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Research article

Nutritional response to water hyacinth (*Eichhornia crassipes*) challenges via blood biochemical profiles in goats and sheep

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A R T I C L E I N F O

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A B S T R A C T

Eichhornia crassipes remains a significant threat to aquatic ecosystems and poses economic challenges globally. Interestingly, its high nutritional value and abundance in water bodies, making it a promising and cost-effective source of animal feed. The purpose of the study was to see how varying inclusion rates of E. crassipise affected the blood biochemical profiles of Doyogena sheep and Woyto-Guji goat local breeds. Twelve sheep and twelve goats were used in a 2*4 randomized crossover design with two species, four diets, and four phases (15-day adaptation plus 7-day experimental diets), and on the last day blood sample collected. The dietary treatments included E. crassipise (0, 25, 50, and 75%) as a substitute for commercial concentrate. The data were analyzed using SAS software tool PROC GLM, and Pearson's correlation coefficient between serum biochemical indices was computed. Results of AST, ALB, GLB, AST/ALT, and A/G showed significant ($P < 0.0001$), ALP ($P < 0.005$), and GLU ($P < 0.05$) differences between species of animals, except for ALT, CREAT, TP, and UREA. Sheep had higher values for AST, ALP, GLB, AST/ALT, CREAT, and UREA, except for A/G, ALB, ALT, and TP. Among treatments and treatment species interaction effect did not show variation in all studied parameters. Positive correlations were observed between ALT and AST, TP and ALB, and A/G and ALB, negative correlations were observed between ALT and AST/ALT, TP and A/G; GLB and A/G in sheep. Furthermore, positive correlations were observed between AST/ALT with ALT and AST and ALB with TP and A/G; however, negative correlations were observed between ALB with TP and A/G in goats. It was concluded that substituting E. crassipise with concentrate had no adverse effect on the serum biochemical profile.

1. Introduction

Sheep and goats are two of the most economically significant small ruminant animals in Ethiopia. About 54 million goats and 43 million sheep are present in the nation [1]. Through direct financial assistance, fertilizer, the production of high-quality meat and skin, and the production of wool, they make a significant contribution to the economy of Ethiopia and the lives of rural resource-poor families, particularly through adaptation and disease resistance, while requiring little care even in vulnerable environments [2]. Although there is a substantial number and ideal environmental conditions, sheep and goat production in Ethiopia is mainly reliant on

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traditional subsistence production with almost negligible industrialization and innovation [3]. Seasonality, inadequate supply, and skyrocketing feed ingredient expenses are major hurdles to the feasible and reasonable distribution of compound feeds [4], which throttle the lucrative productivity of the sector. Thus, it is necessary to look for and use nonconventional feed ingredients that have no direct relevance to human energy and protein demand, and are environmentally and budget friendly.

Aquatic plants, like water hyacinth (*E. crassipes*), are better alternatives to feed that do not attract competition in consumption between humans and livestock. Several studies [5,6,and7]] have suggested that *E. crassipes* can be used as feed for animals, especially ruminants, as basal feed resources or supplements, reducing environmental impact. It consists of more nutrients and protein than many common types of forage, has high resistivity with a high production rate, incurs no production cost, and is an inexpensive source of animal feed [8].

Most aquatic weeds disrupt the natural functioning of water bodies while also generating environmental damage. Among aquatic weeds, *E. crassipes* (Mart.) Solms, sometimes known as water hyacinth, is regarded as the world's worst. It is estimated that water hyacinth alone infests 10–15% of total utilizable water in Ethiopia [9,10].

Despite the fact that the plant is rich in nutrients, it also absorbs heavy metals in the roots and grows in contaminated water [11, 12]. Since serum biochemical markers are used to effectively monitor and assess ruminant nutritional and physiological conditions as well as a variety of environmental challenges [13]. Therefore, this study hypothesized that feeding different inclusion rates of water hyacinth (*E. crassipes*) can affect the blood biochemical profiles of Doyogena sheep and Woyto-Guji goat local breeds. The goals of this study were to determine how varying quantities of water hyacinth (*E. crassipes*) in hay-based diets with commercial concentrate mix influenced the blood biochemical profiles of Doyogena sheep and Woyto-Guji goat breeds in Ethiopian setting.

2. Materials and methods

2.1. Description of the study area

The research was carried out between October 2021 and February 2022 at the Arba Minch University livestock Research Farm at Kulfo campus in southern Ethiopia. The farm is located 435 km south of Addis Ababa, Ethiopia, at a latitude of 6° 2′ 21″ N and a longitude of 37° 34′ 24″ E. It is located at an elevation of 1285 m above sea level, with an average temperature of 29 °C and an annual rainfall of 892 mm.

2.2. Study design and animal management

2.2.1. Animal management

In this experiment, twenty-four indigenous animals (12 male Doyogena sheep and 12 male Woyeto-Guji goats) were used. The sheep and goats had an average age of 12 months and a weight of 20.78 kg and 19.23 kg, respectively. During this time, the animals were drenched with a broad spectrum anthelmintic (albendazole) against internal parasites, sprayed with an accaricide (diazzinole) against external parasites, and immunised against anthrax pasteurelosis. Following the acclimatisation period, each animal was weighed following an overnight fast on two consecutive days, and the average was used as the initial body weight. Animals were also identified with ear tags and housed individually in 1.5 × 1.0 m metabolic enclosures. Each experimental animal was assigned to a separate treatment group at random, and feed was given in two equal quantities at 8:00 and 14:00 h each day, with water and mineralized salt licks supplied ad libitum. The amount of feed given to each animal was modified weekly based on body weight measurements.

Table 1
Nutrient composition of different dietary treatment combinations used in the experiment.

	T1	T2	T3	T4
WHM	0%	25%	50%	75%
Concentrate	100%	75%	50%	25%
Natural grass hay	Adlib	Adlib	Adlib	Adlib
DM (g)	912	914.71	917.43	920.14
OM	921.05	916.01	910.98	905.94
EE	58.4	55.30	52.20	49.10
DCP	107.21	100.31	93.42	86.53
CHO	74.415	74.96	75.51	76.06
NFC	22.035	20.84	19.65	18.46
TDN	315.95	301.44	286.93	272.42
Ash	78.95	83.99	89.03	94.06
DE	5.95	5.67	5.38	5.10
ME	4.885	4.65	4.42	4.18
GE	17.745	17.55	17.36	17.17
ADL	92.3	92.73	93.15	93.58

ADL = acid detergent lignin, CHO = carbohydrate, DCP = digestible crude protein, DE = digestible energy, DM = dry matter, EE = ether extract, GE = gross energy, ME = metabolizable energy, NFC = nitrogen free extract, OM = organic matter, TDN = total digestible nutrient.
Source: Arba Minch University, Analytical Chemistry Laboratory Result

2.2.2. Experimental design and treatments

The study used a randomized two-by-four crossover design, with four treatments consisting of three sheep and goats per treatment group. The experimental diets were fed to the animals for 21 days for each period, with the last day reserved for blood sample collection. To avoid differences in gut content between the first and last days of each experimental session, each animal was weighed individually after overnight fasting. The food allocation for the coming season has been changed based on body weight (BW). The animals were fed total meals containing an estimated 50 g DM/kg BW daily [14]. The daily experimental meal (basal + supplement) supplied to sheep and goats was balanced to provide 8.36 MJ/kg metabolizable energy and 70 g CP/kg on a DM basis [15]. The grass-based hay mixture was taken from Kulfo campus, Arba Minch University, which is made up of various plant groups such as *Astraceae, Fabaceae, Poaceae,* and *Commelinaceae* and few other plant species, with *Asteraceae* and *Fabaceae* dominating. Table 1 illustrates the nutrient combinations used in the experiment.

2.2.3. Blood sampling and collection

Serum biochemical profile analyses were carried out at the laboratory of the Nech-Sar campus, Arba Minch University, Ethiopia. At the end of each experimental period, sheep and goats were restrained for blood collection. In order to perform serum chemistry analysis, 5 ml of blood samples were collected via the jugular vein into sterile test tubes without an anticoagulant. The samples were allowed to coagulate at room temperature for serum separation, then centrifuged at 3500 rpm for 15 min, and finally stored at 20 °C until further analysis. Biochemical indices including total protein (Biuret method), albumin (bromocresol green method), globulin (Total protein-Total albumin), and serum enzymes including urea, creatinine, glucose, aspartate aminotransferase (AST), alanine aminotransferase (ALT), and alkaline phosphatase (ALP) were assessed by using commercially available kits, which were used to ascertain the results (Cogent TM of Span Diagnostic Ltd., Surat, Gujarat, India).

2.2.4. Statistical analysis

All serum biochemical indices data was initially checked for normality using the Shapiro-Wilk test, and homoscedasticity was also verified using the Levene test. Variance analysis was carried out following a 2 × 4 factorial layout for the randomized crossover design using SAS 2013 version 9.4 mixed model procedures (PROC MIXED). Tukey's HSD was used to separate means for serum biochemical parameters that were found to be substantially different at $P < 0.05$. The Pearson correlation coefficient was used to determine the degree of association between serum biochemical indicators. The relevant statistical model is shown below:

$$Y_{ijkl} = \mu + \alpha_i + \beta_j + \gamma_k + \alpha\beta ij + \Sigma_{ijkl}$$

Where,

Y_{ijk} = the response due to the animal i, in period j, treatment k, and interaction effects; μ = the overall mean effect; α_i = the fixed effect of the ith species groups (i = sheep, goat) (subject; I = 1, 2, 3 … 12); β_j = the fixed effect of the kth treatment (k = 1, 2, 3, 4); γ_k = the random effect of the jth collection period (j = 1, 2, 3, 4);

Table 2
Mean for biochemical profile of sheep and goats fed *Eichhornia crassipes*.

Parameters	Species	Treatment, Mean					*P value*		
		T1	T2	T3	T4	SEM	S	T	S × T
ALT, *u/l*	S	20.00	16.08	21.00	20.50	0.74	0.2132	0.8568	0.2903
	G	22.00	22.6	20.75	19.67				
AST, *u/l*	S	100.08^{a}	92.83	98.17	101.17	2.79	<0.001	0.7068	0.4278
	G	67.50^{b}	79.25	86.25	74.33				
AP, *u/l*	S	376.92^{a}	266.08^{a}	260.08^{a}	252.00^{a}	12.04	0.002	0.0061	0.7826
	G	268.08^{a}	202.25^{a}	212.42^{a}	190.17^{a}				
Glucose, *mg/dl*	S	69.50^{b}	69.42^{a}	75.67^{a}	74.50^{a}	1.16	0.022	0.0525	0.0733
	G	84.50^{a}	69.75^{a}	78.25^{a}	76.83^{a}				
Total protein, *g/dl*	S	6.86^{a}	7.04^{a}	7.08^{a}	7.14^{a}	0.05	0.806	0.8042	0.7338
	G	7.08^{a}	6.98^{a}	7.12^{a}	7.05^{a}				
Albumin, *g/dl*	S	2.69^{b}	2.82^{b}	2.80^{b}	2.90^{b}	0.06	<0.001	0.1357	0.5265
	G	3.48^{a}	3.46^{a}	3.78^{a}	3.73^{a}				
Urea	S	55.42^{a}	52.75^{a}	59.17^{a}	55.50^{a}	1.52	0.2021	0.9190	0.4459
	G	48.50^{b}	55.42^{a}	48.75^{b}	54.33^{a}				
Creatinine, *mg/dl*	S	1.02	1.00	0.83	0.91	0.03	0.1340	0.8348	0.3584
	G	0.81	0.83	0.87	0.90				
Globulin, *g/dl*	S	4.17^{a}	4.23^{a}	4.28^{a}	4.24^{a}	0.06	<0.001	0.8579	0.4763
	G	3.60^{b}	3.52^{b}	3.33^{b}	3.33^{b}				
AST/ALT	S	5.42^{a}	5.93^{a}	5.05^{a}	5.38^{a}	0.19	<0.001	0.6042	0.3267
	G	3.19^{b}	3.94^{b}	4.47^{b}	3.94^{b}				
Albumin/globulin	S	0.65^{b}	0.67^{b}	0.66^{b}	0.70^{b}	0.03	<0.001	0.3553	0.5510
	G	1.02^{a}	1.00^{a}	1.16^{a}	1.14^{a}				

[ab]Means with different superscripts in the same column are significantly different ($P < 0.05$); AST/ALT = aspartate aminotransferase/alanine Aminotransferase, A/G = albumin/globulin, S EM = standard error of mean, S = sheep, G = goats, S × T: interaction effect of species and treatment; U/L, units per litter; mg/l, milligram per littere

$\alpha\beta_{ij}$ = the interaction effect between species i and treatment k; and.
Σ_{ijk} = the random error.

3. Results

The effects of feeding different inclusion rate of water hyacinth (*E. crassipes*) on serum biochemical profiles of sheep lambs and goat breeds are presented in Table 2. Certain serum biochemical parameters such as aspartate aminotransferase (AST), alanine aminotransferase (ALT), albumin (A), and globulin (G) were significantly varied between sheep and goats ($P < 0.05$). Sheep had significantly ($P < 0.0001$) higher values for AST, ALP, GLB and AST/ALT than goats while goats had higher values for A/G and ALB levels than sheep.

Other indicators, such as ALT, CREAT, TP, and Urea levels, demonstrated statistically insignificant differences between these small ruminants, with sheep having higher CREAT and UREA levels than goats and goats having higher ALT and TP levels than sheep (Table 2). Similarly, for these tiny ruminants, comparisons of all serum biochemical profiles across treatments and treatment-species interaction effects revealed statistically non-significant ($P > 0.05$) changes.

Table 3 displays the results of Pearson's correlational analysis of the serum-biochemical profile of the Doyogena sheep breed. The content of ALT was extremely substantially positively associated ($p < 0.001$) with the content of AST, whereas the contents of AST and AST/ALT were highly significantly negatively correlated ($P < 0.001$). The level of TP was shown to be extremely substantially positively connected ($P < 0.001$) with ALB, whereas the levels of A/G were found to be highly significantly negatively correlated ($P < 0.001$).The amount of A/G was highly substantially favorably ($P < 0.001$) associated with ALB, whereas GLB contents were highly significantly negatively ($P < 0.001$).

Table 4 shows the results of Pearson's correlational study of the serum-biochemical profile of the Woyto-Guji goat breed. AST and ALT content were substantially significantly positively linked ($P < 0.0001$) with AST/ALT. Similarly, the level of ALB was strongly positively linked with TP and A/G ($P < 0.0001$). On the contrary, GLB content was considerably negative ($P < 0.0001$) associations with ALB and A/G.

4. Discussion

Serum biochemical markers are used to effectively monitor and assess ruminants' nutritional and physiological conditions as well as a variety of environmental challenges (Al-Eissa et al., 2012). In this study, serum biochemical profiles such as proteins, enzymes, metabolites, and renal functional markers were analyzed, and certain parameters were within the normal range in all treatment groups among species, which indicate the normal physiological function of the animals [16].

4.1. Alanine aminotransferase

During the current investigation, there was no discernible variation in ALT levels between goats (19.67–22.6 u/l) and sheep (16.08–21 u/l). Furthermore, the findings appear to be in line with studies that asserted there was no difference in ALT levels across treatment groups [17]. The values in the present study are closer to reference range parameters as reported by Ref. [18] for sheep (4–24 u/l) and [17] for healthy goats (15.78–20.78 u/l). Therefore, this study suggests that neither species suffered from liver impairment as a result of the different rates of water hyacinth incorporation in their diets.

4.2. Aspartate aminotransferase

The AST value (u/l) in sheep (92.83–101.17 u/l) was significantly higher ($P = 0.001$) than in goats (67.50–86.25 u/l). The discrepancies could possibly be attributed to genetic variations of small ruminants. This result falls between (60–280 u/l) range for sheep

Table 3
Pearson's correlation coefficient of serum-biochemical profile of Doyogena sheep breed.

	AST	ALP	GLU	TP	ALB	UREA	CREAT	GLB	AST/ALT	A/G
ALT	0.476***	0.127	−0.08	−0.002	0.127	−0.262	0.108	−0.066	−0.576***	0.133
AST		0.074	0.167	0.12	0.135	−0.097	0.138	0.08	0.338	−0.005
ALP			−0.197	0.054	−0.034	−0.126	0.323	0.083	−0.164	−0.128
GLU				0.298	0.21	0.238	−0.038	0.259	0.068	−0.12
TP					0.604***	0.099	−0.115	0.919	0.004	−0.431**
ALB						−0.004	−0.046	0.239	0.002	0.450**
UREA							−0.077	0.123	0.137	−0.083
CREAT								−0.117	−0.031	0.044
GLB									0.003	−0.749***
AST/ALT										0.011

**$p < 0.01$; ***$p < 0.001$; ALB = albumin, A/G = albumin/globulin, ALP = alkaline phosphate, ALT = alanine Aminotransferase, AST = aspartate aminotransferase, AST/ALT = aspartate aminotransferase/alanine aminotransferase, CREAT = creatinine, GLB = globulin, GLU = glucose, TP = total protein.

Table 4
Pearson's correlation coefficient of serum-biochemical profile of woyto-guji goat breed.

	AST	ALP	GLU	TP	ALB	UREA	CREAT	GLB	AST/ALT	A/G
ALT	0.13	0.344	−0.25	−0.098	−0.254	−0.122	0.216	0.191	0.557***	−0.211
AST		−0.01	−0.13	−0.253	−0.169	0.184	0.05	−0.061	0.667***	−0.062
ALP			0.028	0.097	−0.027	0.069	0.07	0.128	−0.31	−0.038
GLU				−0.039	−0.004	0.082	−0.246	−0.035	0.157	0.036
TP					0.574***	0.091	−0.009	0.354	0.108	0.124
ALB						0.193	−0.149	−0.566***	0.049	0.867***
UREA							0.032	−0.129	0.156	0.158
CREAT								0.161	−0.146	−0.202
GLB									−0.165	−0.863***
AST/ALT										0.096

***$p < 0.001$; ALB = albumin, A/G = albumin/globulin, ALP = alkaline phosphate, ALT = alanine Aminotransferase, AST = aspartate aminotransferase, AST/ALT = aspartate aminotransferase/alanine aminotransferase, CREAT = creatinine, GLB = globulin, GLU = glucose, TP = total protein.

and the (0–300 u/l) range for goats, as described by Ref. [16] for healthy animals. This study did not reveal any significant difference ($p > 0.05$) among treatments or treatment-species interactions. Similarly [19], reported that AST concentrations did not differ among different treatment groups. It's could be that the active elements in the treatment feed might not have any direct effects on the concentration of AST. Hence, this study reveals that both species did not exhibit any symptoms associated with muscle or hepatic cell injury.

4.3. Alkaline phosphatase

Serum Alkaline Phosphatase (u/l) levels were significantly higher ($P = 0.002$) in sheep (252–376.92 u/l) than in goats (190.17–268.08 u/l). The observed disparities in serum alkaline phosphatase concentration were reported as species-specific [20]. The current findings are consistent with the (70.0–390 u/l) range for sheep and the (0–300 u/l) range for goats described by Ref. [16] for clinically healthy animals. Abnormally high serum levels of ALP indicate bone disease, liver disease, or bile obstruction [21] whereas there is no statistically significant difference among different treatment groups or treatment species interactions. These were supported by Ref. [19], who found that the level of ALP was not affected by dietary treatments. It further implies that feeding water hyacinth in this study with different inclusion rates to sheep and goats has no detrimental impact on bone and liver.

4.4. Glucose

The blood glucose (mg/dl) concentration was significantly higher ($P = 0.0215$) in goats (69.75–84.50 mg/dl) than in sheep (69.42–75.67 mg/dl) at T1. This could be associated with different metabolic rate of the animal species. The values in the present study fall within the healthy sheep (50–80 mg/dl) range and closer to the normal range for goats (50–75 mg/dl), as described by Ref. [16]. However, Malecky et al. (2016) revealed a wider reference range for the glucose levels in the blood of Mehraba sheep (66.9–116.5 mg/dl). Whereas [22] obtained lower blood glucose levels in goats (33.15–47.26 mg/dl), nevertheless [23] reported greater blood glucose concentrations in wild goats (126.1 mg/dl) than the findings obtained in this study. Meanwhile, glucose levels are lower than the typical range; this threshold implies hypoglycemia, though elevated levels signal hyperglycemia [24]. The glucose concentration remained unchanged among the treatments and treatments by species interactive effect. These findings agree with the result reported by Ref. [25], who found that dietary treatment had no influence on serum glucose level in goats fed leaf meal mixture as dietary protein supplements. Moreover, this analysis indicates that these species did not illustrate any signs of hypoglycemia or hyperglycemia.

4.5. Total protein

Immense blood protein concentrations can be attributed to considerable grain consumption, dehydration, and high temperatures as a direct consequence of renal failure [26] whereas inadequate serum protein concentration could be a sign of insufficient protein consumption, as stated by Ref. [27]. Total protein levels in sheep (6.86–7.14 g/dl) and goats (6.98–7.12 g/dl) are not statistically different. This result was in accord with recent studies conducted by Ref. [17], who revealed that the total protein contents in ruminant blood serum did not vary significantly. The investigation's results were comparable to Ref. [16] report typical ranges for clinically healthy sheep (6.0–7.9 g/dl) and goats (6.2–7.9 g/dl), indicating the tolerable levels of significant secondary metabolites that could impede nutrient absorption in the gastrointestinal tract of both species. Similarly, total protein levels remained unchanged among the treatments and treatments by species. These results reflect those of [19], who also found that total protein was not influenced by dietary treatments. As a result, this study indicates that neither animal indicated any obvious symptoms of renal failure.

4.6. Albumin

The albumin content (g/dl) were significantly ($P = 0.0001$) higher in goat (3.46–3.78 g/dl) than in sheep (2.69–2.9 g/dl). These results seem to be consistent with other researchers which found (3.7–4.05 g/dl) for different goat breeds by Ref. [28] and closer to (2.9–3.3 g/dl) for different sheep breeds by Ref. [29]. The leaser in its concentration leads to chronic liver disease, protein-losing nephropathies and enteropathies, severe skin burns, malabsorption, and malnutrition [30,31]. On the contrary, there is no statistically significant difference ($P > 0.05$) among the treatments and treatments by species interaction. The findings corresponded with those of [32], who revealed that there is no significant difference in albumin content among different dietary supplements. Hence this study reveals that both species did not show any mentioned symptoms.

4.7. Globulin

Globulins are a heterogeneous group of proteins that include antibodies and other inflammatory molecules, hemostatic and fibrinolytic proteins, and carriers of lipids, vitamins, and hormones [33]. Serum globulin concentrations are an excellent predictor of immunological activation [34]. High globulin concentration in the serum has been suggested as indicator of the animal's immune response [35]. The Globulin content (g/dl) in sheep were higher (4.17–4.28 g/dl) than in goats (3.33–3.6 g/dl), with a statistically significant difference at ($P = 0.0001$). This results remained fall between (2.8–6.1 g/dl) normal range for sheep by Ref. [36] and closer to value (3.04) obtained by Ref. [37] for clinically healthy kanni goat. Globulins had not been significantly affected either by treatment or the interaction effect of treatments and species. The results were consistent with those of [25], who figured out no statistically significant variations in globulin content across different dietary supplements.

4.8. Albumin/globulin ratio

The A/G content (g/dl) in the current study were significantly ($P < 0.001$) higher in goat (1.0–1.16) than sheep (0.65–0.70). The distinct variations in A/G ratio between sheep and goats might be the specific genetic make ups of the animals. This result were in line with the range (1.10–1.15) reported for croatian spotted goats by Ref. [38] and remained within the normal range (0.5–1.0) obtained by Ref. [39] for clinically healthy Dorper × Santa Inês sheep. However, A/G ratio weren't influenced by treatment and the treatment-species interaction effect. This Study coincided with those of [25], who reported no statistically significant differences in the ratio of A/G content among different dietary supplements. Based on the findings, the sheep and goats were not affected by autoimmune diseases and nephrotic syndrome that would produce an increase in antibody production via gamma globulin synthesis. As a result, neither animal displayed any obvious signs of autoimmune disease or nephrotic syndrome in this study.

4.9. Urea

In all treatment groups except T2, serum urea concentrations in sheep (52.75–59.17) were higher than in goats (48.50–55.42), although the difference was not statistically significant. The findings provided here appear to be comparable with those of other researchers who revealed the same range (55.8 mg/dl) for Morada Nova sheep breeds by Ref. [40], (36.6–92.0 mg/dl) by Ref. [41], and (48.7–56.2 mg/dl) for different goat breeds by Ref. [42]. The present results corroborate the findings of [19], who found that dietary treatment had no effect on serum urea concentration. As a result, this study indicates that neither animal indicated any obvious symptoms of renal disorder. On the contrary [43] reported that abnormal increment in serum urea concentration is due to excessive protein ingestion, insufficient energy consumption, or non-synchronized energy and protein decomposition.

4.10. Creatinine

Serum creatinine volume in sheep (0.83–1.02 mg/dl) were a bit higher than in goats (0.81–0.9 mg/dl) across all treatment groups except T3, but the disparity was not statistically significant. These results were remained within the normal range reported for sheep (0.8–1.3 mg/dl) by Ref. [44] and for clinically healthy goat (0.6–1.6 mg/dl) by Ref. [16]. The current findings also back up the findings of [45], who reported that dietary supplements had no influence on serum creatinine concentration. Elevated concentrations of creatinine suggest insufficient protein and amino acid metabolism, which can lead to kidney damage and a coronary artery disease [46]. Moreover, in chronic renal failure and uraemia, the excretion of creatinine by both the glomeruli and the tubules eventually decreases [47]. The rises in creatinine level in cattle fed tannin-rich oak fodder have been corresponding to tannin toxicosis [48]. The analysis showed no signs of renal impairment or coronary artery disease in either species.

4.11. AST/ALT

Sheep had higher AST/ALT (5.05–5.93) ratio than goat (3.19–4.47), with a statistically significant levels at ($P < 0.001$). This result was closer with the value (4.88) reported for clinically healthy red sokoto goats by Ref. [49]. The ratio of AST/ALT is the most convenient way in identifying muscle vs. liver injury as stated by Ref. [50] and A high AST/ALT ratio has been shown to be more suggestive of skeletal muscle injury [51]. With regard to the current findings, both species did not showed skeletal muscle injury as a result of the different rates of water hyacinth incorporation in their diets.

4.12. Correlational studies

Person's correlation coefficients computed among distinct blood biochemical profiles are predicted. Our results revealed a significant positive correlation between ALT and AST levels of in sheep. These findings are in line with estimates by Ref. [52] reported a significant positive correlation between AST and ALT of Kıvırcık sheep. The possible reason for this correlation could be lies in the physiology of liver damage. When liver cells are injured or inflamed, both AST and ALT are released into the bloodstream. On the other hand, AST concentration negatively correlated with AST/ALT. The level of TP was shown to be considerably positive association with ALB, These findings are corroborate with estimates by Ref. [53] reported a significant positive correlation between ALB and TP of Hu sheep. Though, it was exhibited that TP and A/G ratio had a significant negative correlation. A/G ratios were positively correlated with ALB, however, negatively correlated with GLB concentration. This implies that a higher A/G ratio corresponds to more albumins in the blood. This in turn suggests that sheep have healthy liver function and a good nutritional status.

The finding obtained from this study ALT and AST concentrations in goats significantly positively correlation with AST/ALT. This implies that ALT and AST are biochemical markers are predominantly present in liver cells. When the liver cells are damaged or inflamed, these enzymes are released into the bloodstream, causing their levels to rise in blood tests. ALB concentration was positively associated with TP and A/G. On the contrary, the level of GLB was negatively correlated with ALB and A/G. The associations of these serum biochemical indices were expected, it related to the nutritional status of the animals. A well-balanced diet that provides an adequate amount of protein is crucial for maintaining optimal health in goats. When goats are provided a diet rich in protein can positively affect these parameters, resulting in higher ALB concentration, TP, and A/G ratios and vis-verse.

5. Conclusion

Different inclusion rates of water hyacinth (E. crassipise) in the diet of sheep and goats had no adverse effect on the serum biochemical parameters. All the serum biochemical parameters studied for sheep and goats fall within the normal reference range for clinically healthy sheep and goats. A remarkable difference was observed between sheep and goats on certain serum biochemical parameters, except for ALT, total protein, urea, and creatinine. However, treatments and treatment-species interactions had no significant effect on serum biochemical profiles. Both sheep and goats didn't show any signs of Anemia, muscle and bone diseases; autoimmune and infectious diseases; coronary artery disease; traumatic liver injury; hypoglycemia, or hyperglycemia, regardless of the different levels of water hyacinth meal fed. Dried Water hyacinth meal can replace commercial concentrate diets as an alternative feed source up to 75 % for sheep and goats without affecting the metabolic, protein, or energy profiles or the liver, heart, or kidney functions. More investigations need to be conducted to verify this study's speculation and findings, particularly relying on animals with a well-known genetic history and close pedigree.

Ethics approval

The Arba Minch University Animal Research Ethics Committee approved the research techniques and procedures used during the study, certifying that those requirements were reached by approving the study and issuing a certificate (ref. no AMU/AREC/3/2016, dated 20, September 2021).

Informed consent statement

Not applicable.

Data availability statement

The data associated with this research are available at Zenodo. https://doi.org/10.5281/zenodo.10565257, and it can be accessed under the condition (License) of Creative Commons Attribution 4.0 International.

CRediT authorship contribution statement

Yared Fanta: Writing – original draft, Visualization, Software, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Yisehak Kechero:** Writing – review & editing, Supervision, Resources, Funding acquisition. **Nebiyu Yemane:** Writing – review & editing, Supervision.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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