BLOOD COMPOSITION OF THE REINDEER. II. BLOOD CHEMISTRY

NIEMINEN, M. & TIMISJÄRVI, J. 1983. Renblod. II. Blodkemi

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Abstract: The blood chemical composition of 578 semi-domestic reindeer were investigated in respect to age, season, calving and nutrition in Northern Finland during 1973-79. The weight gain was maximally 400 g/day at an age of 4-8 weeks as also reflected by high serum thyroxine (T_4), alkaline phosphatase (SAP), creatine phosphokinase (CPK) and blood glucose values. Low SAP activity in winter indicated a cessation of growth.

The pH of the venous blood was 7.35 and the clotting activity very high (21 sec, 100 %) in summer and autumn. 15 protein bands and 15 fatty acids were discernible in reindeer serum. The total serum protein was 58 g/l in the 20-day-old calf and 87 g/l in adult hind in the autumn, the difference being caused by changes in globulins. The neonatal fluctuation of immunoglobulins suggests that the calf acquires its passive immunity soon after birth by the intestinal absorption of proteins and that its endogenous synthesis of gamma globulins begins in the 4th week of life.

The serum total lipids (2.9 g/l), triglycerides (0.29 mmol/l) and cholesterol (1.6 mmol/l) were low in newborn calves and reached their adult levels at the age of 5 months (average 5.1 g/l, 0.4 mmol/l, 2.7 mmol/l, respectively). The young calves had higher serum cholesterol, total and free fatty acid, myristic acid and palmitic acid, but lower stearic and oleic acid values than adult hinds. The reindeer calf liberates considerable amounts of catecholamines during the first days after birth, but the postpartum dopamine-B-hydroxylase activity was rather low.

The means of blood glucose (3.4 - 4.6 mmol/l), total serum proteins (63 - 87 g/l), albumin (39 - 43 g/l), total globulins (23 - 44 g/l), urea (5.7 - 9 mmol/l), total lipids (2.7 - 5.2 g/l), triglycerides (0.17 - 0.33 mmol/l), total fatty acids (0.89 - 1.54 g/l), calcium (2.2 - 2.6 mmol/l), inorganic phosphorus (1.6 - 2.2 mmol/l), magnesium (0.8 - 1.2 mmol/l) and copper (6.7 - 18 µmol/l) of free-grazing adult hinds were highest in summer and autumn and decreased during winter. The lowest means were measured for the starved hinds in early spring. The high serum urea and CPK, LDH and SAP activities reflected catabolism of the body proteins and tissue breakdown during starvation. Season and nutrition did not affect serum T_4, creatinine, sodium and chloride values. High body weight and blood chemical values were measured for the hinds fed on silage and molasses in winter.

Key words: *Growth, blood values, calving, nutrition, season.*

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Sammandrag: Den kemiska sammansättningen av blodet hos 578 halvvilda vajor undesöktes under år 1973 — 1979 med hänvisning till ålder, årstid, kalvning och näringstillstånd. Viktökningen var störst, 400 g/dygn, vid en ålder av 4 — 8 veckor. Detta återspeglades även i de höga värden av serumthyroxin (T_4), alkalfosfatas (SAP), kreatininfosfokinas (CPK) och i blodsockerhalten. Den låga SAP-aktiviteten under vintern var ett tecken på att tillväxten stannat.

Vårdet av pH i venblodet var 7,46 och koagulationskapaciteten (21 sek, 100%) var mycket hög under sommaren och hösten. 15 olika äggviteämnen och 15 fettsyror skiljdes ur serum. Halten av äggviteämnen i serum var 58 g/l vid en ålder av 20 dygn och 87 g/l hos vajorna pä hösten. Skillnaden berodde på förändringen i globulinmängden. Förändringarna hos immunoglobulinerna påvisar, att kalven får sin motständsförmåga efter födseln ur vajans mjölk och att kalven själv börjar producera gammaglobuliner först då den nått en ålder av 4 veckor.

Den nyfödda kalvens serumlipider (2,9 g/l), triglycerider (0,29 mmol/l), och kolesterol (1,6 mmol/l) var tåmligen låga och uppnådde nivån hos en vuxen ren vid 5 månaders ålder (respektive medeltal 5,1 g/l, 0,4 mmol/l, 2,7 mmol). Halterna av kolesterol, fettsyra, myristinsyra och palmitinsyra var högre i kalvarnas serum, emedan halterna av stearinsyra och oljesyra var lägre ån hos vajor. Under de första levnadsdygnen producerar kalven katekolaminer i rikliga mängder. Däremot är serumdopamid - B - hydroxylas-aktiviteten ganska låg.

En fritt betande vajas blodsockerhalt (3,4 - 4,6 mmol/l), totaläggvitehalt i serum (63 - 87 g/l), albuminhalt (39 - 43 g/l), globulinhalt (23 - 44 g/l), urea (5,7 - 9 mmol/l), totala lipidhalt (2,7 - 5,2 g/l), triglyceridhalt (0,17 - 0,33 mmol/l), fettsyrehalt (0,89 - 1,54 g/l), kalciumhalt (2,2 - 2,6 mmol/l), fosforhalt (1,6 - 2,2 mmol/l), magnesiumhalt (0,8 - 1,2 mmol/l) och kopparhalt (6,7 - 17 µmol/l) var högst under sommaren och hösten emedan de sjönk under vintern. De lägsta halterna mättes hos utsvultna vajor på våren. Den höga ureahalten i serum samt CPK-, LDH- och SAP-aktiviteterna återspeglar äggviteämnens och våvnaders upplösning i kroppen. Årstiderna och näringen inverkade varken på halterna av T_4 kreatinin, natrium eller klorid i serum. De höga siffrorna för kroppsvikt och blodets kemiska värden mättes hos vajor som under vintersäsongen matats med pressfoder och melassflis.

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Yhteenveto: 578 puolivillin poron veren kemiallista koostumusta tutkittiin iän, vuodenajan, vasonnan ja ravitsemustilan suhteen vuosina 1973-79. Painon lisäys oli suurimmillaan 400 g/vrk 4 - 8 viikon iässä ja sitä kuvastivat myös korkeat seerumin tyroksiinin (T_4), alkaalisen fosfataasin (SAP), kreatiinifosfokinaasin (CPK) ja veren sokerin arvot. Alhainen SAP aktiivisuus talvella osoitti kasvun pysähtymistä.

Laskimoveren pH oli 7.35 ja veren hyytymiskyky (21 sek, 100 %) erittäin hyvä kesällä ja syksyllä. Seerumista erotettiin 15 eri valkuaista ja 15 rasvahappoa. Seerumin valkuaisainepitoisuus oli 58 g/l 20 vrk:n iässä ja vaatimilla 87 g/l syksyllä. Ero johtui globuliinien määrän muutoksesta. Immunoglobuliinien muutokset osoittavat, että syntymänjälkeisen vastustuskykynsä vasa saa ilmeisesti emän maidosta ja että oma gammaglobuliinien tuotanto alkaa vasta 4 viikon iässä.

Vastasyntyneen vasan seerumin lipidit (2,9 g/l), triglyseridit (0,29 mmol/l) ja kolesteroli (1,6 mmol/l) olivat melko alhaiset ja saavuttivat aikuisen tason 5 kuukauden iässä (keskimäärin 5,1 g/l, 0,4 mmol/l, 2,7 mmol/l, vastaavasti). Vasojen seerumin kolesteroli-, kokonaisrasvahappo-, myristiinihappo- ja palmitiinihappopitoisuudet olivat korkeammat, mutta steariinihappo- ja öljyhappopitoisuudet alhaisemmat kuin vaatimilla. Ensimmäisinä vuorokausina vasa tuottaa runsaasti katekolamiineja, mutta seerumin dopamiini-B-hydroksylaasin aktiivisuus on melko alhainen.

Vapaana laiduntavan vaatimen veren sokeri (3,4 - 4,6 mmol/l), seerumin kokonaisvalkuainen (63 - 87 g/l), albumiini (39 - 43 g/l), globuliinit (23 - 44 g/l), urea (5,7 - 9 mmol/l), kokonaislipidit (2,7 - 5,2 g/l), triglyseridit (0,17 - 0,33 mmol/l), rasvahapot (0,89 - 1,54 g/l), kalsium (2,2 - 2,6 mmol/l), fosfori (1,6 - 2,2 mmol/l), magnesium (0,8 - 1,2 mmol/l) ja kupari (6,7 - 18 µmol/l) olivat korkeimmillaan kesällä ja syksyllä ja laskivat talvella. Alhaisimmat pitoisuudet mitattiin nälkiintyneille vaatimille keväällä. Seerumin korkeat ureapitoisuudet ja CPK, LDH ja SAP aktiivisuudet kuvastivat kehon valkuaisten ja kudosten hajoamista nälkiintymisen aikana. Vuodenajoilla ja ravinnolla ei ollut vaikutusta seerumin T_4-, kreatiniini-, natrium- ja kloridipitoisuuksiin. Korkeat ruumiinpainot ja veren kemialliset arvot mitattiin vaatimille, joita ruokittiin säilörehulla ja melassileikkeellä talvella.

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INTRODUCTION

The blood chemistry of the domestic animals with respect to age, breed, nutrition and season have been thoroughly studied. The relationship between blood studies and nutritional state of cervid species has also received comparatively much attention (Seal & Erickson 1969; LeResche et al. 1974; Franzmann et al. 1976). Since the semi-domestic reindeer in its northern range experiences wide seasonal variations in weather and the quantity of food available, it is possible that it experiences also metabolic responses to these fluctuating conditions in a manner similar to those described for some wild cervids (LeResche et al. 1974). The objective of the present study is to provide information about the blood chemical composition of the reindeer with special reference to age, growth, season, calving and nutrition.

MATERIALS AND METHODS

Animals and diets

Altogether 578 semi-domestic reindeer (*Rangifer tarandus tarandus* L.) studied were divided into 47 groups according to age and season (Table 1). The animals in the study are the same described in our earlier work (Nieminen & Timisjärvi 1981). The samples were taken throughout the year at 10 reindeer rearing subunits (pahskunta) during 1973-79 as presented earlier. The chemical composition of the important plants and the living conditions and qualitative annual variation of the food of the reindeer are reported also previously (Nieminen et al. 1980a, Nieminen & Timisjärvi 1981). Only the specimens taken from the animals corralled for less than 6 hr are included in the present study (Hyvärinen et al. 1976; Nieminen 1980a).

Blood samples

The blood samples were taken into centrifuge tubes from the jugular vein within 5 min, whereafter the animals were weighed. Ahquots of whole blood were immediately diluted with perchloric acid for determination of glucose and lactate. After cooling the samples to +4°C the serum from coagulated blood was separated by centrifugation within 4 hr. The serum samples were kept at —20°C until analysed.

Analytical methods

The pH and acid-base balance of the venous blood and the concentration of hydrogen carbonate (HCO_3) in plasma were measured according to the method by Saris & Harri (1972). The total serum protein concentration was determined by the biuret method (Reinhold 1953), and the serum protein fractions were separated using cellulose acetate electrophoresis and immunoelectrophore-

Table 1. Animals used in the study and the sampling conditions. Numbering of groups according to age and season. F=female, M=male).
Det undersökta djurmatrialet och provtagningsförhållanden. (Grupperna är numierade enligt ålder och årstid. F=hona, M=hane).

Group *Grupp*	n *n*	Sex *Kön*	Age *Ålder*	Weight (kg) x±SE *Vikt (kg)*	Sampling time *Datum för provtagning*	Locality *Lokalitet*	Living conditions before sampling (at last 1 month) *Liv- och beteförhållanden före provtagning (min 1 mnd)*
1	15	F	3-5 years (pregnant)	67.6±1.4	10.5. -	Inari (69°10'N)	In captivity outdoors. Snow conditions difficult for digging *Cladonia* lichens. Fed on dry horesetails (*Equisetum* spp.) and molasses.
2	13	F	3-5 years (lactating)	60.2±1.4	10.6.1977	”	”
3	20	F,M	1 day	5.3±0.2	”	”	Calves of the hinds in groups 1. and 2. Main food milk from the hind.
4	20	F,M	3 days	6.1±0.2	”	”	”
5	20	F,M	6 days	6.9±0.3	”	”	”
6	20	F,M	7.8±0.3	”	”	”	
7	20	F,M	20 days	10.1±0.5	”	”	”
8	11	F	3-4 years (lactating)	57.7±2.0	20.6.1978	Rovaniemi (66°70'N)	Freely grazing on good summer pasture. Good supply of *Betula* and *Salix* leaves and green grasses.
9	10	F,M	1 month	11.6±0.7	”	”	Calves of the hinds in group 8. Main food milk and *Betula* and *Salix* leaves.
10	10	F	3-5 years (lactating)	57.1±1.2	27.6.1977	Kuusamo (66°30'N)	Freely grazing on especially good summer pasture. Living conditions as group 8.
11	10	F,M	1 month	12.4±0.8	”	”	Calves of the hinds in group 10. Living conditions as group 9.
12	32	F	3-9 years (lactating)	56.2±1.1	30.6.1973	”	Freely grazing on good summer pasture. Living conditions as group 8.
13	33	F,M	1 month	14.8±0.5	”	”	Calves of the hinds in group 12. Living conditions as group 9.
14	7	F,M	2 months	23.6±1.2	2.7.1975	”	Calves grazing on good summer pasture. Living conditions as group 9.
15	24	F	3-9 years	66.3±1.3	2.-5.10.1973	”	Freely grazing in the forests. Good supply of mushrooms (*Boletus* spp.) and green grasses.
16	15	F,M	5 months	35.7±0.8	”	”	Calves of the hinds in group 15. Main food the same as for the hinds, but most were also still suckling.
17	8	F	3-5 years	66.3±1.3	4.10.1978	”	Freely grazing in the forests. Living conditions as group 15.
18	8	F,M	5 months	41.4±1.2	”	”	Calves of the hinds in group 17. Living conditions as group 16.
19	9	F	3-5 years	66.3±1.5	6.10.1977	”	Freely grazing in the forests. Living conditions as group 15.
20	8	F,M	5 months	40.1±1.4	”	”	Calves of the hinds in group 19. Living conditions as group 15.
21.	27	F	3-5 years	66.3±0.9	10.10.1973	Pudasjärvi (65°40'N)	Freely grazing in the forests. Living conditions as group 15.
22	14	F,M	18 months	48.6±1.2	”	”	”
23	11	F,M	5 months	46.2±0.8	”	”	Calves of the hinds in group 21. Living conditions as group 16.
24	10	F	3-5 years	65.0±1.3	10.10.1975	Kittilä (67°70'N)	Freely grazing in the forests. Good supply *Deschampsia flexuosa* grass and *Cladonia* lichens.

25	2	M	3-5 years	27.2±2.4	”	”	”
26	23	F,M	5 months	36.3±0.9	”	”	Calves of the hinds in group 24. Living conditions as the hinds, but most were also still suckling.
27	9	F	3-5 years	65.8±1.5	10.10.1978	Rovaniemi (66°70'N)	Freely grazing in the forests. Living conditions as group 24.
28	9	F,M	5 months	45.1±3.2	”		Calves of the hinds in group 27. Living conditions as group 26.
29	4	F	3-5 years	61.3±0.7	3.11.1975	Pudasjärvi (65°40'N)	Freely grazing in the forests. Living conditions as group 24.
30	7	F,M	18 months	50.1±2.0	”	”	”
31	16	F,M	6 months	38.4±1.2	”	”	”
32	18	F	3-9 years	70.3±1.9	6.9.2.1974	Kuusamo (66°30'N)	Freely grazing in the forests at timber-cutting sites. Snow conditions favourable for digging for *Cladonia* and grass. Good supply of *Alectoria and Bryoria* spp.
33	5	F,M	9 months	40.3±1.8	”	”	”
34	4	F	3-5 years	65.6±3.2	8.2.1978	Savukoski (67°90'N)	Freely grazing in the forests and mountain areas. Snow conditions difficult for digging for *Cladonia* lichens.
35	8	F,M	9 months	40.3±1.0	”	”	”
36	6	F	3-5 years	67.2±1.3	18.2.1978	Kuusamo (66°90'N)	Freely grazing in the forests. Snow conditions difficult for digging for *Cladonia* lichens, but good supply of arboreal lichens (*Alectoria* and *Bryoria* spp.).
37	6	F,M	9 months	38.2±0.8	”	”	
38	6	F	3-5 years	64.7±1.4	22.2.1979	Savukoski (67°90'N)	Freely grazing in the forests or mountain areas. Snow conditions very difficult for digging for *Cladonia* lichens.
39	10	F,M	9 months	36.2±0.9	”	”	”
40	7	F	3-9 years (pregnant)	63.2±2.5	9.-14.3.1973	Kuusamo (66°30'N)	In captivity outdoors. Fed om dry hay (ad libitum), dry leaves *Betula* and *Cladonia* lichens.
41	11	F	3-9 years (pregnant)	61.1±1.4	”	”	Freely grazing in the forests. Living conditions as group 32.
42	7	F	3-5 years (pregnant)	62.3±1.2	23.3.1979	”	In captivity out of doors. Living conditions as group 40.
43	10	F,M	10 months	38.1±0.6	”	”	”
44	6	F	3-5 years (pregnant)	67.8±2.1	29.3.1979	Küminki (65°10'N)	In captivity outdoors, fed on silage and molasses during 3-4 months before sampling.
45	12	F	3-9 years (pregnant or aborted)	55.2±1.3	13.4.1973	Enontekiö (68°30'N)	Freely grazing in the forests or mountain areas. Hard crust on the snow and digging conditions for *Cladonia* lichens very difficult. During sampling a large number reindeer in this area died of malnutrition.
46	9	F,M	11 months	40.6±1.4	21.4.1976	Posio (66°10'N)	In captivity outdoors. Fed on dry hay (*Phleum pratense*), dry leaves of *Betula* and *Salix*, lichens (*Cladonia* spp.) and molasses.
47	8	F	3-5 years (pregnant or aborted)	(50-55)*	30.4.1979	Sodankylä (68°10'N)	Freely grazing in the forests or mountain areas. Living conditions as group 45

*Approximated body weight.

sis was performed in 0.8 % agar gel as previously described (Nieminen et al. 1980a). Serum urea was measured by nesslerization (Annino 1964), and creatinine by Jaffe's reaction (Pierce Chemical Company). Serum uric acid concentration was measured by hydroxylamine method (Musscr & Ortizoga 1966). Serum ammonia was determined colorimetrically (Wako Pure Chemical Industries, Osaka) and plasma fibrinogen concentration according to the method by Rautanen (1972). The clotting activity of the reindeer blood was measured by the Thrombotest (Medica, Helsinki).

The total serum lipid concentration was determined by the sulfophosphovanillin reaction and serum triglyserides fully enzymatically (Boehringer GmbH, Mannheim). Serum cholesterol was measured by Liebermann-Burehard's reaction (Technicon method N-77). The fatty acids were measured with a gas-chromatograph (Perkin-Elmer 811) as described previously (Väyrynen et al. 1980).

Serum thyroxine (T_4) levels were determined by radioimmunological assay (RIA). Blood glucose was determined by the Boehringer GOD-perid enzymatic method and lactate and serum free fatty acids (FFA) by the Boehringer UV-methods (Boehringer GmbH, Mannheim). The serum adrenaline and noradrenaline levels were measured according to the methods of Diamant and Byers (1975) and the activity of dopamine-B-hydroxylase (DBH) by Nagatsu & Udenfriend (1972). Serum cortisol was determined by Cortipack Assay Kits (Amersham, England).

The concentrations of serum sodium (Na), potassium (K), calcium, magnesium, copper and zinc were measured with an atomic absortion spectrophotometer (Perkin-Elmer 290 B) using the routine procedures (Perkin-Elmer Corporation 1972). Serum sodium and potassium concentrations were measured also by flame emission photometry (IL 343), those of calcium by titration with EGTA (ethylenglycol-bis (B-amino-ethylether) N,N'-tetra-acetic acid) using calcein as an indicator and those of chloride by potentiometric titration. Serum inorganic phosphorus and magnesium were determined by quantitative colorimetric methods (Pierce Chemical Company).

The serum alkaline phosphatase (EC 3.1.3.1) (SAP) activity was determined by the method of Bodansky & Schwarz (1961), and the scrum enzyme activities of creatine phosphokinase (EC 2.7.3.2) (CPK), alanine aminotransferase (EC 2.6.1.1) (ASAT=GOT), lactate dehydrogenase (EC 1.1.1.27) (LDH), amylace (EC 3.2.1.1) and lipase (EC 3.1.1.3) were analysed by the methods recommended by The Committee on Enzymes of the Scandinavian Society for Clinical Chemistry and Clinical Physiology (1974) using standard reagents (Medix Biochemica, Helsinki).

Statistical analysis

The significances of the differences between the group mean values were calculatedby standard t-test.

RESULTS

The birth weight and growth rate

No significant sex-related differences were observed in body weight during the calfhood summer.

The mean birth weight of calves was 5.3 kg (Table 1), and the weight almost doubled in the first 3 weeks of life, giving a daily weight gain of 253 g. The average weight gain from the 4th to 8th week was 346 g/day. During the next 3 months weight increased 54 %, the mean daily weight gain being 140 g. The weight gain showed a marked reduction at about 5-6 months of age. The body weight of 9- to 11-month-old calves was from 38 to 41 kg. The 18-month-old calves weighed about 49 kg which was about 15 kg less than the adult hinds.

Acid-base balance of the blood

The pH value of the venous blood plasma was 7.35 in calves and adult hinds during autumn and winter, and the partial pressure of carbon dioxide (pCO_2) in gas in equilibrium with blood was 5.53 kPa. Excess concentration of base (BE) in blood was -4 mmol/l, and concentration of buffer base (BB) in blood was 45.4 mmol/l. The concentration of hydrogen carbonate (HCO_3) in plasma was 21.3 mmol/l (Table 2).

Serum protein profile and fatty acids

15 distinct protein bands and also 15 fatty acids were discernible in reindeer serum. The general electrophoretic mobility of the reindeer proteins corresponded to that found in human serum, but reindeer IgG showed a wider distribution and IgA higher cathodic mobility. IgG was highly heterogenous consisting of two fractions in the 1-day-old calf. It reached its minimum level in 20 days. IgM decreased quickly and was no longer detectable in the 6-day-old calf, whereas IgA became undectable in the 10-day-old calf. At the

age of 18 month IgG, IgM and IgA had reached the normal adult levels. Transferrin remained rather stable during ageing. Beta$_1$ globulin and hemopexin increased slowly reaching the normal adult level by the age of 18 months. Beta lipoproteins were detectable after 18 months of age. Main components of the alpha region remained stable during ageing and some minor components were missing in very young calves (Nieminen et al. 1980a).

The fatty acid composition of reindeer serum completely differed from that e.g. in sheep and cattle. Major difference was the high concentrations of palmitic ($C_{16:0}$) and stearic ($C_{18:0}$) acids in reindeer serum. Only traces of arachidic acid ($C_{20:0}$) were found in reindeer blood lipids. The young calves had higher concentrations of myristic acid ($C_{14:0}$) and palmitic acid ($C_{16:0}$) ($P<0.001$, $P<0.05$, respectively), and slightly lower stearic ($C_{18:0}$) and oleic acid ($C_{18:1}$) levels than adult hinds (Väyrynen et al. 1980).

Blood chemical values

No significant sex-related differences were detected in the blood chemistry of calves during the calfhood summer.

The *total protein* concentration decreased from the birth value 61.6 g/l to 58.2 g/l within 10 to 20 days, thereafter the level again increased progressively up to 70.7 g/l during the following 5 months (Fig. 1). The total protein concentration (average 67.9 g/l) of the 5- to 6-month-old calves was slightly lower than that of 9- to 11-month-old calves but significantly ($P<0.001$) lower than that of 18-month-old calves, which was also true for the difference between the yearlings and adults ($P<0.01$) during autumn. The total protein concentration was significantly ($P<0.01$) lower in two adult stags (83.6 g/l) than in the adult hinds (average 90.3 g/l) during autumn (Nieminen et al. 1980a).

The *albumin* level increased significantly ($P<0.001$) from 27.2 g/l at birth to 38.4 g/l at 20 days of age, and more progressively to 41.3 g/l during the first 5 months, reaching the adult level during autumn (Fig. 1).

The *total globulin* level was high (34.4 g/l) in 1-day-old calves, whereafter a significant decrease ($P<0.001$) during the first 3 weeks followed and the lowest level (19.9 g/l) was found in 20-day-old calves. The total globulin level then increased progressively with age reaching the highest value (average 40.1 g/l) in the adult hinds during autumn (Fig. 1).

The *gamma globulin* concentration was 15.4 g/l in 1-day-old calves. It decreased significantly ($P<0.001$) during the first 3 weeks with the lowest level in 20-day-old calves (4.7 g/l) whereafter gamma globulin level increased progressively with age, the highest level (29.7 g/l) being noted for the adult hinds in autumn.

Beta globulin level was 7.4 g/l in 1-day-old calves and it increased significantly ($P<0.001$) during the first 10 days, whereafter it decreased significantly ($P<0.001$) during the following 5 months. High beta globulin level was again found for the adult hinds in autumn (average 9.3 g/l). Only *alpha globulins* did not show age-related variations in this study.

The *albumin/globulin ratio* (A/G) was lowest at birth (0.79) and increased significantly ($P<0.001$) during the first 3 weeks, the highest values (1.93) being found for 20-day-old calves. The A/G ratio thereafter decreased with ageing and low ratio was found for the adult hinds (average 0.94) in autumn (Nieminen et al. 1980a).

Serum *urea* concentration of the newborn calf was relatively high (8.2 mmol/l), and the values increased during the first 10 days (Fig. 1). Serum *creatinine* concentration was 156.4 µmol/l at birth and it was stable during subsequent months. Serum *uric acid* concentration was 28.7 µmol/l and serum *ammonia* average 65 µmol/l in calves and adult hinds during autumn and winter.

The total serum *lipid*, *triglyceride* (Fig. 1) and *cholesterol* concentrations were low in the newborn calf (2.80 g/l; 0.29 mmol/l; 1.62 mmol/l, respectively), and they showed significantly ($P<0.001$) increases during the subsequent 3 weeks. The 1-month-old calves had slightly higher *total fatty acid* values than adult hinds during summer (1.70; 1.45 g/l) and autumn (1.90; 1.54 g/l, respectively). Serum *free fatty acid* (FFA) concentration was 0.93 mmol/l for 5-month-old calves and 0.95 mmol/l for adult hinds during autumn and winter.

The serum *thyroxine* (T_4) level was high in the newborn (459 nmol/l) and decreased during the first 3 days of life but increased thereafter during summer. Serum *dopamine-B-hydroxylase* (DBH) activity was lowest immediately after birth (9.8 µmol/min/l) and rose to 15.0 µmol/min/l within 20 days ($P<0.001$). Serum *adrenaline* (A)

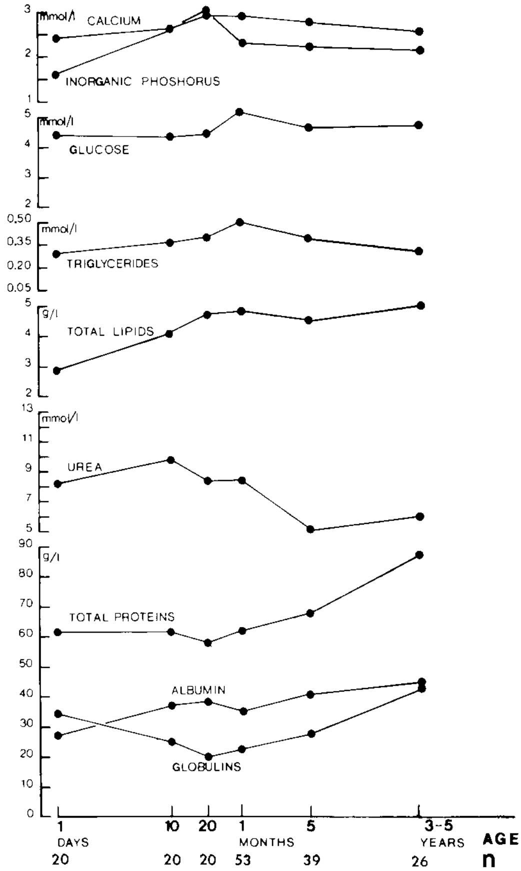

Fig. 1. Changes in reindeer serum chemical values represented on a semilogarithmic scale with respect to age. The filled circles are average means for different age groups as presented in Table 1.

Bild 1. Semilogaritmisk tabell över förändringar i blodets kemiska värden med hänseende till ålder. I cirklarna uppges värden för de olika åldersgrupperna. Se tabell 1.

gradually increased after birth from 37.8 µg/l to 70.8 µg/l in autumn ($P<0.01$). Serum *noradrenaline* (NA) was 17.4 µg/l at birth and decreased to 7.6 µg/l but then increased to 39.8 µg/l within 20 days ($P<0.001$) (Nieminen et al. 1980b). Serum *cortisol* level of calves and adult hinds was 145 nmol/l during autumn and winter.

Blood *glucose* concentration increased slightly from the newborn value (4.4 mmol/l) during the calfhood summer, and high value were found for 5-month-old calves and adult hinds during autumn (4.69 and 4.58 mmol/l, respectively) (Fig. 1). Blood *lactate* concentration of calves was 4.13 mmol/l at birth, and it decreased slightly during the first 3 weeks of life, but increased during the subsequent 4 months.

The serum *sodium* (Na) and *chloride* concentrations of the newborn calves were average 144 mmol/l and 99 mmol/l, respectively. No significant age-related differences were detected in these values during present study. Serum *potassium* (K) values of the newborn calf (4.6 mmol/l) increased ($P<0.05$) during the first 3 weeks and reached adult levels (average 6.5 mmol/l) at about an age of 5 months.

The serum *calcium* (2.4 mmol/l) and *inorganic phosphorus* concentrations (1.6 mmol/l) of the newborn calf increased ($P<0.05$) during the first 3 weeks (Fig. 1). The serum *calcium/inorganic phosphorus* ratio was very high (1.5) in 1-day-old calf and decreased during the first 3 weeks. Serum *magnesium* concentration of the newborn calf was 1.0 mmol/l. Serum *copper* (20.8 µmol/l) and *zinc* (17.9 µmol/l) concentrations were high in 1-day-old calves and they decreased during autumn.

The serum *alkaline phosphatase* activity (SAP) was very high at birth (2075 U/l) and decreased significantly ($P<0.001$) during the first 3 weeks. At the age of one month the SAP activity was also high (1620 U/l), but it dropped ($P<0.001$) during autumn and winter. In the summer and autumn the SAP activity was significantly ($P<0.001$) higher in calves than in adult hinds and it correlated well with body weight and age ($r= -0.88$, $n= 306$, $P<0.001$) (Fig. 2).

The *creatine phosphokinase* (CPK), *alanine aminotransferase* (ALAT=GPT) and *lactate dehydrogenase* (LDH) activities were at birth 106 U/l, 27 U/l and 864 U/l, respectively. These activities increased slightly during the first 3 weeks of life. During summer and autumn the CPK activity was significantly ($P<0.001$) higher in calves than in adult hinds. The *aspartate aminotransferase* (ASAT=GOT) activity was 76 U/l in 1-day-old calves and showed no significant changes during the first weeks. Serum *amylase* activity was 120 U/l in 5-month-old calves and adult hinds during autumn and winter, and the activity of serum *lipase* was 32 U/l.

Seasonal changes

The adult hinds weighed on average 65 kg during autumn and early winter. During late winter and early spring body weight decreased, with the

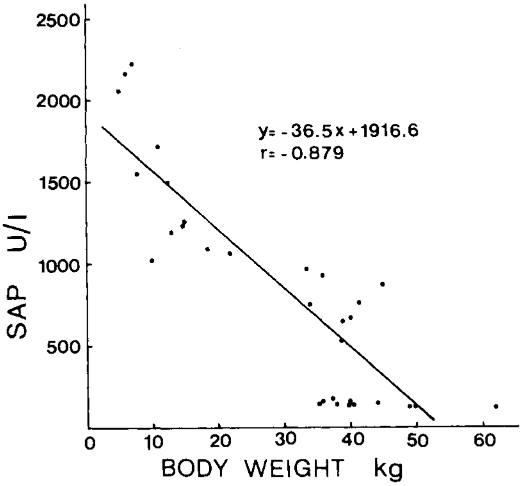

Fig. 2. Relationship between body weight and serum alkaline phosphatase activity (SAP) in reindeer calves (r= —0.88, n= 306, P<0.001).

Bild 2. Relationen mellan kroppsvikt och serum alkalinfosfatasaktivitet (SAP) hos renkalvar (r = —0,88, n = 306, P<0,001).

lowest values (50-55 kg) measured for the freely grazing hinds during April in areas, where very little food was available and the hinds were in poor condition (Group 47, Table 1). The body weight of the hinds decreased by about 7.4 kg (11 %) during calving and the early lactation period. In June-July the lactating hinds weighed about 58 kg, and from summer to autumn the weight of free-grazing hinds increased by about 8 kg (Tables 1 and 2).

Plasma fibrinogen concentration of adult hinds were average 3.19 g/l during autumn and winter. The clotting activity of venous reindeer blood was very high (average 21 sec, 100 %) during summer and autumn and decreased significantly (P<0.001) during winter being on an average 88 sec in late winter and spring (Table 2).

High blood glucose values were found for 5-month-old calves and adult hinds during summer and autumn (average 4.8 mmol/l). The blood glucose values decreased in winter and early spring, and the adult hinds maintained under poor nutritional conditions in late April had very low glucose values (2.1 mmol/l). The highest lactate values were found for calves and adult hinds in summer and autumn (range 4.8 to 5.4 mmol/l) (Table 2).

The serum protein concentration of the calves and adult hinds was highest in autumn and lowest in late winter and early spring (Table 3). Very low serum protein levels (57.4 g/l) were found for the adult hinds maintained under very poor nutritional conditions in late April (Group 47). The serum protein concentration of pregnant hinds dropped (P<0.05) after parturition (from 68.2 to 60.0 g/l). The changes in serum albumin concentration were small at different seasons, but exceptionally low values (34.2 g/l) were found for hinds in a poor conditional state during April. The changes in total protein concentration correlated with changes in serum globulins (r= 0.93, n= 251, P<0.001) (Fig. 3). The lowest albumin/globulin ratios (average 0.94) of the hinds were measured during autumn and the highest ratios during winter and spring.

Serum urea values of calves and hinds were low in autumn and early winter compared to those in summer (Table 3). The highest urea values (12.7 mmol/l) were found for the hinds maintained under very poor nutritional condition in late April (Group 47). Serum creatinine concentration was relatively stable (range 165-211 µmol/l) and only slightly increased values were found during winter and early spring. Serum ammonia concentration of calves and hinds was average 65 µmol/l during autumn and winter.

The serum total lipid, triglyceride and cholestrol concentrations of free-grazing hinds and calves reached their maxima (average 5.1 g/l; 0.38 mmol/l; 2.2 mmol/l, respectively) during summer

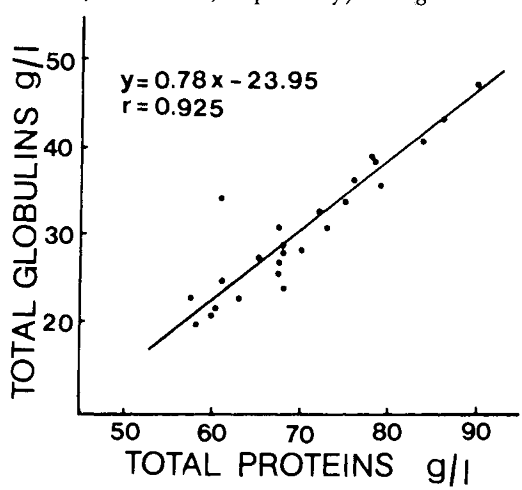

Fig. 3. Relationship between serum total protein and globulin concentrations in reindeer calves and hinds (r= 0.93, n= 251, P<0.001).

Bild 3. Relationen mellan totalprotein- och globulinkoncentrationer hos renkalvar och vajor (r = 0,93, n = 251, P<0,001).

and autumn (Table 3). Very low total lipid (2.08 g/l), triglyceride (0.07 mmol/l) and cholesterol (1.35 mmol/l) values were found for the adult hinds maintained under very poor nutritional conditions in late April. The total lipids and triglycerides increased, but serum cholesterol dropped after parturition (from 2.80 to 2.91 g/l; from 0.19 to 0.23 mmol/l; from 1.64 to 1.43 mmol/l, respectively). The changes in serum total lipid concentration correlated with changes in serum cholesterol (r= 0.65, n= 111, P<0.001) and in serum triglycerides (r= 0.85, n= 251, P<0.001) (Fig. 4).

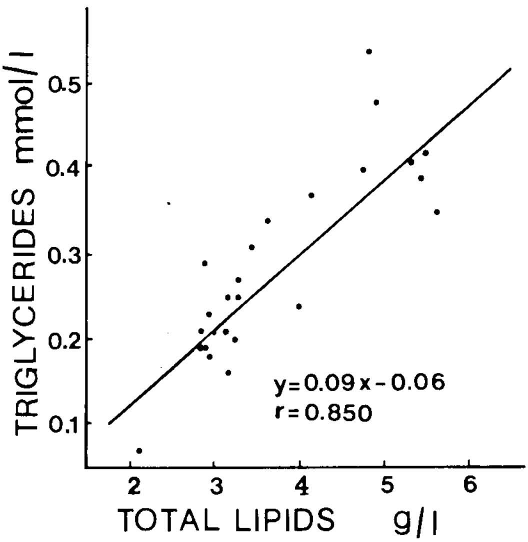

Fig. 4. Relationship between serum total lipid and triglyceride concentrations in reindeer calves and hinds (r= 0.8, n= 251, P<0.001).

Bild 4. Relationen mellan serum totallipid- och triglyceridkoncentrationer hos renkalvar och vajor (r = 0,80, n = 251, P<0,001).

The total fatty acid concentration of serum lipids was highest in autumn (Table 3), and the changes in total fatty acids correlated (r= 0.65, n= 84, P<0.001) with those in serum total lipids. The concentration of all fatty acids in adult hinds increased during summer; polyunsaturated linoleic ($C_{18:2}$) and linolenic ($C_{18:3}$) acids were highest in early summer; stearic acid ($C_{18:0}$) was highest during summer and autumn; palmitic ($C_{16:0}$) and oleic ($C_{18:1}$) acids were significantly (P<0.001, P<0.05, respectively) higher in autumn than in summer. The lowest fatty acid values were found during winter.

The serum thyroxine (T_4) level of the adult hinds increased after calving but remained rather stable regardless of the season. Both serum adrenaline and noradrenaline values in calves and adult hinds declined in winter (Table 3).

No significant season-related differences were detected in serum sodium and chloride concentrations in the material studied (average values 148 mmol/l and 100 mmol/l, respectively) (Table 4). The highest serum calcium (average 2.6 mmol/l), inorganic phosphorus (2.1 mmol/l) and magnesium (1.1 mmol/l) were found for the free-grazing hinds during autumn. The lowest calcium (average 1.8 mmol/l), inorganic phosphorus (1.3 mmol/l) and magnesium (0.6 mmol/l) were measured for the adult hinds living in a poor nutritional state during late April (Group 47). Serum calcium and inorganic phosphorus increased after parturition. Serum calcium changes correlated well with those of serum inorganic phosphorus (r≐ 0.89, n= 251, P<0.001) (Fig. 5).

Serum copper concentration of calves and adult hinds was average 16 µmol/l. Very low copper values (6.6 µmol/l) were found for the adult hinds living in a very poor nutritional state in April. Seasonal changes in serum zinc values in the adult

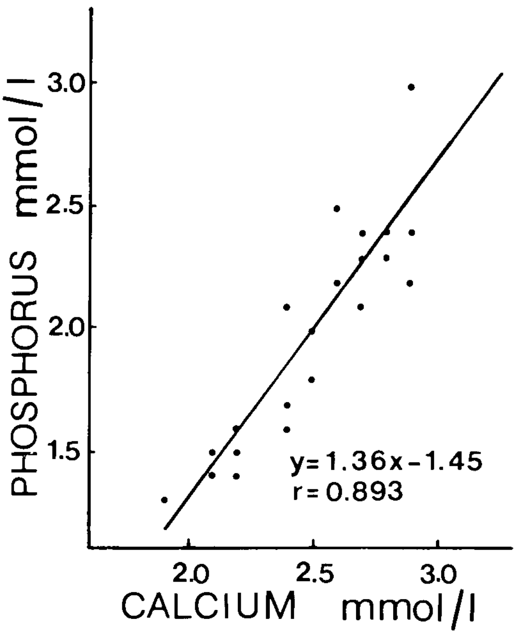

Fig. 5. Relationship between serum calcium and inorganic phosphorus concentrations in reindeer calves and hinds (r= 0.89, n= 251, P<0.001).

Bild 5. Relationen mellan koncentrationerna av serum kalcium och oorganisk fosfor hos renkalvar och vajor (r = 0,89, n = 251, P<0,001).

Table 2. Body weight, plasma pH, blood olotting activity, plasma fibrinogen and blood glucose and lactate values ($\bar{x}\pm$SE) for the free-grazing reindeer oalves (age from 1 to 11 months) and adult hinds during different seasons. Numbers of animals ere given in parentheses and statistical significanoes in the text.

Tabell 2. Kroppsvikt, venblodets koaguleringskapacitet, serum fibrinogen och blodsocker samt äggviteämnen ($\bar{x}$ ± SE) för fritt betande renkalvar (ålder 1 månad - 11 månader) och för vuxna vajor under olika säsonger. Antalet djur är givet inom parentes och de statistiska värdena är givna i texten).

Parameter *Parameter*	Unit *Enhet*		Spring *Vår* Mar.-May	Summer *Sommar* Jun.-Aug.	Autumn *Høst* Sep.-Nov.	Winter *Vinter* Dec.-Feb.
Body weight	kg	calves	40.6±1.4 (09)	12.9±0.7 (53)	40.5±1.4 (90)	38.8±1.1 (29)
		hinds	61.4±2.4 (27)	57.8±1.4 (66)	65.3±1.2 (91)	65.6±1.9 (48)
Plasma pH		calves			7.36±1.1 (09)	7.34±0.8 (09)
		hinds			7.35±0.4 (20)	7.35±0.2 (20)
Plasma pCO_2	kPa	calves			5.51±0.3 (09)	5.56±0.8 (09)
		hinds			5.53±0.7 (20)	5.54±0.4 (20)
Plasma HCO_3	mmol/l	calves			21.3±0.8 (09)	21.4±0.9 (09)
		hinds			21.3±1.2 (20)	21.5±0.8 (20)
Base in blood (BE)	mmol/l	calves			-3±0.8 (09)	-4±0.6 (09)
		hinds			-4±0.5 (20)	-4±0.3 (20)
Buffer base (BB)	mmol/l	calves			45.1±0.8 (09)	45.4±0.3 (09)
		hinds			45.4±1.2 (20)	45.6±0.8 (20)
Blood clotting activity	sec, 100%	calves				
		hinds	88±2 (05)	21±1 (5)	21±1 (05)	68±2 (05)
Plasma fibrinogen	g/l	calves				
		hinds			3.23±0.4 (05)	3.14±0.6 (05)
Blood glucose	mmol/l	calves	3.48±1.1 (10)	5.23±0.8 (53)	4.69±1.0 (32)	4.09±1.0 (24)
		hinds	3.38±0.9 (49)	4.55±0.6 (53)	4.58±0.6 (49)	4.02±0.7 (28)
Blood lactate	mmol/l	calves	2.68±0.7 (10)	5.40±1.1 (53)	5.27±0.8 (32)	4.40±0.7 (24)
		hinds	2.60±0.6 (49)	4.91±0.7 (53)	4.82±0.9 (49)	4.37±0.5 (28)

Table 3. Serum protein, urea, uric acid, creatinine, ammonia, lipid, fatty acid, triglyceride, cholesterol, thyroxine (T_4), corisol and catecholamine values ($\bar{x}\pm SE$) for det free-grazing reindeer calves (age from 1 to 11 months) and adult hinds during different seasons. Numbers of animals are given in parentheses and statistical significances in the text.

Tabell 3. Värden för serum protein, urea, urinsyra, kreatinin, ammoniak, lipider, fettsyror, triglycerider, kolesterin, thyroxin (T_4), cortisol och katekolaminer ($\bar{x} \pm SE$) för fritt betande renkalvar (ålder 1 månad - 11 månader) och vuxna vajor under olika säsonger. Antalet djur är givet inom parentes och de statistiska värdena är givna i texten).

Parameter	Unit		Spring Mar.-May	Summer Jun.-Aug.	Autumn Sep.-Nov.	Winter Dec.-Feb.
Total serum protein	g/l	calves	65.8±1.8 (10)	61.7±1.3 (20)	67.9±1.4 (48)	73.5±1.6 (41)
		hinds	63.3±2.2 (49)	77.0±2.9 (21)	86.9±1.5 (26)	71.3±2.1 (12)
Albumin	g/l	calves	38.3±0.9 (10)	39.5±1.2 (20)	41.3±0.9 (48)	40.7±0.9 (41)
		hinds	38.5±0.6 (49)	39.2±2.0 (21)	42.7±1.4 (26)	41.0±1.1 (12)
Total globulins	g/l	calves	27.5±0.8 (10)	22.4±1.2 (20)	27.1±1.0 (48)	31.4±0.8 (41)
		hinds	22.7±1.3 (49)	37.8±1.0 (21)	44.1±1.0 (26)	32.7±0.9 (12)
Albumin/Globulin		calves	1.39±0.06 (10)	1.77±0.10 (20)	1.57±0.10 (48)	1.30±0.07 (41)
		hinds	1.52±0.10 (49)	1.04±0.09 (21)	0.94±0.09 (26)	1.27±0.08 (12)
Urea	mmol/l	calves	9.7±1.2 (10)	8.4±1.1 (20)	5.0±1.0 (48)	6.6±1.1 (41)
		hinds	8.7±1.2 (49)	9.0±0.7 (21)	5.7±1.1 (26)	7.1±0.9 (12)
Uric acid	µmol/l	calves			28.8±1.6 (05)	28.7±0.8 (05)
		hinds			28.7±1.2 (06)	28.4±0.7 (06)
Creatinine	µmol/l	calves	185.7±7.4 (10)	174.6±8.0 (20)	173.2±10.5 (48)	200.5±8.1 (41)
		hinds	196.7±9.3 (49)	184.5±7.8 (21)	164.8±12.2 (26)	210.7±10.9 (12)
Ammonia	µmol/l	calves			65.2±1.3 (05)	65.0±0.5 (05)
		hinds			64.9±0.8 (06)	65.0±0.8 (06)
Total lipids	g/l	calves	3.12±0.81 (10)	4.73±0.82 (34)	5.10±0.79 (60)	3.07±0.8 (46)
		hinds	2.69±0.79 (55)	3.38±0.80 (50)	5.18±0.80 (51)	3.08±0.73 (32)
Total fatty acids	g/l	calves	1.18±0.08 (05)	1.70±0.08 (02)	1.92±0.13 (07)	1.21±0.05 (05)
		hinds	0.89±0.14 (03)	1.45±0.09 (23)	1.54±0.14 (15)	1.03±0.08 (17)
Triglycerides	mmol/l	calves	0.16±0.02 (10)	0.47±0.03 (34)	0.40±0.03 (60)	0.24±0.03 (46)
		hinds	0.17±0.06 (55)	0.30±0.03 (50)	0.33±0.04 (51)	0.23±0.03 (32)
Cholestrol	mmol/l	calves	1.97±0.04 (10)	2.53±0.05 (34)	2.74±0.07 (60)	2.00±0.08 (46)
		hinds	1.56±0.13 (55)	1.71±0.09 (50)	1.85±0.06 (51)	1.58±0.07 (32)
Free fatty acids	mmol/l	calves			0.94±0.03 (05)	0.91±0.04 (06)
		hinds			0.93±0.01 (06)	0.96±0.02 (06)
Thyroxine (T_4)	nmol/l	calves	438.3±28.9 (10)	472.0±33.6 (20)	444.7±35.4 (48)	423.9±26.5 (41)
		hinds	360.4±30.3 (49)	424.4±37.4 (21)	375.5±36.5 (26)	415.7±17.9 (12)
Cortisol	nmol/l	calves			145.3±1.2 (05)	145.0±2.3 (06)
		hinds			145.6±2.0 (06)	144.8±1.8 (06)
Adrenaline	µg/l	calves		44.7±2.4 (05)	70.8±11.1 (04)	50.1±8.2 (06)
		hinds	108.9±4.2 (17)		166.2±13.2 (11)	143.6±8.6 (11)
Noradrenaline	µg/l	calves		19.7±2.5 (05)	16.4±2.9 (04)	11.76±2.3 (06)
		hinds	53.8±4.2 (17)		24.3±3.2 (11)	28.2±3.5 (11)

Table 4. Serum mineral and enzyme values ($\bar{x}\pm SE$) for the free-grazing reindeer calves (age from 1 to 11 months) and hinds during different seasons. Numbers of animals are given in parentheses and statistical significances in the text.

Tabell 4. Serummineral- och enzymvärden ($\bar{x} \pm SE$) för fritt betande renkalvar (ålder 1 — 11 månader) och tjurar genom olika säsonger. Antalet djur är givet inom parentes och de statistiska värdena är givna i texten.

Parameter	Unit		Spring Mar.-May	Summer Jun.-Aug.	Autumn Sep.-Nov.	Winter Dec.-Feb.
Serum sodium (Na)	mmol/l	calves	151±0.8 (10)	142±2.2 (26)	148±3.3 (52)	144±5.0 (46)
		hinds	148±2.1 (63)	144±1.9 (34)	150±2.8 (35)	148±2.5 (32)
Potassium (K)	mmol/l	calves	5.2±0.6 (10)	4.2±0.3 (26)	4.4±0.3 (52)	5.4±0.4 (46)
		hinds	5.0±0.3 (63)	4.7±0.1 (34)	4.4±0.1 (35)	5.4±0.4 (32)
Chloride	mmol/l	calves	100±1.2 (10)	100±0.9 (26)	99±1.0 (52)	101±1.0 (46)
		hinds	99±1.6 (63)	100±1.1 (34)	100±1.1 (35)	101±1.1 (32)
Calcium	mmol/l	calves	2.5±0.04 (10)	2.8±0.08 (26)	2.8±0.09 (52)	2.3±0.03 (46)
		hinds	2.2±0.07 (63)	2.3±0.05 (34)	2.6±0.07 (35)	2.4±0.08 (32)
Inorganic phosphorus	mmol/l	calves	2.0±0.05 (10)	2.3±0.04 (32)	2.3±0.05 (32)	1.6±0.07 (24)
		hinds	1.8±0.12 (49)	1.6±0.06 (34)	2.2±0.05 (49)	1.7±0.06 (28)
Calcium/Phosphorus		calves	1.3±0.02 (10)	1.2±0.02 (26)	1.2±0.02 (32)	1.5±0.02 (24)
		hinds	1.3±0.02 (49)	1.5±0.01 (34)	1.2±0.02 (49)	1.4±0.02 (28)
Magnesium	mmol/l	calves	1.1±0.07 (10)	1.1±0.03 (26)	1.1±0.04 (32)	1.0±0.04 (24)
		hinds	0.8±0.05 (49)	0.9±0.04 (34)	1.2±0.03 (49)	0.9±0.06 (28)
Copper	µmol/l	calves		20.2±1.2 (08)	13.0±1.2 (07)	15.3±0.8 (05)
		hinds	6.7±0.7 (15)	18.0±1.6 (2)	13.0±1.2 (17)	17.2±0.8 (20)
Zinc	µmol/l	calves		16.2±1.1 (08)	13.1±1.1 (07)	11.6±1.3 (05)
		hinds	15.1±1.1 (15)	15.7±1.0 (15)	12.5±1.0 (17)	13.7±1.2 (20)
Alkaline phosphatase	U/l	calves	151±10 (10)	1620±116 (26	780±31 (32)	170±15 (24)
		hinds	176±42 (49)	523±74 (34)	165±30 (49)	129±21 (28)
Creatine phosphokinase	U/l	calves	255±8 (10)	614±21 (26)	453±29 (32)	269±18 (24)
		hinds	247±14 (49)	298±30 (34)	276±26 (49)	247±21 (28)
Aspartate aminotransferase	U/l	calves	108±4.3 (10)	73±3.0 (26)	76±5.0 (32)	89±4.9 (24)
		hinds	100±7.1 (49)	90±9.7 (34)	80±3.5 (49)	86±3.4 (28)
Alanine aminotransferase	U/l	calves	39±3.2 (10)	45±3.6 (26)	36±3.4 (32)	42±4.0 (24)
		hinds	36±2.7 (49)	42±3.1 (34)	37±3.2 (49)	39±3.6 (28)
Lactate dehydrogenase	U/l	calves	1030±112 (10)	839±55 (26)	1025±57 (32)	1113±114 (24)
		hinds	1042±79 (49)	803±63 (34)	1059±62 (49)	1090±94 (28)
Amylase	U/l	calves			121±1.2 (05)	119±1.0 (06)
		hinds			119±0.8 (06)	122±1.1 (06)
Lipase	U/l	calves			32±0.6 (05)	31±0.4 (06)
		hinds			32±0.5 (06)	32±0.4 (06)
Dopamine-B-hydroxylase	µmol/min/l	calves		13.5±1.5 (05)	14.1±0.9 (04)	36.0±2.6 (06)
		hinds	18.9±0.7 (17)		18.1±4.5 (11)	

hinds were similar to those in serum copper, although the zinc values in the hinds maintained under poor nutritional condition were not low (Table 4).

The alkaline phosphatase activity (SAP) of calves and adult hinds dropped during autumn and winter (Table 4). Slightly elevated SAP (average 279 U/l), and very high creatine phosphokinase (CPK) (1044 U/l) activities were found for the adult hinds living under poor nutritional state in April (Group 47). No significant changes were noted in alanine aminotransferase (ALAT) activity, and the activities of lactate dehydrogenase (LDH) and aspartate aminotransferase (ASAT) showed only slight increases during late winter. The CPK and LDH activities of pregnant hinds increased slightly, and the ASAT activities significantly ($P<0.001$) after parturition (from 185 to 234 U/l; from 986 to 1216 U/l; from 66 to 115 U/l, respectively).

Artificial feeding

The body weight of the hinds fed on silage and molasses during 3 to 4 months in winter (Group 44, Table 1) was 67.8 kg, and serum total protein (78 g/l), albumin (38.8 g/l), total lipid (3.2 g/l), triglyceride (0.2 mmol/l), cholesterol (2.36 mmol/l), calcium (2.6 mmol/l), inorganic phosphorus (2.2 mmol/l), magnesium (1.2 mmol/l), and blood glucose (4.18 mmol/l) values were high compared with all the other winter groups. The serum CPK, SAP, ASAT and LDH activities were relatively low.

DISCUSSION

Reindeer, like other northern ungulates, undergo seasonal physiological changes which adapt them to the annual variations in ambient conditions. The result is a cycle with highest metabolic demands in the spring and early summer suited to rapid growth and the high nutritive quality of vegetation (Steen 1968, Klein 1970, Nieminen 1980a) as expressed by the growth of calves (McEwan & Whitehead 1971, Ryg & Jacobsen 1982, Timisjärvi et al. 1982) and antler growth, recovery from the rigors of winter and lactation in females (White 1975, McEwan et al. 1976). The most critical period for the semi-domestic reindeer in Finland is usually late winter and early spring, and in recent years large numbers of reindeer have died of starvation, because of particularly bad conditions (Nieminen et al. 1982).

Serum thyroxine (T_4), alkaline phosphatase (SAP), creatine phosphokinase (CPK) and blood glucose in calves were high during summer and autumn in present studies indicating very rapid growth. The maximum rate of live weight gain in the reindeer occurs at time of weaning giving an excess of 0.3-0.4 kg/day (Krebs & Cowan 1962, McEwan & Whitehead 1971) which is in accordance with the results in Finnish reindeer (Nieminen et al. 1980a, Timisjärvi et al. 1982). The SAP activity of the reindeer calves was in February at the same level as in the adult hinds, which indicates a cessation of growth during the winter months. In the winter calves, even in captivity, when offered unlimited quantities of high quality food voluntarily reduce their food intake, and growth ceases and metabolic rates drop to a relatively low level (McEwan 1968).

The reindeer has, however, adapted well a depression of food intake and reduction of body weight and in normal years when digging conditions are good, wintering and also reproduction are quite successful. During the long winter the main part of the food intake consists of lichens containing mainly carbohydrates. Although the growing reindeer foetus almost triples its weight during the six weeks before parturition (Roine et al. 1982), at the same time the energy demand of the hind increases by only 15 % (McEwan & Whitehead 1971). The food protein requirements is therefore reduced, and the requirement caused by metabolism, movement or maintenance of body temperature is satisfied by carbohydrates. According to McEwan & Whitehead (1970) the caloric intake is 35 to 45 % lower in winter than in summer.

Ringberg et al. (1978) reported that serum thyroxine (T_4) values in free-ranging, semi-domestic reindeer calves were higher in July than in February. The T_4 level, which reflects thyroic activity and thus is correlated directly with fasting metabolic rate and food intake, was relatively stable and unaffected by age and season during present study which is in agreement with observations on white tailed deer (Bubenik & Bubenik 1978). Thyroxine secretion rate in reindeer on a supplemented diet and at different season does not change (Yousef & Luick 1971), although it has been found that hydrocortisone secretion is more intensive during winter than during summer (Yousef et al. 1971). However, Ryg & Jacobsen (1982) reported, that triiodothyronine (T_3) levels in the young reindeer were primarily regulated by the flow of energy of nutrients into the animal, and that T_4 changed roughly corresponding to feed intake and weight gain.

Although calving in itself usually seems to be relatively easy in all species of *Cervidae*, the elevated serum CPK, ASAT and LDH activities in hinds after parturition may be indicative of stress during calving. The newborn reindeer calf is highly developed and is able to suck milk rich in protein (10 %) and fat (20 %), about half an hour after birth. At birth the calf is essentially monogastric and absolutely dependent upon milk until the rumen develops, usually between 4 and 6 weeks of age (Leat 1970), and hence the rapid growth of calves can be correlated with milk production. Young reindeer calves get lipids and proteins mainly from the hind's milk. The calf has no subcutaneous fat layer, but brownish fat is interpersed among its skeletal muscles (Blix & Steen 1979, Hissa et al. 1981) and shivering after birth continues until the fur is dry (Krog et al. 1977, Wika et al. 1979 and Wika & Krog 1980). According to our results the calf liberates considerable amounts of catecholamines during the first day after birth, and brown adipose tissue may play an integral and important role in non-shivering thermogenesis (Nieminen et al. 1980b) According to Hissa et al. (1981) newborn reindeer calves can maintain their body temperature even at —15°C, and they can increase their metabolic rate five- to sixfold. Heat production is primarily stimulated by the sympathetic nervous system.

The relative concentrations of myristic, palmitic, oleic and linoleic acids were higher in the serum of calves than in the serum of hinds, and in the milk of hind the concentrations of these acids are also high (Hatcher et al. 1967). The results indicate that after weaning, when the rumen fermentation is functioning normally, the values of the serum fatty acids of calves change and reach those of the hinds. Serum immunoglobulins of reindeer calves were minimal between the 10th and 20th day after birth suggesting a hypogammaglobulinaemic state due to the disappearance of immunoglobulins in the milk. The endogenous synthesis of immunoglobulines begins in the 4th week of life (Nieminen et al. 1980a). Thus, the period before the endogenous synthesis of immunoglobulins is a very critical stage in the development and could partly explain the high mortality of reindeer calves during the strenuous summers brought about by heat and blood-sucking insects.

In the reindeer studied here and also in those studied by Afanasev (1963) and Hyvärinen et al. (1975), the decrease in serum proteins is at first associated with a decrease in serum globulin concentration (Fig. 3), and the albumin/globulin ratio thus increases. The results are in agreement with the earlier findings on white-tailed deer (Ullrey et al. 1967) and black-tailed deer (Bandy et al. 1957). Franzmann et al. (1976) reported, however, that serum total protein and mainly albumin reflect the nutritive state of the Alaskan moose. It is obvious that the reindeer is well adapted to seasonal variations of food composition, and the high concentrations of globulins in autumn may represent reserve protein for the winter and spring. Since, the protein content of lichens is very low (3 - 4 %) (Isotalo 1971), the reindeer will show a negative nitrogen balance during winter (Nordfeldt et al. 1961, Person et al. 1975). The serum albumin content of hinds living in a poor nutritional state in April was also lower, which must be caused by severe protein malnutrition.

Like other ruminants, cervids increase the percentage of recycled urea when the protein content of their diet decreases (Franzmann et al. 1976, Bahnak et al. 1979). According to Hove & Jacobsen (1975) and Valtonen (1979) reindeer are capable of minimizing their urinary losses and increasing the availability of nitrogen for synthetic processes during the period of low protein diet. Recent results (Nieminen et al. 1980c) suggest that nitrogen loss via faeces is also reduced on a lichen diet, and so the reindeer have a greater potential for recycling urea than other ruminants, and the whole potential may be brought into action during winter (Wales et al. 1975). The clear seasonal variation in serum urea concentration of reindeer in the present study agrees closely with earlier findings on Finnish reindeer (Hyvärinen et al. 1975). The increase in serum urea in late spring, although there was a significant decrease in total serum protein concentration, is in agreement with previous reports dealing with reindeer (Hyvärinen et al. 1975, Bjarghov et al. 1976) and this most probably reflects an increased catabolism of body proteins at this time. The very high serum CPK activity may also indicate catabolism of muscles during severe starvation, and slightly elevated serum LDH and ASAT activities are obviously associated with tissue breakdown in reindeer (Nieminen 1980a). The elevation in serum creatinine value during late winter may be indicative of increased excretion of nitrogen, via an alternate pathway, caused by the increased protein catabolism. Halse et al. (1976) have shown that the plasma creatinine level in reindeer tended to increase during the actual fasting period.

The clear seasonal variation observed in serum total lipids, triglycerides and cholesterol, and the very high levels of these in calves during summer, most probably reflect the differences in lipid content and nutritional value of diets. In good agreement with present results LeResche et al. (1974) and Franzmann et al. (1976) have shown that serum cholesterol level in the Alaskan moose reflects diet, dietary changes and the state of rumen metabolism. The serum total lipid, triglyceride and cholesterol concentrations of the hinds maintained under poor nutritional conditions in late April were very low. Bones of dead animals were very thin, apparently as a result of severe undernutrition and all fat in the medullas of the long bones was consumed. Autopsy of the dead hinds also showed that no perirenal and coronary fat was present.

Blood glucose levels remain constant in the reindeer, except in cases of severe malnutrition, and the concentration of glucose in the blood is higher than that recorded for other ruminants (Luick et al. 1973). It is suggested that the high blood glucose concent of the reindeer is a species characteristic which helps it to survive periods of malnutrition in wintertime. Blood glucose levels in the presents studies were in the same range as observed earlier in reindeer (Dieterich & Luick 1971, Hyvärinen et al. 1976). Variation between the observed blood glucose and also blood lactate values may be due to different methods of capturing, handling and restraining of the animals (Hyvärinen et al. 1976, Nieminen & Laitinen 1982). The higher blood glucose values found in calves than in adult hinds during summer and autumn is probably associated with the rapid metabolism of the young animals. Glucose is an important intermediate in metabolism and growth of animal in general and it is particularly important also for foetal growth and development (Luick et al. 1973).

The lichen diet is deficient in minerals and trace elements and the reindeer also suffer a negative mineral balance during winter (Halse et al. 1976). The very hard conditions endured by hinds living free in the forest and mountain areas have a pronounced effect on the mineral status of the animals. Serum calcium, inorganic phosphorus and magnesium values were low, and comparison of the values for other reindeer clearly showed that the reindeer in this area were also suffering from mineral deficiences. This is in agreement with earlier findings on Finnish reindeer (Hyvärinen et al. 1977). The results suggest that minerals, and also proteins, must be recycled between the body fluid and tissue pool and alimentary tract even in normal winters, and that the role of the skeleton as a mineral bank must be of great importance at this time.

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