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Original study

Clinical chemistry of farmed red deer (*Cervus elaphus*) yearling hinds reared on grass or *papillonaceous* pasture paddocks in Hungary

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Abstract

Yearling red deer (*Cervus elaphus*) hinds of identical initial body weight were reared on a monocotyledonous grass (group 1) or on a *papillonaceous* plant pasture (group 2) for 212 days. At the end of the experiment (when deer were shot) blood was taken from ten animals of each group for serum biochemical analysis. Hinds of group 2 provided higher final body weight (90±3.5 vs. 101±6.6 kg) and higher daily body weight gain (105.7±10.7 vs. 153.8±26.8 g/day). Within serum nitrogenous compounds group 2 provided higher total protein concentrations, while from the lipids only serum triglyceride levels were higher in this group. Serum potassium was in both groups higher than the reference range with a superposed slight hyperkalaemia in group 2. Higher lactate dehydrogenase and alkaline phosphatase activities were found in group 2 and lower aspartate aminotransferase activity values. Inorganic phosphate concentration showed a significant difference (group 1 provides higher values). Results refer to an expressed venison growth as a result of the rich dietary protein supply of group 2. Findings were evaluated as well with discriminant factor analysis, outlining the relative importance of the single blood biochemical parameters in shaping the inter-group differences.

Keywords: red deer, nutrition, grass, *papillonaceae*, clinical chemistry

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Abbreviations: ADF: Acid Detergent Fibre; ADL: Acid Detergent Lignin; ALT: alanine aminotransferase; ALP: alkaline phosphatase; AST: aspartate aminotransferase; BW: body weight; CK: creatine kinase; DFA: discriminant factor analysis; GLM: general linear model; gamma-GT: gamma glutamyl transferase; HDL: high density lipoprotein; LDH: lactate dehydrogenase; LDL: low density lipoprotein; NDF: Neutral Detergent Fibre; TP: total protein; TG: triglyceride, VLDL: very low density lipoprotein

Introduction

Red deer (*Cervus elaphus*) is the most important big game of Hungary due to its large and imposing antler, unique rutting behaviour and newly its meat. Thus, farming or semi-controlled keeping is spreading in Hungary. In *Cervidae*, nutritional demands are mostly influenced by the ontogenetic growth and reproduction phase (e.g. rutting or lactation). Grazing on grasslands is a vital component of deer nutrition and according to Trdan & Vidrih (2008), under moderate climate, herbage from grassland represents ca. 50 % of the total diet during the spring-autumn period in wild living cohorts and food choice of *Cervidae* is rather conservative even under altered environmental conditions (Fischer *et al.* 2008). In Hungary, red deer are exposed to changing seasonal variations; the spring-summer phase diet consists of green plants and leaves of high nutritional value. To compensate for the winter and also the expressed mid-summer (a strong burden in Hungary) nutritionally challenging feed shortage, additional feeding (e.g. grass silage) is applied for semi-domestic populations. This is primarily reasoned by the fact that deer are not able to digest strongly fibrous components quickly or to store enough feed in their rumen compared to cattle (Short 1963).

To estimate the nutritional status and growth performance of *Cervidae*, blood sampling is the most widely used method (Reindeer and Svalbard Reindeer: Säkkinen *et al.* 2001, reindeer: Ropstad *et al.* 1997, Soppela *et al.* 2008, Iberian red deer (*Cervus elaphus hispanicus*): Gaspar-López *et al.* 2009, Rocky Mountain elk (*Cervus elaphus nelsoni*): Wolfe *et al.* 1982, red deer: Rosef *et al.* 2010, Soetrisno *et al.* 1994, Kent *et al.* 1980, Padilla *et al.* 2000). Säkkinen *et al.* (2001) proposed serum urea and creatinine and their quotient to estimate protein and energy intake. Deficient protein supply leads to decreased blood urea levels since deer recycle urea by low dietary protein intake (Hove & Jacobsen 1975). In contrast, digestible protein load increases serum urea concentration, which may as well occur if low protein supply is coupled with energy restriction (Warren *et al.* 1982). According to Säkkinen *et al.* (2001), seasonality-associated fasting and feed restriction increases serum creatinine levels in deer. This variation has been found to be related to changes of muscle mass and the excretion of creatinine (DelGiudice *et al.* 1992, Wolkers *et al.* 1994). Compared to pure perennial ryegrass (*Lolium perenne*), additive *papillonaceous* plants, such as red and white clover (*Trifolium pratense and T. repens*) provide augmented venison growth due to their higher protein, calcium and phosphorus contents (Soetrisno *et al.* 1994).

This study aimed to describe the metabolic reactions (via blood serum analysis) and growth of farmed red deer yearling hinds grazed on two, markedly different pastures of defined and known herbal and chemical composition in South-Western Hungary, Bőszénfa.

Material and methods

Animals

The weaned red deer calves were penned in ten boxes for 20 individuals in each throughout the winter (from November to April) of 2010-2011. On the 11th of April 2011 (initial feed sampling and body weight measurement) 44 yearling hinds were allocated to two different pasture covered paddocks of each 2 ha (22 animals/paddock). Animals were only treated once during the entire study interval (June 2011) with Albendanin 5 % suspension (Pharmatéka Inc., Budapest, Hungary), orally, as an anthelmintic treatment. The body weight (initial and final) of the deer is given in Table 1. On the 16th of November 2011 (final feed sampling and body weight measurement) deer were shot and hanged (onto a digital scale supported facility); the jugular vein was cut and effluent venous blood was collected. Blood samples of randomly selected ten hinds/group (total n=2×10=20) were analysed. Tranquilisers were avoided since farmed deer venison served as a commercial product. The shooting was performed within ca. 10 min. The study was performed under the hunting licence of the Bőszénfa Deer Park, allowance no.: 2/1364-2/2011 by the Somogy County Government Agency, Directorate of Agriculture.

Table 1
Body weight results of the deer in study

Group Body weight, kg	1 (n=10) Mean±SD	2 (n=10) Mean±SD	*P*
Initial	67.6±3.2	68.4±4.4	ns
Final	90.0±3.5	101.0±6.6	<0.0001
Body weight gain, g/day	105.7±10.7	153.8±26.8	<0.0001

ns: $P>0.05$

Feeding conditions

The monocotyledonous grass based pasture (group 1) was dominantly composed of perennial ryegrass (*Lolium perenne*) and common meadow grass (*Poa pratensis*). The *papillonaceous* pasture (group 2) was based dominantly on alfalfa (*Mecicago sativa ssp. varia*), red clover (*Trifolium pratense*) and white clover (*Trifolium repens*). Pasture compositional sampling and analysis was performed with the Braun-Blanquet method (Podani 2006). In each paddock there were four measurements taken by the same diagonal way. Results of the plant composition are given in Table 3, while feed chemical composition is given in Table 2. Water was offered *ad libitum*. Additional feed ingredients (grain, etc.) were not fed at all.

Blood serum analysis

After withdrawal into Falcon 13 mL tubes the blood was immediately placed on ice, left to clot, centrifuged (1 500 × g/10 min) and serum was stored frozen (–70 °C) until analysis. Clinical chemical analysis was performed on automated equipment (Hitachi 917, Boehringer Mannheim, Germany) in a single analytical run. Reagent kits for triglyceride, total cholesterol, HDL and LDL cholesterol, albumin, total protein, creatine kinase, AST, ALT, urea and uric

acid were purchased from Human Ltd. (Wiesbaden, Germany), reagents for creatinine and calcium were obtained from Roche Diagnostics (Quebec, Canada), those for phosphate and chloride from Pharmacia Biosystems (Freiburg, Germany), while those for gamma-GT, lipase, alkaline phosphatase and magnesium from Diagnosticum Ltd. (Budapest, Hungary). Na and K were measured with ion selective electrodes. Total lipid content was determined with the sulfophosphovanillin method, spectrophotometrically (Johnson *et al.* 1977).

Table 2
Feed chemical composition (initial and final samplings)

pasture	Grass	*Papillonaceae*	Grass	*Papillonaceae*
group	1	2	1	2
Dry matter, %	26.1	19.2	26.7	21
Crude protein, %DM	2.2	3.7	3.3	4.8
Crude fat, %DM	0.5	0.4	0.6	0.4
Crude fiber, %DM	5.7	3.6	5.2	3.2
Crude ash, %DM	1.8	1.8	2.2	1.9
N free extract, %DM	15.9	9.7	15.7	10.7
NDF, %DM	11.7	6.2	11.5	6.2
ADF, %DM	7.4	4.4	5.9	4.1
ADL, %DM	0.6	0.7	0.9	0.7
Hemicellulose, %DM	4.3	1.8	5.6	2.1
Crude cellulose, %DM	6.8	3.7	5	3.4
Ca, g/kg DM	1.93	2.8	1.18	2.33
P, g/kg DM	0.61	0.57	0.85	0.73

Table 3
Herbal composition of the paddocks

Grass pasture	Covered % of the area	Paillonaceous pasture	Covered % of the area
-		*Alfalfa* (*Mecicago sativa ssp. varia*)	5.1-25
White clover (*Trifolium repens*)	0.1-1	White clover (*Trifolium repens*)	5.1-25
Red clover (*Trifolium pratense*)	0.1-1	Red clover (*Trifolium pratense*)	5.1-25
Perennial ryegrass (*Lolium perenne*)	5.1-25	Perennial ryegrass (*Lolium perenne*)	0.1-1
Soft brome (*Bromus mollis*)	1.1-5	Soft brome (*Bromus mollis*)	0.1-1
Common medow grass (*Poa pratensis*)	5.1-25	Common medow grass (*Poa pratensis*)	0.1-1
Meadow fescue (*Festuca pratensis*)	0.1-1	Meadow fescue (*Festuca pratensis*)	0.1-1
Cock´s foot (Dactylis glomerata)	*0.1-1*	*Field eryngo (Eryngium campestre)*	*0.1-1*
Tall fescue (Festuca arundinacea)	*1.1-5*	*Common dandelion (Taraxacum officinale)*	*0.1-1*
Eringeron annual (Stenactis annua)	*0.1-1*	*Broad-leaved Dock (Rumex obtusifolius L.)*	*0.1-1*
Giant plumeless thistle (Carduus acanthoides)	*0.1-1*	*Common yarrow (Achillea millefolium)*	*0.1-1*
Field bindweed (Convolvulus arvensis L.)	*0.1-1*	*Creeping thistle (Cirsium arvense)*	*0.1-1*

Italic typed plants are characteristic for only one pasture.

Feed chemical composition analysis

The chemical composition of the plant samples was determined according to the following methods: Dry matter: AOAC 934.01, vacuum oven; Crude Protein: Kjeldahl, AOAC 984.13; Ether extract: AOAC 920.39; Crude fibre: AOAC 978.10; Ash: AOAC 942.05; Nitrogen-free Extract

calculation: 100 - (Moisture + Ash + Protein + C. fibre + Ether e.); Neutral Detergent Fibre (NDF): Holst (1973); Acid Detergent Fibre (ADF): AOAC 973.18; Acid Detergent Lignin (ADL): AOAC 973.18; Hemicellulose calculation: NDF-ADF. Ca and P were determined with flame atomic absorption spectroscopy, according to the AOAC methods 975.03B and 966.01, respectively.

Statistics

Initial and final body weight data, as well as body weight gain were compared with paired samples t-test, since deer were individually marked by ear tags. Blood serum parameters of the two groups were compared with analysis of variance (GLM procedure). The group was a fixed factor, while body weight was a covariant in the model. Factor effects are provided in Table 4.

Discriminant factor analysis (DFA) was performed on the dataset in order to identify the different groups based on the blood biochemical data. SPSS 10 for Windows (SPSS Inc., Chicago, IL, USA) and AlphaSoft 12.3 (Alpha M.O.S., Toulouse, France) were used for the analyses.

Table 4
Composition of the experimental groups

Feeding	Grass pasture Mean±SD	*Papillonaceae* Mean±SD	*P*	Group	BW	G×BW
Nitrogenous compounds						
total protein, g/L	**65.9±4.38**	**72.6±8.53**	**0.016**	-	-	-
albumin, g/L	24.7±3.56	27.4±5.19	ns	-	-	-
urea, mmol/L	7.46±0.89	8.00±0.81	0.092	-	-	-
uric acid, mmol/L	1.90±0.99	1.80±1.03	ns	-	-	-
creatinine, µmol/L	103.9±22.8	114.7±14.5	ns	-	-	-
Lipid metabolites						
total lipid, g/L	1.20±0.50	1.55±0.70	ns	-	-	-
triglyceride, mmol/L	**0.13±0.04**	**0.16±0.04**	**0.006**	-	-	-
total cholesterol, mmol/L	0.81±0.19	0.98±0.37	ns	-	-	-
HDL chol, mmol/L	0.53±0.12	0.61±0.20	ns	-	-	-
LDL chol, mmol/L	0.22±0.08	0.29±0.19	ns	-	-	-
Ions						
Na, mmol/L	138.4±7.02	140.2±2.11	ns	-	-	-
K, mmol/L	**4.95±0.48**	**5.64±0.77**	**0.046**	-	-	0.092
Ca, total, mmol/L	2.17±0.25	2.35±0.23	ns	-	-	-
Ca, ion, mmol/L	1.34±0.17	1.45±0.19	ns	-	-	-
P inorg, mmol/L	**2.11±0.33**	**1.72±0.24**	**0.007**	-	-	-
Cl, mmol/L	97.9±7.84	100.2±6.29	ns	-	-	-
Mg, mmol/L	0.69±0.07	0.73±0.07	ns	-	-	-
Enzymes						
LDH, IU/L	**843.9±246.6**	**1 003.5±290.0**	**0.048**	**-**	**-**	**-**
AST, IU/L	**111.1±110.5**	**101.9±30.0**	**0.029**	0.084	-	-
ALT, IU/L	37.1±12.59	43.4±12.6	ns	-	-	-
gamma-GT, IU/ L	27.3±27.37	15.7±4.27	ns	-	-	-
lipase, IU/L	42.3±12.93	50.4±10.6	ns	0.024	0.035	0.036
alkaline phosphatase, IU/L	**113.9±50.85**	**168.3±64.0**	**0.048**	0.076	-	-
creatine kinase, IU/L	526.0±121.3	757.6±321.1	ns	-	-	-

ns: $P>0.05$; Inter-group comparison and the effect of group, body weight and their interaction on the differences; Bold lines indicate significant difference between groups on different pasture types.

Results

Growth

The final body weight (BW) of group 2 reached significantly higher values and the daily BW gain provided a similar difference (Table 1).

Blood serum

Nitrogenous compounds
The serum total protein (TP) level was higher in group 2 reared on *papillonaceous* plants (Table 4). In contrast, albumin, uric acid and creatinine did not differ in the two groups, meanwhile serum urea concentration was slightly, but not significantly higher in group 2.

Lipid metabolites
While total lipid, total, HDL and LDL cholesterol tended to be higher in group 2, statistical significance was only proven for triglyceride concentration; higher values were measured in group 2.

Serum ions
No inter-group differences were found between serum sodium, total and ionic calcium, chloride and magnesium concentrations. In contrast, higher potassium concentration was found in group 2 (with significant group×BW interaction). Group 1 reared on monocotyledonous grass pasture provided higher inorganic phosphate concentrations in the sera.

Enzymes
Lactate dehydrogenase (LDH) and alkaline phosphatase (ALP) activities were significantly higher in group 2 (compared to group 1), while aspartate aminotransferase (AST) activity was lower in this group. Alkaline phosphatase was significantly influenced by group, as a fixed factor, while for AST a similar, borderline significant effect was proven. Alanine aminotransferase (ALT), gamma-GT, lipase and creatine kinase (CK) activities were not different between groups.

Discriminant factor analysis

In the discriminant factor analysis factor 1 (parallel with the horizontal axis) was covering practically 100 % of the variance, resulting to a robust (100 %) differentiation of the two groups. The biochemical factors playing the most determinant role in the discrimination were those characterised by the most horizontal and long vectors in Figure 1.

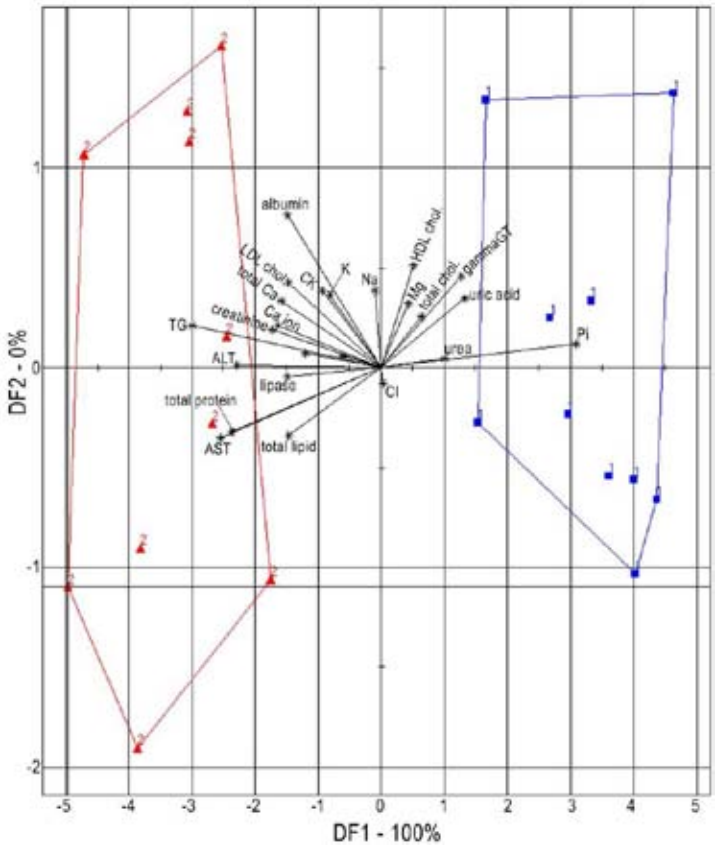

Figure 1
The effects of the two discriminating functions on the separation of the deer groups (horizontal: DF1; vertical: DF2)

Discussion

Blood serum

Nitrogenous compounds

Nutritional status is primarily evaluated in deer taking serum nitrogenous compounds into consideration (DelGuidice *et al.* 1992, 1994, Phillip *et al.* 2007). This is based on the condition that deer are able to conserve nitrogen when protein restriction occurs via increased renal re-absorption and urea recycling, thus limiting urinary nitrogen loss (Robbins *et al.* 1974). According to Thrall (2004), serum total protein (TP) concentration increases with aging in deer and reachs a plateau at about ten months of age. The hinds of this study were allocated to the different pasture types at the age of 11 months, thus, serum TP differences were attributed to the diet-compositional differences. The TP concentrations of both groups fall into the reference range of red deer (54-81 g/l), as reported by Kent *et al.* (1980). Rosef *et al.* (2010) reported on a lower TP interval (63.6-66.3 g/l) for free living deer in Norway, while high altitude (2450 m) keeping (Mexico) led to higher values (50-80 g/l, Padilla *et al.* 2000). Based on the above-mentioned results it was stated that elevated dietary protein content

can significantly increase serum protein concentration of farmed red deer hinds. This was further supported by the results of Soppela *et al.* (2008) in reindeer undergoing a lichen-reindeer pellet feed transition coupled with increasing total serum protein levels. Moreover, Figure 1 accurately demonstrates the role of total serum protein in the discrimination of the groups, the vector is directly pointing to group 2.

The main role of albumin is maintaining the oncotic pressure in the vascular system, thus its concentration is less variable, as it was found in our study as well. In contrast, we found lower albumin values than Rosef *et al.* (2010, 35.7-37.5 g/l in red deer) and English & Lepherd (1981, 30.3-35.3 g/l in fallow deer) in all instances in free living cohorts.

For body condition estimations creatinine concentration (mostly as an urinary excrete) is favoured in deer. This is underpinned by several factors: creatinine is excreted at a rather constant diurnal rate, after complete glomerular filtration and minimal re-absorption in mammals. According to DelGiudice *et al.* (1994), urinary creatinine concentration is not affected by herbivorous diets, but is a correlate of mass-specific nitrogen intake and is thus related to lean muscle mass. While our data failed to provide a significant relation of serum creatinine to body weight, total serum protein content was significantly related with it (Pearson correlation coefficient r=0.625, P=0.007). According to Soppela *et al.* (2008), increased serum creatinine levels (over 250 µmol/l) are associated with tissue protein catabolism induced by dietary protein shortage. We report the opposite, low serum creatinine levels are associated with optimal dietary protein supply and higher muscle mass. (For uric acid a similar tendency was found as for urea (and creatinine), but without significant inter-group differences.)

In ruminants dietary protein intake, but rather rumen degradable protein intake is reflected by serum urea concentration, but is as well related to its balance to fermentable metabolic energy. According to our results, feed compositional differences (crude protein) were only slightly (but not significantly) reflected by the serum urea concentration. This lack of difference, even with largely different (nearly 2-fold) crude protein intake and serum levels is interesting, because the *papillonaceous* mixture was rather rich in crude protein compared to grass pasture. The rumen degradability of the protein in the two feed sources is rather similar, as reported by Cassida *et al.* (2000). However, the marked difference in the dietary level of NDF and ADF, on the excess of the grass mixture (group 1), results in a higher structural fibre content, leading to a slower rumen outflow rate of this feed source. The longer rumen degradation may lead ultimately to lower feed intake, which is disadvantageous for the microflora. In contrast, the rumen fermentation of the *papillonaceous* feed, due to its lower structural fibre (NDF and ADF) content, is quick, ensuring a higher substrate concentration for the microbiota per time unit, leading to a more intensive rate of ruminal fermentation. Thus, microbial ammonia utilisation and protein synthesis is augmented by the higher energy supply. The intensive microbial protein synthesis leads finally to a higher microbially synthesised protein content in the small intestine, resulting in an elevated amino acid absorption and a better protein supply of the animals of the latter group (2). The more efficient microbial ammonia utilisation was indicated by the fact that higher protein intake from the *papillonaceous* pasture did not ultimately lead to an elevation of the serum urea level in group 2. This is moreover also supported by the fact that not only blood TP, but also the body weight gain of group 2 was significantly higher.

Enzymes

According to Thrall (2004), deer are anxious animals; hence any handling related excitement leads to increased serum CK, LDH and AST activities. In our study the hunting of animals was performed very quickly, thus, the burden of premortal stress in this context can be excluded from the etiological factors. We rather suppose an expressed muscular growth in group 2, as a partial result of the *ad libitum* feeding with a high-protein diet. The diet composition of group 2 was uncommon, namely free-living deer are rarely supplied with high-protein sources (Mitchell *et al.* 1977). (The slight hyperkalaemic status (compared to group 1) of these animals seems to support higher muscle mass as well; see ions section) Moreover, AST was lower in group 2 providing higher LDH (and slightly higher CK) activities, contradicting to marked premortal stress.

In our case deer were *ab ovo* providing relatively high CK enzyme activity values, e.g. compared to data of Kent *et al.* (1980; 12-250 IU/l in shot deer) and Rosef *et al.* (2010; 266±253 IU/l in tranquillised free ranging deer) most probably associated with expressed muscle growth (Thrall 2004) and their farmed, fenced keeping conditions. The CK activity values in this cohort (both groups) were higher compared to free-living (Padilla *et al.* 2000; 221±103 IU/l), restrained sampled animals and also higher than in New Zealand farmed deer (Wilson & Pauli 1983, 197.9 IU/l). Samplings in both cited cases were performed without tranquilisation.

Alkaline phosphatase is a membrane-bound enzyme and its activity is expressed in osteoblasts, biliary and renal epithelium and intestines (Thrall 2004). This analysis handled the isoforms not separately, but compared to relevant literature (Kent *et al.* 1980; 3-36 IU/l, Rosef *et al.* 2010; 224±130 IU/l) we found either lower or consonant results. Animals involved were yearling hinds, thus, antler ossification effects were excluded. The Ca supply was nearly two-fold higher in the *papillonaceous* pasture, while an opposite, but less expressed trend was found for dietary phosphorus (Ca/P ratios of 1.39 and 3.19 in the *papillonaceous* and the grass pastures, resp.). In addition, sexual activity was already ceased, as assessed by the absence of visible corpus luteum in the hinds. While significant correlation was found neither between carcass bone content nor serum Pi levels, serum Ca concentration provided a significant correlation with ALP ($r=0.48$, $P=0.008$). Moreover, dietary protein supply has as well been published to increase serum ALP activities (Klinger *et al.* 1986, white tailed deer), and the relationship is met primarily via the augmented growth (Table 1) and the coupled ossification needs of young and growing hinds. In addition, this was as well fortified with the rich dietary Ca supply compared to the grass pasture reared deer.

Ions

From the two most abundant ions Na and Cl were not significantly different between groups. Serum sodium level is regulated by glomerular filtration, re-absorption or renal excretion. The extent of sodium and chloride re-absorption is shaped by physiological needs. In this study both ion concentrations definitely fluctuated around literature data for red deer (Padilla *et al.* 2000, Rosef *et al.* 2010). In Figure 1, discriminant factor 1 had a separation efficiency of 100 %, thus, horizontal vector-like biochemical factors contributed largely to the spatial separation of the groups. It is clearly visible that Na aligns to a vertical vector with minimal length (such as Cl), referring to its nearly constant concentration in a group-independent manner.

In contrast K did differ between groups, on the excess of the larger bodied deer (group 2). The serum potassium concentration of deer was not pathologic, as Rosef *et al.* 2010 provided a reference range of 5.5-6.6 mmol/l, while the International Species Information System (ISIS 2002) applies a range for K in *Cervidae* of 4.3±0.9 mmol/l. Interestingly, Stringer *et al.* (2011) reported on hyperkalaemia in free-ranging white-tailed deer with unknown etiology, excluding late serum separation, dietary factors, poor nitrogen supply and premortal stress. Interestingly, CK, LDH and K were not providing a significant correlation in our study with the K concentration values. Thus, mild hyperkalaemia was rather attributed to slight osmotic changes.

In contrast, inorganic P provided an opposite inter-group difference as also indicated in Figure 1. The reason of the difference not agreeing with the dietary levels may be that ALP activity and somatic growth, and thus Pi demand of group 2 was more expressed, sequestering the substrate from the blood circulation. Neither total, nor ionic Ca was different between groups in spite the large dietary difference, most probably due to hormonal control. Magnesium concentrations of the sera in both groups were similar to those in the relevant studies (Padilla *et al.* 2010, 0.91±0.2, Rosef *et al.* 2010, 0.48±0.11 mmol/l).

Lipid metabolites

Dietary crude fat content was less different between the two diets (Table 1). Although nearly all lipoprotein fractions analysed (total, HDL and LDL cholesterol) tended to be higher in group 2, only triglyceride (TG) concentrations were statistically higher in this group. Circulating TG concentrations resemble the balance between hepatic synthesis and secretion and adipose tissue uptake (Dijkstra *et al.* 2005). Thus, higher serum TG levels refer to an augmented hepatic secretion via VLDL, most probably related to rich energy supply. This was accompanied by a slightly (but not significantly) elevated pancreatic lipase activity. Comparing our results to captive (Peinado *et al.* 1999, 0.07-0.09 mmol/l) or free ranging deer (Rosef *et al.* 2010: 0.1±0.08 mmol/l), we found higher levels in both groups. Lipoprotein synthesis of *Cervidae* is a less studied area, but similarly to other ungulates, circulating TG is mostly present in the form of chylomicrons of intestinal and VLDL of intestinal and hepatic origin. Compared to domestic ruminant feeds, the feed of deer in this study was a low-fat diet. Thus, we supposed behind the results the relative rich energy supply compared to wild foraging circumstances.

Based on our results the conclusions can be drawn that in red deer yearling hinds, reared either on a monocotyledonous grass mixture (1) or on a pure *papillonaceous* plant pasture (2) under farmed conditions for 212 days, the higher dietary protein content led to markedly higher body weight gain and higher serum total protein levels. Results refer to the need of digestibility studies on red deer unexplored from this aspect. The protein rich *papillonaceous* diet let to a higher muscle mass, leading ultimately to slightly, but not pathologically elevated potassium and AST levels, while ossification needs were met by elevated ALP activities. Lipid metabolites showed minor inter-group differences.

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