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Small ruminant lentivirus-infected dairy goats' metabolic blood profile in different stages of lactation*

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The study aims to determine the differences in metabolic parameters in blood serum between asymptomatic animals with small ruminant lentivirus (SRLV) and uninfected goats. Pearson correlations were also estimated between biochemical parameters. The study included 26 goats which were divided into SRLV-infected and SRLV-free groups. Blood samples were taken at four points of lactation (days 14, 45, 85, and 240, reflecting perinatal period, early lactation, the peak of lactation, the end of lactation). Hepatic, kidney, bone, cardiac, pancreatic, lipid profiles and CRP concentrations were analyzed. Choline esterase (CHE), calcium (Ca*), creatine kinase (CK), and

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triglyceride (TRI) levels differed between groups, on day 240 ($p \leq 0.05$). Some parameters varied during lactation, with similar patterns observed in both groups. Mainly positive correlations between biochemical parameters were observed in the SRLV-free and SRLV-infected groups both within organ profiles and between them. CRP was not correlated with any biochemical parameters in the SRLV-free group but was negatively correlated with parameters of the liver, kidney, cardiac, and lipid profiles in the SRLV-infected group. The correlations suggest that SRLV may affect the kidneys, liver and heart, even in asymptomatic animals. Some differences were found between asymptomatic SRLV-infected and SRLV-free goats in the last stage of lactation; however, the nature of these changes requires further detailed studies.

KEYWORDS: dairy goat / SRLV-asymptomatic / milk yield / metabolic indicators / lactation

Small ruminant lentivirus (SRLV) causes chronic diseases in goats (caprine arthritis encephalitis, CAE) and sheep (maedi-visna disease, MV), and serological evidence of infection has been reported in wild ruminants [Olech *et al*. 2020]. The main target cells for SRLV are monocytes, macrophages, and dendritic cells. The maturation of blood monocytes into tissue macrophages initiates virus replication within these cells [Peluso *et al*. 1985]. SRLV causes persistent infections, however, clinical signs appear in less than 30% of infected animals. In some of them, long-lasting infection results in severe symptoms, leading to chronic debilitating diseases, and ultimately, premature culling or death [Caroline *et al.* 2010]. SRLV causes a systemic infection that mainly affects the mammary gland, joints (arthritis) and the respiratory system and in rare cases, mainly kids, the central nervous system [Blacklaws 2012]. All seropositive animals constitute a potential source of infection [Tavella *et al*. 2018]. Even asymptomatic, SRLV-infected goats produce milk of lower quality, implying that infection alters their metabolism long before clinical signs become apparent [Milczarek *et al*. 2019]; however, the nature of changes has never been determined. Some studies indicate that SRLV infection has no influence on goat productivity [Kaba *et al*. 2012, Nowicka *et al*. 2015]. As no specific therapy exists for SRLV-infected animals, and no vaccine is available to prevent infection, the most effective way to eradicate the disease is proper herd management: diagnosis, the removal of infected animals from the herd or weaning kids from infected dams immediately after birth and rearing them on bovine colostrum/milk or milk replacement. Although CAE eradication programs have been applied successfully in many EU countries [Peterhans *et al.* 2004], none have been used in Poland. The prevalence of SRLV in Poland has risen steadily since the 1990s, when the import of live animals from Western countries began. Between 1996 and 2007, the seroprevalence in Polish herds increased from 30.8 to 71.9% [Kaba *et al.* 2013]. The foundation of SRLV testing in goats is serological test, but serum biochemical analyses can also provide information on organs, the state of hydration and nutrition, and disease progression. They can help detect metabolic disorders [Kaba *et al.* 2013, Brzóska *et al.* 2014, Czopowicz *et al.* 2017] which may occur during infections, even in asymptomatic form or at the infection early stage.

The aim of the present study was to identify the differences in blood serum metabolic parameters between asymptomatic SRLV-infected animals and those that

are SRLV-free. The Pearson correlation coefficients between biochemical parameters were also estimated.

Material and methods

Animals

Twenty-six Polish White Improved (PWI) and Polish Fawn Improved (PFI) goats between their second and sixth lactation were included in the study. The animals were kept in a free stall barn but in separate pens with constant access to water and salt licks. They were fed according to a system established by the *Institut National de la Recherche Agronomique* (INRA), France, and adopted by the National Research Institute of Animal Production (NRIAP-INRA), Poland [Brzóska *et al*. 2014]. The animals were fed a routine diet used in this herd for many years. The basic diet consisted of corn silage and concentrates, supplemented with minerals and vitamins. During the spring and summer, the animals were additionally grazed. The goats were machine-milked twice a day. The herd has been serologically tested against SRLV antigens for 20 years at least once a year as part of another long-term research project. Thus, all animals had received regular serological testing for their whole lives. The presence of the virus in the herd was also confirmed by its prior isolation [Kaba *et al.* 2009]. The animals were divided into two groups, viz. SRLV-infected (N=13) and SRLV-free (N=13), based on results from at least two consecutive serological tests (ID Screen MVV/CAEV indirect screening test, IDVet Innovative Diagnostics, Grabels, France). To eliminate any newly-infected goats from the control group, the testing was also conducted during the study period. No animal converted serologically during the study. The two groups were strictly separated for the entire study period and kept under similar conditions. Both groups included seven PWI and six PFI goats; in each breed, three goats were in their second lactation, and four (or three in PFI) were in their third and higher lactation. Goats assigned to the SRLV-infected group did not show any clinical signs of CAE. Blood tests based on RT-qPCR analysis (LightCycler 480 System, Roche, Basel, Switzerland) found that despite the presence of antibodies, the virus load was below detection levels in all animals (Bagnicka – personal communication). In both groups, goats did not have any clinical mastitis signs, and SCC in milk was lower than 1.6×10^6, indicating a low probability of subclinical mastitis. The animals were free from parasitic infections, as determined by standard parasitological methods, such as floatation and McMaster methods.

Analysis of the biochemical profile of blood serum.

The following blood biochemical parameters were investigated as markers of internal organ health in goats: (a) hepatic profile – albumin (ALB), total bilirubin (BILT), the activity of alkaline transaminase (ALT), aspartate aminotransferase (AST), choline esterase (CHE) (butyrylcholinesterase), lactate (LACT), (b) kidney profile – level of creatinine (CRE) and total protein (TP), (c) bone profile – calcium (Ca) and

alanine aminotransferase (ALP), phosphor (P), (d) cardiac profile – level of creatine kinase (CK), and electrolytes (chloride – Cl, sodium – Na, potassium – K, magnesium – Mg, iron – Fe), (e) pancreatic profile – level of lipase (LIP) and glucose (GLU), (f) lipid profile – level of cholesterol (CHOL) including high-density lipoprotein (HDL), low-density lipoprotein (LDL), and triglycerides (TRI), (g) infection propagation – C-reactive protein (CRP). Gamma glutyltranspeptidase (GGT). Gamma glutyltranspeptidase (GGT) is the parameter assigned to both hepatic and cardiac profiles.

Blood samples were collected four times during lactation: 1. Perinatal period=day 14, 2. Early lactation=day 45, 3. Peak of lactation=day 85, 4. End of lactation=day 240. Blood was collected via jugular venipuncture into the clot activator tubes. The samples were centrifuged at 3000 rpm for 10 minutes. The serum was transferred to a new tube and stored at -80°C until biochemical analysis.

All analyses were performed with the Cobas Integra analyzer (Roche, Basel, Switzerland) with Precipath U-plus tests. The serum total Ca concentration was adjusted according to albumin concentration as follows: Corrected Ca (Ca*) (mmol/L)=determined Ca (mmol/L)+0.02*(40-albumin marked (g/L) [Mbuh and Mbwaye, 2005]. The CRP level was determined using an ELISA test (Goat C Reactive Protein ELISA kit, Shanghai BlueGene Biotech CO., China) according to the protocol. The values of parameters were compared with reference values for goats [Winnicka 2021].

Statistical analysis

All studied traits (blood serum biochemical parameters) were tested for normality of distribution using UNIVARIATE procedure (SAS/STAT software, ver. 9.4) and all of them did not deviate substantially from the Gaussian curve. Multi-factorial analysis of variance was performed to compare the fixed effect of stage of lactation, SRLV infection (SRLV-free or SRLV-infected), breed, parity, and interaction SRLV infection and the stage of lactation (procedure GLM, SAS/STAT software, ver. 9.4). The Tukey post-hoc test was used for to assess the significance of differences between means. Values differing significantly at $p \leq 0.01$ were indicated as A, B; those differing at $p \leq 0.05$ were indicated as a, b. Those differing at $0.05 < p < 0.1$ were regarded as trends (indicated as 1, 2). Additionally, each trait that differs significantly between SRLV-free and SRLV-infected groups was subjected to one-way ANOVA regarding the stage of lactation for each group separately; the results were used to construct a graph of the data points for each animal in the form of box plots. The linear relationships between blood serum biochemical parameters were estimated separately for SRLV-free and SRLV-infected animals using Pearson correlation (PROC CORR, SAS/STAT software, ver. 9.4).

Results and discussion

Blood serum biochemical profiles

Hepatic profile. No differences were found in the blood serum levels of most of parameters between SRLV-infected and SRLV-free groups (Tab. 1). CHE level was

Table 1. Least squares means (LSMEAN) and their standard errors (SE) of the biochemical parameters of the liver profile during lactation in the blood serum of SRLV-free and SRLV-infected animals with reference values

Biochemical parameter	Lactation stage	Group				Reference values for goats[#] (unit)	*p*-value
		SRLV-free		SRLV-infected			
		LSMEAN	SE	LSMEAN	SE		
ALB	perinatal	37.9^{A}	1.06	38.3^{A}	1.12	24-39 (g/L)	1.00
	early	33.1^{B}		33.6^{B}			1.00
	peak	32.9^{B}		33.8^{B}			0.99
	end	35.8		32.9			0.89
ALT	perinatal	$^{\vee}$22.7	2.16	23.5	2.32	23-44 (U/L)	1.00
	early	$^{\vee}$18.8		$^{\vee}$20.3			0.98
	peak	$^{\vee}$22.4		$^{\vee}$20.6			0.98
	end	$^{\vee}$18.5		$^{\vee}$18.8			1.00
AST	perinatal	136.7^{A}	7.51	$^{\vee}$121.1^{A}	8.09	122-321 (U/L)	0.78
	early	$^{\vee}$107.1^{B}		$^{\vee}$108.6^{A}			0.99
	peak	$^{\vee}$109.6^{B}		$^{\vee}$107.3^{A}			1.00
	end	$\vee$92.7^{B}		$^{\vee}$82.4^{B}			0.98
BILT	perinatal	0.72	0.08	0.63	0.09	0.1-1.9 (mg/dl)	0.98
	early	0.52		0.51			0.99
	peak	0.48		0.59			0.99
	end	0.64		0.48			0.95
CHE	perinatal	70.3^{A}	7.54	$^{\vee}$57.8	8.12	no reference values (µKat/L)[##]	0.22
	early	$^{\vee}$42.3^{B}		$^{\vee}$68.4^{A}			0.56
	peak	$^{\vee}$42.9^{B}		$^{\vee}$59.7^{A}			0.95
	end	$^{\vee}$**61.9***		$^{\vee}$**33.6*^{B}**			**0.01**
LACT	perinatal	$^{\vee}$0.86	0.09	$^{\vee}$0.76	0.09	2.75-3.95 (mmol/L)**	0.99
	early	$^{\vee}$0.93		$^{\vee}$1.02			0.98
	peak	$^{\vee}$0.97		$^{\vee}$0.98			0.99
	end	$^{\vee}$0.92		$^{\vee}$0.90			1.00
GGT	perinatal	$^{\vee}$46.4	2.27	$^{\vee}$47.0	2.46	60-101 (U/L)	0.99
	early	$^{\vee}$44.0		$^{\vee}$48.2			0.94
	peak	$^{\vee}$43.7		$^{\vee}$45.9			0.98
	end	$^{\vee}$46.6		$^{\vee}$43.9			1.00

SRLV – small ruminant lentivirus; ALB - albumins; BILT – total bilirubin; ALT – alanine aminotransferase; AST - aspartate transferase; CHE – cholinesterase; LACT – lactate; GGT – gamma glutyltranspeptidase; lactation stage – perinatal=day 14, early=day 45, peak=day 85, end=day 240; [#]reference intervals for goats according to Winnicka [2021]; [##]reference interval for people; $^{\vee}$values reaching the lowest limit of the reference interval.
^{AB}Within columns means bearing different superscript differ significantly at p≤0.01.
*Within rows means differ significantly at p<0.05.

higher for SRLV-infected goats than SRLV-free ones, on day 240 of lactation (p≤0.01); no reference intervals could be found for CHE for goats. ALT, AST, and GGT values were slightly below the reference values for goats, while LACT level was much below reference limits. The results for CHE for both groups at different lactation stages are presented as box plots with confidence intervals in Figure 1 a and 1b.

Kidney profile. In the kidney profile, no differences were found between SRLV-infected and SRLV-free goats for both CRE and TP (Tab. 2). CRE levels were below reference values for goats in both groups.

Bone profile. No differences were found between SRLV-infected animals and SRLV-free animals, except lover Ca* concentration in SRLV-infected goats at the end of lactation (p≤0.05) (Tab. 3). Almost all parameters were within the reference intervals

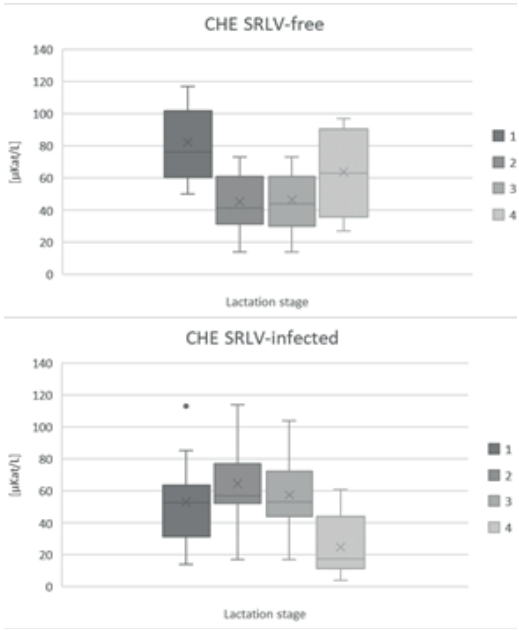

Fig.1. Box plot with confidence intervals, showing the data points for each animal at different lactation stages for choline esterase (CHE); a) SRLV-free– small ruminant lentivirus free goats; b) SRLV-infected – small ruminant lentivirus infected goats; lactation stages – 1 (14th day – perinatal period), 2 (45th day – early lactation), 3 (85th day – peak of lactation), 4 (240th day – end of lactation).

Table 2. Least squares means (LSMEAN) and their standard errors (SE) of the biochemical parameters of the renal profile during lactation in the blood serum of SRLV-free and SRLV-infected animals with reference values

Biochemical parameter	Lactation stage	Group				Reference values for goats[#] (unit)	*p*-value
		SRLV-free		SRLV-infected			
		LSMEAN	SE	LSMEAN	SE		
CRE	perinatal	∨56.4	1.96	∨51.8	2.06	88.4-195 (μmol/L)	0.64
	early	∨46.9		∨46.2[a]			0.97
	peak	∨46.5		∨48.9			1.00
	end	∨55.2		∨54.2[b]			1.00
TP	perinatal	66.9	1.87	68.7	2.01	59-78 (g/L)	0.98
	early	61.6		63.2			0.99
	peak	61.2		62.8			0.99
	end	66.1		61.7			0.96

SRLV – small ruminant lentivirus; CRE - creatinine; TP – total protein; lactation stage – perinatal = day 14, early = day 45, peak = day 85, end = day 240; [#]reference intervals for goats according to Winnicka [2021]; [∨]values reaching the lowest limit of the reference interval; [ab]Within columns means bearing different superscript differ significantly at p≤0.05.

for goats. Box plots with confidence intervals, showing the data points for each animal at different lactation stages for Ca* regarding health state, are presented in Figure 2.

Table 3. Least squares means (LSMEAN) and their standard errors (SE) of the biochemical parameters of the bone profile in the SRLV-free and SRLV-infected animals with reference values

Biochemical parameter	Lactation stage	Group				Reference values for goats[#] (unit)	*p*-value between groups
		SRLV-free		SRLV-infected			
		LSMEAN	SE	LSMEAN	SE		
Ca*	perinatal	2.21^{A}	0.07	2.11^{A}	0.08	2.2-3.05 (mmol/L)	0.94
	early	$\vee 1.88^{B}$		$\vee 1.85^{Ba}$			0.99
	peak	$\vee 1.89^{B}$		$\vee 1.84^{Ba}$			0.99
	end	**2.22*^{A}**		**1.97***			**0.03**
ALP	perinatal	$^{V}68.2^{a}$	6.60	81.7	7.11	75-228 (U/L)	0.92
	early	82.2		99.8^{A}			0.99
	peak	95.9^{b}		95.5^{a}			1.00
	end	74.6		62.8^{Bb}			0.81
P	perinatal	2.24	0.17	2.10	0.18	1.62-4.43 (mmol/L)	0.99
	early	1.9		1.99			0.98
	peak	1.97		1.95			1.00
	end	1.92		2.26			0.84

SRLV – small ruminant lentivirus; Ca* – corrected Ca (calculated according to Mbuh and Mbwaye [2005]); ALP – alka-line phosphatase; P – potassium; lactation stage – perinatal = day 14, early = day 45, peak = day 85, end = day 240; #reference intervals for goats according to Winnicka [2021]. ^{aA}Within rows means bearing different superscript differ significantly at: small letters – $p \leq 0.05$; capitals – $p \leq 0.01$.

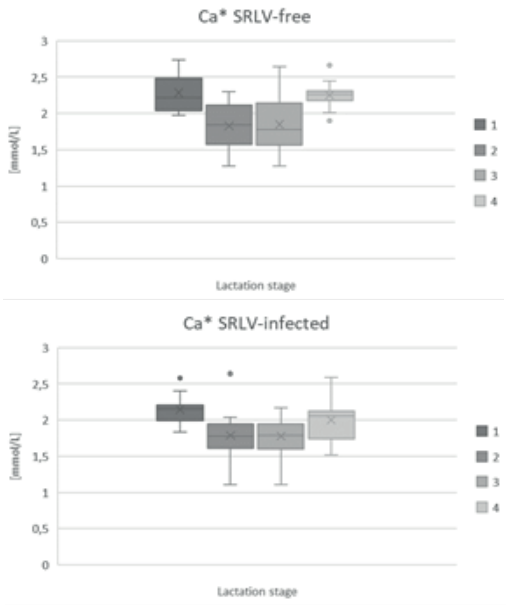

Fig. 2. Box plot with confidence intervals, showing the data points for each animal at different lactation stages for calcium (Ca*); a) SRLV-free – small ruminant lentivirus free goats; b) SRLV-infected – small ruminant lentivirus infected goats; lactation stages – 1 (14th day – perinatal period), 2 (45th day – early lactation), 3 (85th day – peak of lactation), 4 (240th day – end of lactation).

Cardiac profile. No differences were found between groups in blood serum levels of any cardiac parameters, except CK (Tab. 4) however, only ones at the end of

Table 4. Least squares means (LSMEAN) and their standard errors (SE) of the biochemical parameters of the cardiac profile during lactation in the blood serum of SRLV-free and SRLV-infected animals with reference values

Biochemical parameter	Lactation stage	Group				Reference values for goats[#] (unit)	*p*-value between groups
		SRLV-free		SRLV-infected			
		LSMEAN	SE	LSMEAN	SE		
CK	perinatal	^186.5	74.83	^186.6	78.70	28-130 (U/L)	1.00
	early	^232.7		^204.3			1.00
	peak	^236.0		^204.1			0.44
	end	**^232.8***		**^158.8***			0.05
Cl	perinatal	109.2	2.83	110.2[a]	2.98	98-111 (mmol/L)	1.00
	early	96.6		98.3			0.99
	peak	96.5		68.3[b]			0.99
	end	105.6		95.8[b]			0.33
Fe	perinatal	28.6[a]	1.52	29.8[A]	1.60	14.3-39.4[##] (µmol/L)	1.00
	early	23.0[b]		25.4			0.99
	peak	24.1		24.5			1.00
	end	27.0		22.9[B]			0.61
K	perinatal	4.17[a]	0.15	4.08	0.16	2.5-4.1 (mmol/L)	0.99
	early	3.49[b]		3.65			0.98
	peak	3.52[b]		3.62			0.99
	end	4.02		3.95			1.00
Mg	perinatal	1.18	0.05	1.14	0.05	0.75-1.62 (mmol/L)	0.99
	early	1.15		1.05			0.82
	peak	1.12		1.0.6			0.94
	end	1.14		1.01			0.66
Na	perinatal	148.5	3.76	149.7	4.09	141-157 (mmol/L)	1.00
	early	∨130.7		∨131.4			1,00
	peak	∨130.3		∨131.8			1.00
	end	∨143.1		∨132.5			0.67

SRLV – small ruminant lentivirus; CK - creatine kinase; Cl - chlorides; Fe - iron; K – potassium; Mg – magnesium; Na – calcium; lactation stage – perinatal = day 14, early = day 45, peak = day 85, end = day 240; #reference intervals for goats according to Winnicka (2021); ##reference intervals for sheep according to Winnicka [Winnicka, 2021]; ^-values reaching the highest limit of the reference interval; ∨- values reaching the lowest limit of the reference interval.

[aA]Within rows means bearing different superscript differ significantly at: small letters – $p \leq 0.05$; capitals – $p \leq 0.01$.

lactation ($p \leq 0.05$). Values were higher than the maximal reference level for goats in both groups. Cl, K, and Mg values were within the reference range. For Fe, the applied reference intervals were for sheep due to the lack of reference for goats [Winnicka 2021]. Box plots with confidence intervals, showing the data points for CK for each animal at different lactation stages are presented in Figure 3.

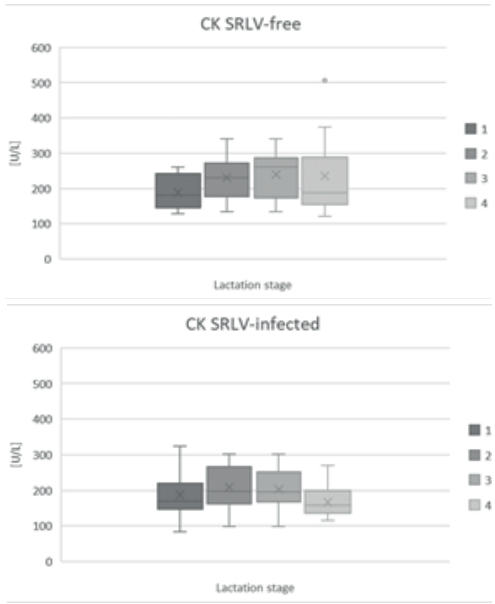

Fig. 3. Box plot with confidence intervals, showing the data points for each animal at different lactation stages for creatinine kinase (CK); a) SRLV-free – small ruminant lentivirus free goats; b) SRLV-infected – small ruminant lentivirus infected goats; lactation stages – 1 (14th day – perinatal period), 2 (45th day – early lactation), 3 (85th day – peak of lactation), 4 (240th day – end of lactation).

Pancreatic profile. No differences were noted between groups. All values were within reference ranges (Tab. 5); however, sheep values were used for reference for LIP due to the lack of any reference values for goats.

Table 5. Least squares means (LSMEAN) and their standard errors (SE) of the biochemical parameters of the pancreatic profile during lactation in the blood serum of SRLV-free and SRLV-infected animals with reference values

Biochemical parameter	Lactation stage	Group				Reference values for goats[#] (unit)	*p*-value between groups
		SRLV-free		SRLV-infected			
		LSMEAN	SE	LSMEAN	SE		
LIP	perinatal	31.3	2.78	27.3	2.82	0-71[##] (U/L)	0.98
	early	23.5		24.2			1.00
	peak	22.6		25.3			0.94
	end	23.8		19.6			0.98
GLU	perinatal	3.35	0.09	3.48^{Aa}	0.10	3.0-5.2 (mmol/L)	0.95
	early	3.02		3.13^{b}			0.99
	peak	3.02		3.13^{b}			0.98
	end	3.21		2.95^{B}			0.60

SRLV – small ruminant lentivirus; LIP - lipase; GLU – glucose; lactation stage – perinatal = day 14, early = day 45, peak = day 85, end = day 240; #reference intervals for goats according to Winnicka (2021); [##]reference intervals for sheep according to Winnicka [2021].
[aA]Within columns means bearing different superscript differ significantly at: small letters – p≤0.05; capitals – p≤0.01.

Lipid profile. No differences were noticed in CHOL, HDL, and LDL between groups, while TRI level was higher at the end of lactation in the SRLV-infected group

Table 6. Least squares means (LSMEAN) and their standard errors (SE) of the biochemical parameters of the lipid profile parameters during lactation in the blood serum of SRLV-free and SRLV-infected animals with reference values

Biochemical parameter	Lactation stage	Group				Reference values for goats[#] (unit)	*p*-value between groups
		SRLV-free		SRLV-infected			
		LSMEAN	SE	LSMEAN	SE		
CHOL	perinatal	^2.9	0.17	^3.0	0.18	1.6-2.8 (mmol/L)	0.99
	early	^3.1		^3.2			1.00
	peak	^3.0		^3.3			0.94
	end	^3.0		2.8			0.99
HDL	perinatal	1.93	0.09	1.98	0.10	no reference values (mmol/L)	0.99
	early	1.91		1.89			1.00
	peak	1.88		1.93			0.99
	end	2.11		1.91			0.99
LDL	perinatal	0.65	0.07	0.72[a]	0.08	no reference values (mmol/L)	0.99
	early	0.95		1.00			0.99
	peak	0.89		1.05[b]			0.82
	end	0.80		0.81			1.00
TRI	perinatal	0.20	0.02	0.19	0.03	0-0.2 (mmol/L)	1.00
	early	0.18		0.21			1.00
	peak	0.17		0.21			0.83
	end	**0.19***		**^0.31***			**0.03**

SRLV – small ruminant lentivirus; CHOL - cholesterol, HDL - high-density lipoprotein, LDL - low-density lipoprotein, TRI - triglycerides; lactation stage – perinatal = day 14, early = day 45, peak = day 85, end = day 240; [#]reference intervals for goats according to Winnicka [2021]; ^values reaching the highest limit of the interval.
[ab]Within columns means bearing different superscript differ significantly at p≤0.05.

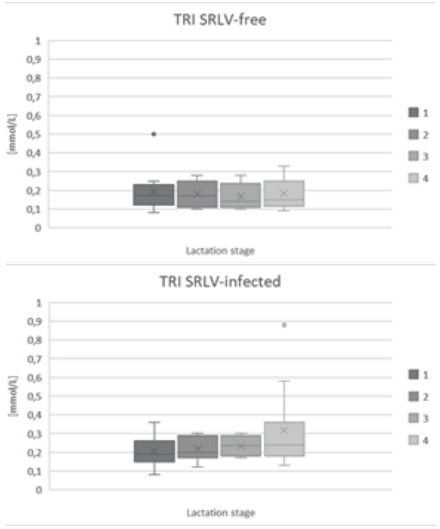

Fig. 4. Box plot with confidence intervals, showing the data points for each animal at different lactation stages for triglycerides (TRI); a) SRLV-free – small ruminant lentivirus free goats; b) SRLV-infected – small ruminant lentivirus infected goats; lactation stages – 1 (14th day – perinatal period), 2 (45th day – early lactation), 3 (85th day – peak of lactation), 4 (240th day – end of lactation).

than in SRLV-free animals ($p \leq 0.05$) (Tab. 6); its value was above the upper limit in the SRLV-infected group (>0.20). Box plots with confidence intervals, showing the TRI data points for each animal, at different lactation stages, indicating health state, are presented in Figure 4.

C-reactive protein as an infection marker. No differences in blood serum CRP concentration were found between SRLV-free and SRLV-infected animals (Tab. 7). The CRP level was within reference values for goats.

Table 7. Least squares means (LSMEAN) and their standard errors (SE) of the biochemical parameters of the C-reactive protein level in the blood serum of SRLV-free and SRLV-infected animals with reference values

Biochemical parameter	Lactation stage	Group				Reference values for goats[#] (unit)	*p*-value
		SRLV-free		SRLV-infected			
		LSMEAN	SE	LSMEAN	SE		
CRP	perinatal	0.03	0.02	0.02	0.02	0 – 5[##] (mg/L)	0.99
	early	0.07		0.07			1.00
	peak	0.02		0.02			1.00
	end	0.08		0.07			0.99

SRLV – small ruminant lentivirus; CRP – C-reactive protein; lactation stage – perinatal = day 14, early = day 45, peak = day 85, end = day 240; [##]reference for people [Kabata 2005].

Tables 8-14 and 9-21 show the differences between studied breeds and parities in biochemical parameters in blood serum of dairy goats. Only differences in P between breeds was stated. Some fluctuation between parities were found for ALB and GGT of the liver profile, CRE of renal profile, Ca* and ALP of bone profile, Fe of cardiac profile, GLU of pancreatic profile, and of all parameters of lipid profile.

Pearson correlations between blood biochemical parameters for SRLV-free or SRLV-infected goats. Many correlations were found between the biochemical profiles of SRLV-free and SRLV-infected animals (Tab. 22). In the liver profile, slightly different relationships were found between the SRLV-infected and SRLV-free groups: the ALBxAST (0.61, $p \leq 0.01$) and ASTxALT (0.63, $p \leq 0.01$) correlations were much stronger, and some other correlations appeared, such as ALBxALT (0.46, $p \leq 0.01$), GGTxCHE (0.28, $p \leq 0.05$) in SRLV-infected group. While moderate and strong correlations were found between ALB and BILT (0.36, $p \leq 0.01$) and between ALB and CHE (0.51, $p \leq 0.05$) in the SRLV-free group. However, these were not observed in the SRLV-infected group; no ALBxBILT, ALTxCHE, ALTxGGT or LACTxGGT correlations were noted in this group. In contrast, a correlation was noted between ALB and ALT (0.46, $p \leq 0.01$) in the SRLV-infected group but not the SRLV-free group. No correlations were found between three bone parameters (ALP, Ca, P) and two pancreatic indicators (GLU, LIP) in either group. Some moderate to very high positive correlations were found between cardiac parameters; however, CK was not correlated with any parameters, while Cl, Fe, K, and Na were correlated with all other cardiac parameters. The CHOL level was positively correlated with almost all other parameters in the lipid profile. No correlation was found between CHOL and TRI in the SRLV-infected group. Within the kidney profile, the opposite results were found for all correlations.

Table 8. Least squares means (LSMEAN) and their standard errors (SE) of the biochemical parameters of the liver profile during lactation in the blood serum of Polish White Improved (PWI) and Polish Fawn Improved (PFI) animals with reference values

Biochemical parameter	Breed				Reference values for goats[#] (unit)	*p*-value between groups
	PWI		FWI			
	LSMEAN	SE	LSMEAN	SE		
ALB	34.85	0.51	34.68	0.63	24-39 (g/L)	0.83
ALT	$^{\vee}$21.52	1.06	$^{\vee}$19.79	1.28	23-44 (U/L)	0.30
AST	$^{\vee}$105.16	3.62	$^{\vee}$109.15	4.44	122-321 (U/L)	0.48
BILT	0.55	0.04	0.56	0.05	0.1-1.9 (mg/dl)	0.98
CHE	49.32	3.63	54.68	4.46	no reference values (µKat/L)[##]	0.35
LACT	$^{\vee}$0.90	0.04	$^{\vee}$0.91	0.05	2.75-3.95 (mmol/L)**	0.94
GGT	$^{\vee}$44.99	1.09	$^{\vee}$46.11	1.34	60-101 (U/L)	0.52

ALB - albumins; BILT – total bilirubin; ALT – alanine aminotransferase; AST - aspartate transferase; CHE – cholinesterase; LACT – lactate; GGT – gamma glutyltranspeptidase; [#]reference intervals for goats according to Winnicka [2021]; [##]reference interval for people; $^{\vee}$values below the reference interval.

Table 9. Least squares means (LSMEAN) and their standard errors (SE) of the biochemical parameters of the renal profile during lactation in the blood serum of Polish White Improved (PWI) and Polish Fawn Improved (PFI) animals with reference values

Biochemical parameter	Breed				Reference values for goats[#] (unit)	*p*-value between groups
	PWI		FWI			
	LSMEAN	SE	LSMEAN	SE		
CRE	$^{\vee}$49.77	0.95	$^{\vee}$50.31	1.16	88.4-195 (µmol/L)	0.72
TP	63.35	0.90	63.76	1.11	59-78 (g/L)	0.68

CRE - creatinine; TP – total protein; [#]reference intervals for goats according to Winnicka [2021]; $^{\vee}$values below the reference interval.

Table 10. Least squares means (LSMEAN) and their standard errors (SE) of the biochemical parameters of parameters of the bone profile of Polish White Improved (PWI) and Polish Fawn Improved (PFI) animals with reference values

Biochemical parameter	Breed				Reference values for goats[#] (unit)	*p*-value between groups
	PWI		FWI			
	LSMEAN	SE	LSMEAN	SE		
Ca*	$^{\vee}$2.03	0.03	$^{\vee}$1.97	0.04	2.2-3.05 (mmol/L)	0.24
ALP	80.98	3.18	86.23	3.90	75-228 (U/L)	0.29
P	1.90$^{\mathbf{A}}$	0.08	2.27$^{\mathbf{B}}$	0.10	1.62-4.43 (mmol/L)	**0.005**

Ca* – corrected Ca (calculated according to Mbuh and Mbwaye [2005]; ALP – alka-line phosphatase; P – potassium; #reference intervals for goats according to Winnicka [2021]; ∨values below the reference interval; ^{AB}values differ significantly at p≤0.01 within rows.

Table 11. Least squares means (LSMEAN) and their standard errors (SE) of the biochemical parameters of parameters of the cardiac profile during lactation in the blood serum of Polish White Improved (PWI) and Polish Fawn Improved (PFI) animals with reference values

Biochemical parameter	Breed				Reference values for goats[#] (unit)	*p*-value between groups
	PWI		FWI			
	LSMEAN	SE	LSMEAN	SE		
CK	**^254.41**	36.09	**^254.08**	44.25	28-130 (U/L)	0.99
Cl	101.23	1.37	101.51	1.68	98-111 (mmol/L)	0.89
Fe	26.63	0.74	24.48	0.90	14.3-39.4[##] (µmol/L)	0.07
K	3.84	0.07	3.83	0.09	2.5-4.1 (mmol/L)	0.94
Mg	1.14	0.02	1.08	0.03	0.75-1.62 (mmol/L)	0.13
Na	136.55	1.82	138.03	2.23	141-157 (mmol/L)	0.61

CK - creatine kinase; Cl - chlorides; Fe - iron; K – potassium; Mg – magnesium; Na – calcium; #reference intervals for goats according to Winnicka [2021]; ##reference intervals for sheep according to Winnicka [2021]; ^-values above the reference interval.

Table 12. Least squares means (LSMEAN) and their standard errors (SE) of the biochemical parameters of in parameters of the pancreatic profile during lactation in the blood serum of Polish White Improved (PWI) and Polish Fawn Improved (PFI) animals with reference values

Biochemical parameter	Breed				Reference values for goats[#] (unit)	*p*-value between groups
	PWI		FWI			
	LSMEAN	SE	LSMEAN	SE		
LIP	22.94	1.34	26.20	1.64	0-71[##] (U/L)	0.13
GLU	3.09	0.05	3.21	0.06	3.0-5.2 (mmol/L)	0.09

LIP - lipase; GLU – glucose; #reference intervals for goats according to Winnicka [2021]; [##]reference intervals for sheep according to Winnicka [2021].

Table 13. Least squares means (LSMEAN) and their standard errors (SE) of the biochemical parameters of the lipid profile parameters during lactation in the blood serum of Polish White Improved (PWI) and Polish Fawn Improved (PFI) animals with reference values

Biochemical parameter	Breed				Reference values for goats[#] (unit)	*p*-value between groups
	PWI		FWI			
	LSMEAN	SE	LSMEAN	SE		
CHOL	2.92	0.08	^3.15	0.10	1.6-2.8 (mmol/L)	0.08
HDL	1.88	0.05	2.02	0.06	no reference values (mmol/L)	0.05
LDL	0.83	0.03	0.89	0.04	no reference values (mmol/L)	0.23
TRI	^0.22	0.01	0.20[b]	0.02	0-0.2 (mmol/L)	0.06

CHOL – cholesterol, HDL – high-density lipoprotein, LDL – low-density lipoprotein, TRI – triglycerides; [#]reference intervals for goats according to Winnicka [2021]; ^values above the interval; [ab]values differ significantly at $p \leq 0.05$ within rows.

Table 14. Least squares means (LSMEAN) and their standard errors (SE) of the biochemical parameters of the C-reactive protein level in the blood serum of Polish White Improved (PWI) and Polish Fawn Improved (PFI) animals with reference values

Biochemical parameter	Breed				Reference values for goats[#] (unit)	*p*-value between groups
	PWI		FWI			
	LSMEAN	SE	LSMEAN	SE		
CRP	0.04	0.01	0.06	0.01	0-5[##] (mg/L)	0.36

PWI- Polish White Improved; FWI – Polish Fawn Improved; CRP – C-reactive protein; LSMEAN – Least-squares mean; SE – standard error; [##]reference for people [Kabata 2005].

Table 15. Least squares means (LSMEAN) and their standard errors (SE) of the biochemical parameters of the liver profile in the blood serum of dairy goats regarding parity with reference values

Biochemical parameter	Parity	LSMEAN	SE	Reference values for goats[#] (unit)
ALB	2	35.25	0.95	24 – 39 (g/L)
	3	36.42[A]	0.67	
	4	34.36	0.86	
	>4	33.03[B]	0.72	
ALT	2	[V]20.05	1.93	23 – 44 (U/L)
	3	[V]19.55	1.36	
	4	23.96	1.79	
	>4	[V]19.07	1.46	
AST	1	[V]103.37	6.72	122 – 321 (U/L)
	2	[V]106.02	4.73	
	3	[V]104.25	6.11	
	>3	[V]114.96	5.09	
BILT	1	0.65	0.08	0.1 – 1.9 (mg/dl)
	2	0.52	0.06	
	3	0.44	0.07	
	>3	0.63	0.06	
CHE	1	48.60	6.75	no reference values (μKat/L)[##]
	2	55.47	4.75	
	3	58.45	6.13	
	>3	45.49	5.11	
LACT	1	[V]0.84	0.08	2.75 - 3.95 (mmol/L)**
	2	[V]0.82	0.06	
	3	[V]0.97	0.08	
	>3	[V]1.00	0.06	
GGT	1	[V]39.66[A]	2.03	60 – 101 (U/L)
	2	[V]48.47[B]	1.43	
	3	[V]49.23[B]	1.84	
	>3	[V]44.84	1.54	

ALB - albumins; BILT – total bilirubin; ALT – alanine aminotransferase; AST - aspartate transferase; CHE – cholinesterase; LACT – lactate; GGT – gamma glutyltranspeptidase; [#]reference intervals for goats according to Winnicka [2021]; [##]reference interval for people; [V]values reaching the lowest limit of the reference interval. [AB]Within columns means bearing different superscript differ significantly at $p \leq 0.01$.

Table 16. Least squares means (LSMEAN) and their standard errors (SE) of the biochemical parameters of the renal profile during lactation in the blood serum of dairy goats regarding parity with reference values

Biochemical parameter	Parity	LSMEAN	SE	Reference values for goats[#] (unit)
CRE	1	$^{V}45.53$	1.76	88.4-195 (µmol/L)
	2	$^{V}54.91^{a}$	1.24	
	3	$^{V}49.35^{b}$	1.59	
	>3	$^{V}50.37^{b}$	1.33	
TP	1	62.81	1.68	59-78 (g/L)
	2	65.03	1.79	
	3	64.68	1.52	
	>3	63.69	1.27	

CRE - creatinine; TP – total protein; [#]reference intervals for goats according to Winnicka [2021]; [V]values reaching the lowest limit of the reference interval.
[ab]Within columns means bearing different superscript differ significantly at $p \leq 0.05$.

Table 17. Least squares means (LSMEAN) and their standard errors (SE) of the biochemical parameters of parameters of the bone profile in the blood serum of dairy goats regarding parity with reference values

Biochemical parameter	Parity	LSMEAN	SE	Reference values for goats[#] (unit)
Ca*	1	$^{V}2.18^{A}$	0.07	2.2-3.05 (mmol/L)
	2	$^{V}2.03^{a}$	0.05	
	3	$^{V}1.96$	0.06	
	>3	$^{V}1.83^{Bb}$	0.05	
ALP	1	125.64^{A}	5.91	75-228 (U/L)
	2	86.53^{B}	4.16	
	3	$^{V}67.77^{C}$	5.36	
	>3	$^{V}54.47^{C}$	4.47	
P	1	2.09	0.15	1.62-4.43 (mmol/L)
	2	2.12	0.11	
	3	2.05	0.14	
	>3	2.06	0.12	

Ca* – corrected Ca, calculated according to Mbuh and Mbwaye [2005]; ALP – alkaline phosphatase; P – potassium; #reference intervals for goats according to Winnicka [2021].
[aA...]Within columns means bearing different superscripts differ significantly at: small letters – $p \leq 0.05$; capitals – $p \leq 0.05$.

Many associations were found between profiles describing the health state of different organs. In both groups, many parameters demonstrated correlations above 0.70. Many differences between the two studied groups were also noticed. It should be pointed out that CRP was not correlated with any parameters in the SRLV-free group but was negatively correlated with many parameters in the SRLV-infected group, i.e. with ALB, CHE (liver profile), TP (kidney profile), Cl, GGT, Mg, Na (cardiac profile), CHOL, HDL, LDL (lipid profile). No correlations were observed between the

Table 18. Least squares means (LSMEAN) and their standard errors (SE) of the biochemical parameters of parameters of the cardiac profile in the blood serum of dairy goats regarding parity with reference values

Biochemical parameter	Parity	LSMEAN	SE	Reference values for goats[#] (unit)
CK	1	^203.58	67.00	28-130 (U/L)
	2	^291.74	47.14	
	3	^299.77	60.81	
	>3	^221.90	50.69	
Cl	1	104.41	2.53	98-111 (mmol/L)
	2	102.75	1.79	
	3	98.02	2.30	
	>3	100.30	1.91	
Fe	1	27.68[a]	1.36	14.3-39.4[##] (µmol/L)
	2	26.45[a]	0.96	
	3	24.98	1.24	
	>3	23.11[b]	1.03	
K	1	3.97	0.13	2.5-4.1 (mmol/L)
	2	3.82	0.09	
	3	3.92	0.12	
	>3	3.64	0.10	
Mg	1	1.17	0.05	0.75-1.62 (mmol/L)
	2	1.11	0.03	
	3	1.13	0.04	
	>3	1.05	0.03	
Na	1	141.30	3.37	141-157 (mmol/L)
	2	[V]139.93	2.37	
	3	[V]132.24	3.06	
	>3	[V]135.68	2.55	

CK – creatine kinase; Cl – chlorides; Fe – iron; K – potassium; Mg – magnesium; Na – calcium; #reference intervals for goats according to Winnicka [2021]; ##reference intervals for sheep according to Winnicka [2021]; ^values reaching the highest limit of the reference interval; [V]values reaching the lowest limit of the reference interval; [ab]Within columns means bearing different superscript differ significantly at p≤0.05.

Table 19. Least squares means (LSMEAN) and their standard errors (SE) of the biochemical parameters of parameters of the pancreatic profile in the blood serum of dairy goats regarding parity with reference values

Biochemical parameter	Parity	LSMEAN	SE	Reference values for goats[#] (unit)
LIP	1	20.53	2.49	0-71[##] (U/L)
	2	25.13	1.75	
	3	28.30	2.26	
	>3	24.32	1.88	
GLU	1	3.39[Aa]	0.09	3.0-5.2 (mmol/L)
	2	3.22[ac]	0.06	
	3	3.05[bc]	0.08	
	>3	2.98[Bb]	0.07	

LIP – lipase; GLU – glucose; LSMEAN - Least-squares mean; SE – standard error; #reference intervals for goats according to [ab]Within columns means bearing different superscript differ significantly at p≤0.05. Winnicka [2021]; [##]reference intervals for sheep according to Winnicka [2021]; [aA…]Within columns means bearing different superscripts differ significantly at: small letters – p≤0.05; capitals – p≤0.05.

Table 20. Least squares means (LSMEAN) and their standard errors (SE) of the biochemical parameters of the lipid profile parameters in the blood serum of dairy goats regarding parity with reference values

Biochemical parameter	Parity	LSMEAN	SE	Reference values for goats[#] (unit)
CHOL	1	^2.86	0.15	1.6-2.8 (mmol/L)
	2	^3.26[a]	0.11	
	3	^3.25[a]	0.14	
	>3	2.78[b]	0.12	
HDL	1	1.87[a]	0.09	no reference values (mmol/L)
	2	2.15[b]	0.06	
	3	1.97	0.08	
	>3	1.82[a]	0.07	
LDL	1	0.72[B]	0.07	no reference values (mmol/L)
	2	0.85[a]	0.05	
	3	1.07[Ab]	0.06	
	>3	0.80[B]	0.05	
TRI	1	^0.26[a]	0.02	0-0.2 (mmol/L)
	2	^0.23[a]	0.02	
	3	0.16[b]	0.02	
	>3	0.18[b]	0.02	

CHOL – cholesterol, HDL – high-density lipoprotein, LDL – low-density lipoprotein, TRI – triglycerides; [#]reference intervals for goats according to Winnicka [2021]; ^values reaching the highest limit of the interval.
[aA...]Within columns means bearing different superscripts differ significantly at: small letters – $p \leq 0.05$; capitals – $p \leq 0.05$.

Table 21. Least squares means (LSMEAN) and their standard errors (SE) of the biochemical parameters of the C-reactive protein level in the blood serum of dairy goats regarding parity with reference values

Biochemical parameter	Parity	LSMEAN	SE	Reference values for goats[#] (unit)
CRP	2	0.04	0.02	0-5[##] (mg/L)
	3	0.05	0.01	
	>3	0.06	0.02	
		0.06	0.01	

CRP – C-reactive protein; [##]reference for people [Kabata 2005].

parameters assigned to the bone and pancreatic profiles. The identified correlations show the probability of some parameters co-occurring, but these findings should be supported by experimental study.

Differences in blood biochemical parameters between goats infected with SRLV and non-infected

It is hard to analyze the condition of the liver based only on CHE as no reference values currently exist in ruminants and no other parameter differed between the groups and were within reference values. In humans, decreased CHE level may suggest

Table 22. Significant Pearson correlation coefficients between biochemical parameters of SRLV-free (below diagonal) and SRLV-infected (above diagonal) goats

	ALB	ALT	AST	BILT	CHE	LACT	CRE	TP	ALP	Ca	P	CK	Cl	Fe	GGT	K	Mg	Na	GLU	LIP	CHOL	HDL	LDL	LHDL	TRI	CRP
ALB	x	0.46**	0.61**				0.32*	0.87**		0.73**	0.45**	0.32*	0.87**		0.50**	0.65**	0.53**	0.91**	0.70**	0.44**	0.37*	0.68**		0.79**		-0.38**
ALT		x	0.63**					0.45*		0.40**		0.54**	0.36*	0.54**	0.31*		0.39**	0.36*	0.31*	0.33*				0.64**		
AST	0.34*	0.45**	x	0.30*				0.59**		0.39**		0.64**	0.50**	0.62**	0.49**		0.41**	0.51**	0.34*	0.54**	0.32*	0.41**		0.73**		
BILT	0.36**		0.41**	x	-0.37*								0.32*	0.42**				0.30*	0.40**	0.34*						
CHE	0.51*				x																					-0.35*
LACT									0.36*		0.29*				0.39**	0.36*					0.31*	0.30*	0.31*			
CRE	0.31*			0.32*	0.39**		x				0.31*									0.37*						
TP	0.79**		0.46**	0.36**	0.35*		0.40**	x		0.71**	0.41**	0.33*	0.82**	0.40**	0.57**	0.57**	0.50**	0.86**	0.67**	0.30*	0.42**	0.67**		0.72**		-0.36*
ALP							-0.30*	ns	x															0.32*		
Ca	0.87**		0.28*	0.32*	0.55**		0.38**	0.66**		x			0.73**	0.58**	0.29*	0.51**	0.47**	0.74**	0.51**			0.44**		0.52**		
P											x		0.44**			0.67**		0.54**	0.43**			0.46**		0.31*		
CK						0.41**						x	0.29*	0.57**			0.43**			0.41**	0.37*	0.34*	0.34*	0.51**		
Cl	0.73**		0.33*	0.41**	0.38**		0.42*	0.71**		0.69**			x	0.52**	0.36*	0.66**	0.41**	0.97**	0.83**			0.60**		0.66**		-0.32*
Fe	0.69**				0.40**			0.50**		0.67**	-0.33*		0.57**	x			0.54**	0.50**	0.47**	0.38**				0.56**		
GGT	0.56**		0.38**		0.28*			0.51**		0.50**			0.40**	0.28*	x	0.38**		0.34*			0.51**	0.55**	0.42**	0.42**		-0.33*
K	0.64**				0.45**		0.44**	0.64**		0.74**			0.67**	0.46**	0.34*	x		0.69**	0.45*			0.49**		0.39**		
Mg	0.42**						0.34*	0.48**		0.45**			0.40**	0.35*		0.46*	X	0.38**				0.30*	0.34*	0.50**		-0.41**
Na	0.72**		0.36**	0.45**	0.35*		0.48**	0.69**		0.67**			0.98**	0.50**	0.41**	0.66**	0.40**	x	0.82**	0.32*		0.64**		0.67**		-0.30*
GLU	0.68**				0.32*			0.48**	0.43**	0.66**			0.56**	0.40**	0.36**	0.55**	0.49**	0.57**	x			0.33*		0.59**		
LIP			0.60**	0.28*				0.35**	-0.29*						0.28*	0.30*				x				0.37**		
CHOL	0.29*														0.61**				0.30**		x	0.79**	0.75**	0.29*		-0.46**
HDL	0.40**									0.38**					0.69**			0.30*	0.35*		0.91**	x	0.29*	0.51**		-0.39**
LDL															0.40**						0.85**	0.61**	x			ns
LHDL	0.57**		0.57**	0.36**				0.58**		0.30*			0.53**	0.46**				0.51**	0.29*	0.35*			-0.28*	x		-0.38**
TRI	0.30*				0.29*	-0.40**			0.39**	0.35**	-0.28*								0.31*		0.31*	0.30*			x	ns
CRP																										x
	ALB	ALT	AST	BILT	CHE	LACT	CRE	TP	ALP	Ca	P	CK	Cl	Fe	GGT	K	Mg	Na	GLU	LIP	CHOL	HDL	LDL	LHDL	TRI	CRP

Hepatic profile (gray): ALB - albumins; BILT – total bilirubin; ALT – alanine aminotransferase; AST - aspartate aminotransferase; CHE – cholinesterase; LACT – lactate; kidney profile (blue): CRE - creatinine; TP – total protein; bone profile (pink): Ca - calcium; ALP – alkaline phosphatase; P – phosphorus; cardiac profile (green): CK - creatine kinase; Cl - chlorides; GGT – gamma glutyltranspeptidase; Fe - iron; K – potassium.

damage to the liver parenchyma; it is also observed in many infectious and acute inflammatory diseases. The serum/plasma activity of CHE has been primarily used in clinical biochemistry to test for reduced protein-synthesizing capacity in the liver and poisoning with organophosphorus toxins [Lampón *et al.* 2012]. The plasma of ruminants (bovine, goat, sheep, and reindeer) contains very low levels of an esterase that hydrolyzes butyrylcholine [Dafferner *et al*. 2017]. Lower CHE activity was observed on day 7 post-infection with *Babesia bigemina* for infected than uninfected cattle [Doyle *et al.* 2016]. CHE was also lower in the cattle with botulism compared with the control group [Aytekin *et al.* 2015]. Moreover, lowered CHE activities after day 7 post-infection may inhibit the release of IL-1, TNF-α, and other proinflammatory agents. If the disease causes severe liver damage, decreased liver function will result in reduced enzyme levels [Doyle *et al*. 2016]. During our present study, we found that asymptomatic SRLV-infected goats demonstrated a lowered level of CHE at the end of lactation. While it is hard to draw any clear conclusion, it is possible that CAE may affect liver tissue even during subclinical asymptomatic infection. As such, this area merits study, including histopathological research of the liver.

Serum CK is released into the bloodstream in response to muscle injury or inflammation – in humans, increased CK serum activity is detected in cases of myopathy and myositis. Our present findings indicate lower CK levels in SRLV-infected than SRLV-free goats, and again, only at the last stage of lactation; values for both groups were above the reference values for goats. Elevated CK values may indicate tissue damage or other systemic pathological states, which may occur due to excessive metabolic burden in high-yielding goats. Elevated CK levels in Black Bengal goats after infection with Peste des petits ruminants were found [Begum *et al*. 2018] as well as in cattle during Lumpy skin disease [El-Mandrawy and Alam 2018], and during the early stage of toxaemic in the pregnancy of Shamia goats [Barakat et al., 2007]. CK may also be released into the plasma in response to stress [Kannan *et al*. 2000, 2002]. This may mean that other effects may affect the homeostasis of SRLV-free goats at the end of lactation to an even greater degree than SRLV in infected animals, or that it might be connected with the involution of secretory tissue at the end of lactation. If SRLV lowers milk production, it may mean that share of secretory tissue in mammary gland parenchyma is lower in infected goats. Thus, the drying-off period may have a lesser effect on tissue in this group; however, this supposition requires further study.

Higher TRI level was found in SRLV-infected group at the end of lactation. Values for SRLV-free goats were within goat reference values, while those found in infected animals were elevated [Winnicka 2021]. In humans, an elevated level of TRI is related to atherosclerosis, coronary heart disease, stroke, and acute pancreatic inflammation [Kurhaluk *et al.* 2021]. The data on the relationship between TRI concentrations and the disease risk in goats is limited. As SRLV belongs to the *Retroviridae* family, like HIV, the two viruses may have similar action. It has been observed that elevated TRI are common in HIV-positive patients; in addition, conditions that traditionally result in increased TRI, e.g., insulin resistance, diabetes mellitus, and fatty liver,

are prevalent in HIV-positive patients. The physiological distress that results from untreated HIV infection may cause lipid perturbations, particularly elevated TRI [Worm *et al.* 2011]. However, such studies have never been conducted on SRLV-infected animals. Moreover, elevated TRI concentration was only observed at the end of lactation in the SRLV-infected goats. These differences are hard to explain based on animal health status; they may be due to lactation itself and drying-off period. It needs to be confirmed by further studies.

Ca is involved in the normal functioning of various tissues and physiological processes, including bone formation, muscle contraction, nerve transmission, hormone secretion, and blood clotting. It serves as a second messenger regulating the actions of some hormones. Although we did not find the differences in P level between the two groups, Ca and P need to be analyzed together. P is needed for energy metabolism, cell signaling, and stabilizing phospholipid content on the cell membrane. Changes in Ca and P have various effects, including growth rate, osteomalacia, skeletal and dental anomalies, muscle spasms, nephrolithiasis, hypocalcemia and convulsions since Ca and P are essential components in bone mineralization [Sun *et al.* 2020]. The fact that differences occur in the metabolism of Ca* between both groups at the lactation end imply that SRLV infection has an effect on some of the mentioned physiological processes during this period. SRLV causes a systemic infection that mainly affects the musculoskeletal system [Blacklaws 2012], even in asymptomatic individuals. The differences between SRLV-infected and SRLV-free goats found only at the end of lactation are hard to explain only by infection itself; maybe interaction occurs between health state and drying off period. This phenomenon needs to be confirmed by further studies.

Pearson correlations between blood biochemical parameters for SRLV-free or SRLV-infected goats

Some correlations identified within the analyzed profiles differed between the two groups. The main differences are related to CRP: it does not show any correlations in SRLV-free goats but is correlated with ten biochemical parameters in SRLV-infected goats and these correlations are only negative. Over the course of infection, CRP concentration should increase, as it is categorized as a moderate APP in cattle and sheep but not in goats [Reczyńska *et al.* 2018]. However, further study is needed to confirm whether CRP can be also considered as APP in goats. Even so, the negative correlations observed between CRP and some biochemical indicators may indicate the presence of inflammatory processes in some organs of infected but asymptomatic goats; this could be true despite the lack of significant changes in certain biomarkers e.g. ALB and CHE, indicating inflammatory processes in the liver, or TP indicating disturbances in colloidal osmotic pressure. In addition, its functioning is also negatively influenced by low levels of Cl, Mg, and Na.

Summing up

Blood serum biochemical parameters exceeding reference values may suggest disturbances in systemic or organ level homeostasis, while those below reference values

may imply irregularities in organ function. A significant correlation was observed between both parameters assigned to the kidney profile in the SRLV-free group, but not in SRLV-infected animals. Within the cardiac profile, many significant positive correlations with CK were found in SRLV-infected animals while no correlation was noted in the SRLV-free group, suggesting that infection with SRLV may influence the interaction between cardiac parameters. Different sets of correlations between parameters assigned to lipid profiles were found between the SRLV-infected and SRLV-free goats; however, it is hard to evaluate the effect of SRLV infection on the lipid profile itself. Our results indicate that further studies including more parameters are needed to determine the effect of SRLV infection on kidneys, liver and heart.

Conclusions

Most studied parameters did not differ between the groups. Only CHE, Ca*, CK and TRI levels differed, typically at the end of lactation: CHE, Ca*, and CK were elevated for SRLV-free animals, and TRI for SRLV-infected animals. The correlations suggest that SRLV may affect the kidneys, liver and heart, even in asymptomatic animals. Therefore, further molecular and histopathological studies involving symptomatic goats are needed, especially regarding bone, lipid, liver, heard, and kidney profiles.

Conflict of Interests Statement

The authors declare that they have no competing interests

Animal Rights Statement

All procedures involving animals were performed in accordance with Guiding Principles for the Care and Use of Research Animals and were approved by the III Local Ethics Commission (Warsaw University of Life Science; Permission No. 31/2013).

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