.32 ± 2.12^{A}	3.32 ± 1.14^{B}	3.53 ± 0.91^{B}	***
Creatinine (µmol/L)	97.61 ± 24.4^{A}	86.17 ± 15.25^{B}	75.50 ± 16.01^{C}	***
TP (g/L)	58.7 ± 11.7	56.5 ± 6.5	59.5 ± 8.0	ns
Conjugated Bilirubin (µmol/L)	3.08 ± 1.88^{A}	1.88 ± 1.71^{B}	0.85 ± 0.34^{C}	***
Total Bilirubin (µmol/L)	4.96 ± 2.74^{A}	4.79 ± 2.39^{B}	3.93 ± 1.37^{C}	*
GGT (U/L)	44.73 ± 43.42^{A}	20.78 ± 8.38^{B}	20.12 ± 8.00^{B}	***
AST (U/L)	52.70 ± 32.56^{A}	58.38 ± 10.86^{B}	61.86 ± 20.56^{B}	***
ALP (U/L)	235.86 ± 112.85^{A}	376.75 ± 196.40^{B}	247.05 ± 91.39^{A}	***
Glucose (mmol/L)	5.04 ± 1.94	4.86 ± 1.88	5.18 ± 1.36	ns

[a] Differences among periods according to ANOVA are shown in p column. *p<0.05, **p<0.01, ***p<0.001, ns = non-significant. [A, B, C] different letters in the same line show significant differences among periods according to post-hoc Tukey-Kramer test (p<0.05).

The blood cations that were investigated did not statistically differ between the periods except K^+, which significantly decreased from t1 until t3 (p<0.001).

No statistical differences for blood gas pressure were detected.

Table 3 summarizes chemistry profile values obtained from the veal calves at three different periods of the livestock cycle. Mean and standard deviations were reported for each tested parameter.

The main differences in biochemical parameters concerned urea, creatinine, conjugated and total bilirubin, GGT, AST, ALP, and Fe. A drop in urea mean values was recorded from t1 to t2 (p<0.001), then the mean value remained constant at t3. Creatinine (p<0.001), conjugated (p<0.001) and total bilirubin (p<0.05) and GGT (p<0.001) mean values were statistically higher in t1 than in t2 and t3. AST significantly increased in t2 and t3 with respect to t1 (p<0.001). The highest level of ALP was found in t2 (p<0.001), then it decreased and values in t3 were similar to those found in t1.

Serum Fe levels were higher in t1 than in t2 and in t3 (p<0.001). The mean value recorded in t3 was lower than the minimum value of the normal range.

Figure 1 shows the trend of haemocytometric parameters according to sampling periods. A significant reduction in HGB, RCB and MCH values was recorded in t3 with respect to those determined in t1 and t2 (p<0.001). Significant differences were found among the three time points in HCT and MCV (p<0.001).

Discussion

Blood pH represents the overall index of acid-base status. The pH values range between 7.35 and 7.45 in healthy calves. The mean values for pH Tc were within the normal range in all the periods with

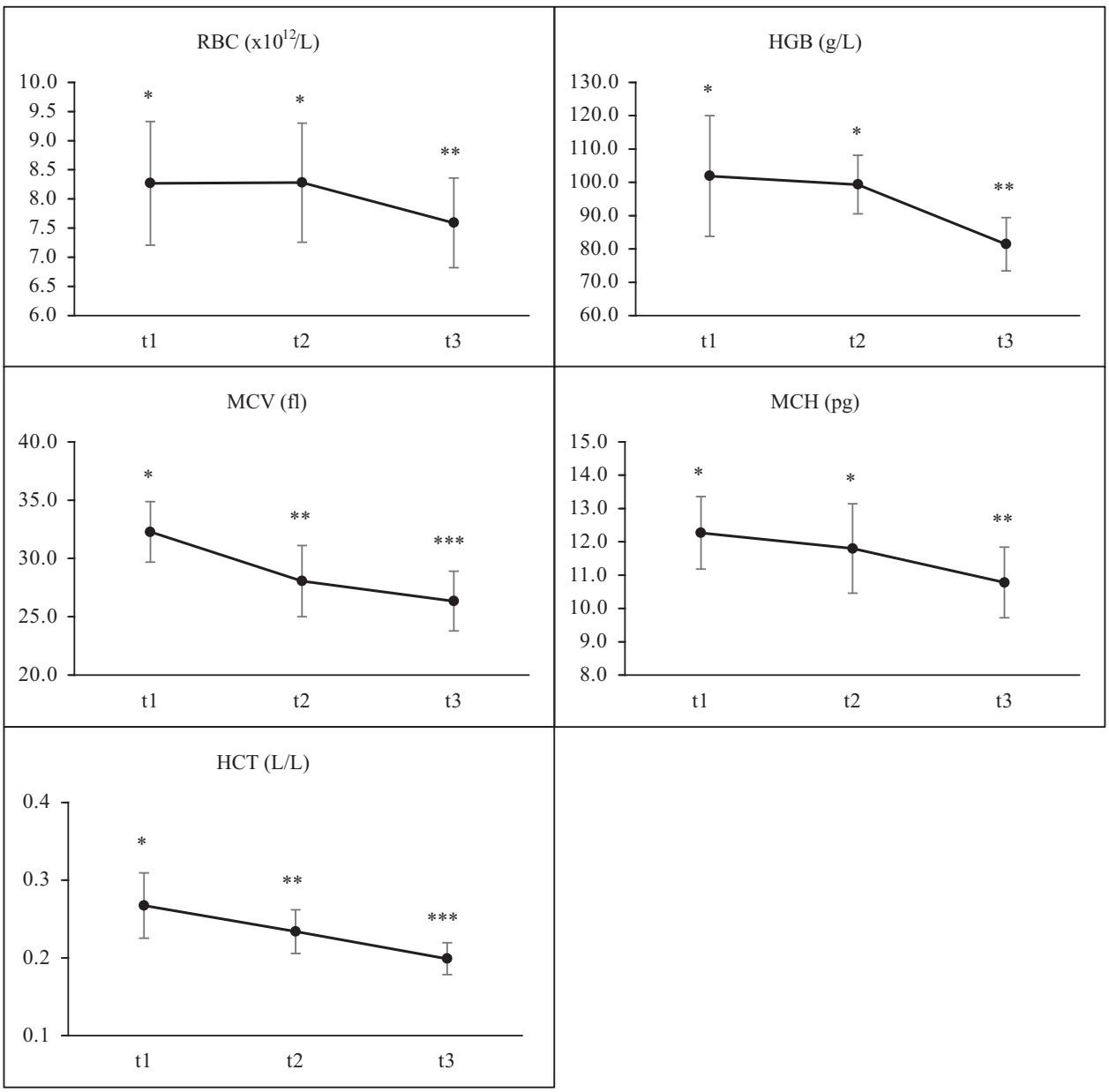

Fig 1. Haemocytometric parameters (Mean ± SD) in milk fed veal calves at different periods of livestock cycle; RBC: Red Blood Cells; HGB: Hemoglobin concentration; MCV: Mean Corpuscular Volume; MCH: Mean Corpuscular Haemoglobin; HCT: Hematocrit; *,**,*** Different asterisks denote significant differences between periods according to post-hoc Tukey-Kramer test.

a significant augmentation from t1 to t3. Blood acid-base balance is affected by respiratory and metabolic components. While pCO2 represents the respiratory component, HCO_3^- and BEecf denote the metabolic constituents of acid base imbalance. The HCO_3^- mean value for t1 in this study corresponded with the values found by Naylor (1987): 30.9 ± 2.8 mmol/L. A significant HCO_3^- increase was detected in the calves in t2 and t3. This augmentation could be probably due to the daily administration of $NaHCO_3$ with the diet after 40 days of breeding.

Normal values for BEecf are close to zero and negative values indicate metabolic acidosis. The normal range of base excess in large animals is 0-6 mmol/L (Radostis et al. 2007). However, Naylor (1989) reported that healthy calves had a BEecf from 11.8 to 1 mmol/L. Moreover milk-fed calves are known to have higher values of BEecf than conventionally fed calves (Reece 1980). BEecf mean values for calves in this study were normal according to literature in all the periods. However, statistical analysis showed extremely significant differences among

periods with the highest values in t3. This trend is in accordance with HCO_3^- increase. Slightly increasing trends of pH Tc, HCO_3^- and BEecf in relation to age were recorded by Nagy et al. (2003) in conventionally fed calves.

No statistical differences were found for pO_2 Tc and pCO_2 Tc values at different periods. Most previous studies reported values obtained from arterial rather than venous blood because the partial pressures of carbon dioxide (pCO_2) and oxygen (pO_2) are affected by the uptake of carbon dioxide and the release of oxygen in the peripheral tissues (Waizenhöfer and Mülling 1978). Nagy et al. (1994) performed a comparison of arterial and venous blood samples which revealed statistically significant differences in pH, pCO_2 and pO_2 values; no significant differences were observed in the previous study for HCO_3^- and BEecf. Bleul et al. (2007) showed a strong correlation between the BEecf, HCO_3^- and pH values of arterial and venous blood, but only weak correlation between the pO_2, pCO_2. Venous blood analysis is therefore not reliable for the evaluation of pulmonary gas exchange and reliable measurements of these variables can only be obtained from arterial blood samples (Nagy et al. 2001, Bleul et al. 2007). A correlation (r^2=87.5%) between pCO_2 in arterial and venous blood was found by Gunes and Atalan (2006) in clinically healthy cross-bred calves. In this study, pCO_2 mean values were lower in all the periods than the 7.13 ± 0.84 kPa reported by Cambier et al. (2002). This result suggests the absence of respiratory alkalosis and supports the hypothesis that pH increase could be caused by the diet administered.

Normal levels were obtained in all periods for hematic K^+ (3.9-5.8 mmol/L; Radostis et al. 2000). In t2 and t3 a progressive significant decrease was observed compared to the mean K^+ value in t1. This result could be a consequence of pH increase. It is known that in metabolic alkalosis K^+ level tends to shift from the extracellular to the intracellular space. The consequence is a trend to hypokalemia even if this may not necessarily be a sign of deficiency of the total level of K in the body (Radostis et al. 2007).

As regards the other electrolytes and minerals analyzed, no statistical differences were detected among the periods for Na, Ca, Mg and P, and the values recorded were within the normal ranges for adults (Radostis et al. 2000) with the exception of P. The recorded amounts of P higher in calves than in the adults are caused by the growth hormone, which is high in the growing animals and enhances renal phosphate reabsorption (Rosol and Capen 1997).

Electrolyte imbalance is often associated with diseases of the alimentary tract. Normal values for electrolyte found in this study are thus in accordance with the absence of diarrhea.

Most of blood biochemical and haemocytometric parameters analyzed in this study may be considered normal according to the physiological ranges presented in the literature but several parameter mean values change between the periods.

Regarding renal parameters, urea serum mean values dropped from t1 to t2 and t3 and a gradual decrease was found for creatinine. Values obtained for urea in t2 and t3 correspond with the data reported by Egli and Blum (1998) in conventionally fed calves (3.8 ± 0.16 mmol/L). Urea mean levels obtained in t1 were higher than those determined in previous findings (Egli and Blum 1998, Mohri et al. 2007), even if only 14.8% of the animals showed levels higher than the reference range for adults reported by Radostis et al. (2000). Urea serum level changes might be related to the level of protein intake (Mohri et al. 2007). Conversely, creatinine concentration is slightly affected by diet or protein catabolism but may be slightly affected by muscle mass (Russell and Russel 2007). The creatinine values obtained were within the ranges reported by Egli and Blum (1998) (70-130 µmol/L) and by Radostis et al. (2000) (67-175 µmol/L), and the progressive reduction could be due to changes in muscle mass.

Sampling time had a significant effect on bilirubin. Conjugated bilirubin markedly decreased from t1 to t3 and a diminution of total bilirubin in t3 was recorded. Values were always in reference range for adult cattle [0.70-7.54 and 0.17-8.55 µmol/L for conjugated and total bilirubin, respectively (Radostis et al. 2000)], however, lower values were recorded by Mohri et al. (2007). Egli and Blum (1998) recorded high values for total bilirubin in suckling simmental calves during the first days of life probably due to the destruction of fetal RBC in the liver and spleen.

The GGT mean values were higher than the normal range values reported for cattle (6.1-17.4 U/L; Radostis et al. 2000) and values recorded by Dubreuil and Lapierre (1997) (11.4-16.7 U/L). Higher values could be considered normal in young calves since GGT is an enzyme greatly present in colostrum administered to calves (Bostedt et al. 1983). In calves, the GGT activity can be more than 200-fold higher than the upper limit of the adult reference interval during the first 3 days after birth. Typically, a three to four-fold decrease occurs in this activity by the end of the first week and the activity gradually continues decreasing to the adult reference interval by 6 to 13 weeks of age. Alberghina et al. (2016) found that GGT was correlated with the growing phase in beef cattle.

The AST values obtained were similar to those reported by Dubeuil and Lapierre (1997) (51.3-60.1 U/L). Egli and Blum (1998) reported that the activity of AST decreased after the first week, then slowly increased from the 42nd to the 84th day of life. Mohri et al. (2007) observed an increase in AST activity from the 14th to the 84th day of age. A gradual significant augmentation during the livestock cycle was found also in this study.

The ALP level manifested a significant increase in t2. This is consistent with previous reports of Mohri et al. (2007) in which the ALP activities rose from the 28th to the 84th day of age. Increasing levels of ALP may be related to endogenous sources such as bone growth in calves (Zanker et al. 2001). In contrast with previous findings (Egli and Blum 1998, Mohri et al. 2007) the ALP levels were within the adult range values (0-500 U/L; Radostis et al. 2000).

Low Fe intake with milk replacer diets in veal calves is necessary to produce white meat. However, a consequent serum Fe deficiency could have important metabolic effects. In all the sampling periods, the serum Fe was lower than the reference value of 10-29 µmol/L for adult cattle reported by Radostis et al. (2000). According to the literature, calves with Fe deficiency present reduced insulin concentrations (Ceppi and Blum 1994). Glucose levels in this study were slightly higher than the reference values reported for adults (1.9-3.8 mmol/L; Radostis et al. 2000) even if no statistical differences were detected among sampling periods. Thus the high serum glucose levels determined in this study could depend on the observed Fe deficiency.

An effect of low Fe intake was found by Lindt and Blum (1993) also for blood lactate, which was higher in veal calves fed lower amounts of Fe in comparison with those fed higher amounts of Fe. No statistical differences between sampling periods were found for blood lactate and the mean values obtained can be considered to be in accordance with the normal range of 0.6-1.3 mmol/L (Constable et al. 1997).

Fe in blood is the most important constituent of hemoglobin molecule, so Fe deficiency in calves also causes a decrease in hemoglobin and myoglobin concentration (Underwood and Suttle 2001). HGB mean values determined in this study decreased in association with the serum Fe drop observed at the end of the study. The HGB concentrations were lower than the reference range (88-125 g/L) suggested by Brun-Hansen et al. (2006) in conventionally fed calves, but always above the limits found in Council Directive 2008/119/EC. An equivalent decrease in RBC and MCH was recorded. The HCT and MCV values significantly decreased from t1 until t3 and were lower than the values obtained by Brun-Hansen et al. (2006) (23-31% and 40-50 fl for HCT and MCV, respectively). Erythrocytes size continues to decrease during the first 3-4 months in calves. This gradual reduction in MCV coincides with a disappearance of fetal Hb and replacement by Hb A (Jain 1986) but may be predominantly due to Fe deficiency (Katunguka-Rwakishaya et al. 1985). These results confirm the consequences of Fe restriction on the haemocytometric profile.

Our results indicate that variations in blood gas parameters can be found at different periods of breeding in milkfed veal calves. The main variations are related to metabolic components of acid-base balance. Moreover, the administration of $NaHCO_3$ during breeding cycle does not compromise the normal levels of pH, but could seriously affect levels of HCO_3 and BEecf in venous blood.

The data obtained from blood chemistry analysis did not show severe alterations of metabolic functions according to the sampling period. However, significant differences found at different stages of the livestock cycle confirm that the age of the animal should be taken into account for a correct evaluation of clinical data. Since milk-fed calves are exposed to Fe deficiency to obtain the characteristic pale color of meat, important changes in their haemocytometric profile occur during the breeding cycle. Periodical haemocytometric survey should be performed to check health conditions of calves.

This study provides some useful information for a better interpretation of blood gases and hematological values in veal calves.

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