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Reproductive and Productive Efficiency of Baladi Goats Fed on *Azolla pinnata* as an Alternative Source of Ration Protein in South Sinai, Egypt

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ABSTRACT

The objective of the present study was to investigate the effect of feeding *Azolla pinnata* as source of ration protein on reproductive and productive performance as well as blood biochemical parameters of Baladi goat under South Sinai conditions, Egypt. A total number of 45 healthy Baladi goats, with an average weight of 28.65 ± 1.35 kg, were randomly assigned to three experimental groups. The 1st group served as control (G1); does fed on ration contain soya bean as a source of ration protein. The 2nd group (G2); does fed on the same ration with the *Azolla pinnata* replaced by 50 % soya bean. While the 3rd group (G3); does fed on the same ration, with the *Azolla pinnata* replaced by 100 % soya bean. Results indicated that no significant differences among groups in conception and kidding rates which recorded 100 % in control and G3 and 93.3 % in G2. Number of kids born alive recorded 22, 19 and 21 kids, while number of kids weaned recorded 20, 17 and 20 kids. Mortality rate significantly decreased in G3. Weaning weight and daily gain were significantly increased in *Azolla pinnata* groups than control group. Also, milk yield was significantly higher in G3 (787 g/d) followed by G2 (734 g/d), while control group recorded 665 g/d. Except total protein and albumin, blood biochemical parameter didn't affected by different type of ration protein. Immunoglobulin IgA was significantly higher in control and G2 as compared to G3 with values being 0.031, 0.033 and 0.029 ng/dl, respectively. While, IgM was significantly higher in G3 compared to control and G2 with values being 0.034, 0.030 and 0.029 ng/dl, respectively. From these findings, it could be concluded that incorporating *Azolla pinnata* into the diets of Baladi goats can enhance reproductive performance, milk production and composition and blood biochemical parameters without any adverse effects.

Keywords: *Azolla pinnata*, Baladi goats, reproductive, productive, milk yield, biochemical parameters

1. Introduction

In Egypt, animal production development faces a set of current and future challenges that limit the desired such as lack of available fodder resources needed to cover the nutritional needs of animals, low productivity of local farm animal, climate changes and the limited water resources available (Shoukry, 2021). Goats have gained recognition for their remarkable adaptability to diverse climatic conditions, from arid and semi-arid regions to mountainous terrains and humid environments (Teixeira *et al.,* 2024). Goats have metabolic adaptations that allow them to efficiently utilize available resources and tolerate periods of feed and water scarcity, making them well-suited to challenging environments (Silanikove, 2000). Moreover, goats are more efficient in nutrient utilization than cattle, which are particularly advantageous in regions with limited forage resources (Teixeira *et al.,* 2024). Protein is required for most normal functions of the body, including maintenance, growth, reproduction, lactation, hair production, and the immune system. Erickson *et al.* (2020) found that excessive feeding, especially protein intake, to increase animal production leads to a decline in reproductive parameters.

Azolla pinnata is one of the most commonly available unconventional feed which grows abundantly in most of the water bodies. It is a water plant fern and very rich in protein, essential amino acids, vitamin A, B12 and β-carotene, growth promoter intermediate and minerals like calcium, phosphorus, potassium, iron, copper, manganese etc. (Pillai *et al.,* 2002). Moreover, due to high fiber and low lignin

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content it is easily digested by livestock (Sujatha and Jeyakumar, 2009). Aquatic plant species, because of their growth habit, appear not to accumulate secondary plant compounds and therefore offer a great potential than tree leaves as a source of protein for animals (Becerra *et al.,* 1995).

Little studies have been done to utilize *Azolla pinnata* in poultry ration, but no systematic study has been done to utilize *Azolla pinnata* as ruminant animal feed. So, the present study attempt was taken to utilize *Azolla pinnata* in goat ration replacing high-cost protein source to reduce cost of feeding and investigate its effect on reproductive and productive performance as well as blood biochemical parameters of Baladi goat under South Sinai conditions.

2. Material and Methods

The current investigation aimed to evaluate the impact of replacing soybean with Azolla pinnata on reproductive efficiency, productivity and some blood parameters of Baladi goats under semi-arid conditions of South Sinai, Egypt. The field work of the present study was carried out at Elmaghraby farm in Tur Sinai.

2.1. Animals and Management

Forty-five Baladi doe goats (2-3 years old and averaged 28.65 ± 1.35 kg live body weight) were randomly assigned into three equal groups (15 does/ group). The 1st group served as control (G1); does fed ration contain soya bean as a source of ration protein. The 2nd group (G2); does fed the same ration with the *Azolla pinnata* replaced by 50 % soya bean while, the 3rd group (G3); does fed the same ration with the *Azolla pinnata* replaced by 100 % soya bean as shown in Table (1).

Table 1: Ingredients percentage of different experimental rations.

Items	G1	G2	G3
Yellow corn	45.0	45.0	45.0
Barley	10.0	10.0	10.0
Wheat bran	14.0	14.0	14.0
Rice bran	10.0	10.0	10.0
Soya bean	18.0	9.0	0.0
Azolla pinnata	0.0	9.0	18.0
Limestone	1.5	1.5	1.5
Sodium chloride	1.0	1.0	1.0
Minerals mixture	0.5	0.5	0.5

G1= control group, does fed on basal ration contain soya bean as a source of ration protein.
G2= does fed on the basal ration with the *Azolla pinnata* replaced by 50 % soya bean.
G3= does fed on the basal ration with the *Azolla pinnata* replaced by 100 % soya bean.

Azolla pinnata was air dried and mixed to concentrate feed mixture. All groups were offered berssem (*Trifolium alexandrnum*) hay *ad libitum* and rations were adjusted monthly to cover their requirements during their different physiological status according to Kearl (1982). Chemical composition of *Azolla pinnata* and different rations were determined according to A.O.A.C. (1995). Animals were fed three weeks as a transitional period, on the tested rations before the start of the experiment work. Fresh water was available to all groups daily. Animal were kept in semi-open pens roofed with wood, and were clinically healthy and free from internal and external parasites.

2.2. Reproductive and productive measurements

Mating season started in September 2023 and lasted for 42 days (equal to 2 estrous cycles). Five fertile bucks were allowed to rotate among different goat groups to avoid buck/group confounding

effect. Bucks were fed the control concentrate ration and removed from the does groups at early morning before offering rations. Conception rate, kidding rate, litter size at birth, twining rate, litter size at weaning and mortality rate from birth to weaning were recorded. Once kidding took place, the born kids were ear tagged and weighed to record their birth weight and then biweekly till weaning that took place at 3 months then weaning weight was recorded.

Milk yield was determined biweekly from kidding up to 12 weeks lactation period, through the complete hand milking of the udder after fasting kids for 12 hours for two consecutive days once at night and the next at morning to cover 24 hours. Milk samples (50 ml) were taken biweekly from 5 does within the respective groups during 12 weeks lactation period, in plastic bags and kept under -20 ºC for further analysis. Chemical composition of milk in terms of fat, protein, lactose, total solids and solids not fat was determined using milk scan (Bently-Belguim).

2.3. Blood sampling and analysis

For five months, blood samples (10 ml) were taken from ten does in each group in the morning before feeding through vein puncture (using a clinical needle) at biweekly internals. For serum separation, blood samples were centrifuged at 3000 rpm for 20 minutes and stored at -20 ºC until further analysis. Blood levels of total proteins, albumin, glucose, cholesterol and triglyceride determined using commercial kits supplied by Biodiagnostic Company for Laboratory Services, while globulin concentration was calculated. Aspartate and alanine aminotransferases (AST and ALT), urea and creatinin were determined by commercial kits supplied by Biostc Company for Laboratory Services, Egypt. Immunoglobulins (IgG, IgA and IgM) were determined by commercial colorimetric kits supplied by Clinical Chemistry Company.

2.4. Statistical analysis

Data of blood parameters were analyzed by the least square analysis of variance using the General Linear Model Procedure (SAS, 2004). The model was one-way analysis as follows:

$$Y_{ij} = \mu + G_i + e_{ij}$$

Where:

Y_{ij} = any observations of i^{th} animal within j^{th} group.
μ = overall mean
G_i = effect of group, (i: 1-3)
e_{ij} = experimental error.
Means were compared using Duncan Multiple Range Test (Duncan, 1955).
Data of reproductive parameters were analyzed by Chi square analysis.

3. Results and Discussion

3.1. Chemical analysis of different experimental rations, soya bean and *Azolla pinnata*

Results of the chemical analysis of different experimental rations and *Azolla pinnata* are shown in Table (2). The present results indicated that dry matter, ether extract and nitrogen free extract were nearly similar in all tested rations. While, crude protein was higher in control group followed by G2 (50% *Azolla pinnata*), while G3 (100% *Azolla pinnata*) recorded the lowest percentage. On the other side, ash content was higher in G2 and G3 as compared to control group.

On the other hand, crude protein was higher in soya bean meal than *Azolla pinnata* (46.5 and 20.6%), respectively. Ether extract was higher in *Azolla pinnata* than soya bean with values being 19.8 and 6.9%, respectively. This indicated that *Azolla pinnata* could be considered among the richest protein and energy sources in ruminant diets. These results were in harmony with those reported by Abdullah *et al.* (2024).

3.2. Reproductive parameters

As shown in Table (3), number of does used in mating season was 45 does (15 in each group), but 1 of them was barren. Data showed that conception rate did not differ significantly among different experimental groups with values being 100.00, 93.33 and 100.00% for G1, G2 and G3, respectively. Also, kidding rate followed the same trend as conception rate with values being 100.00, 93.33 and 100.00% for G1, G2 and G3, respectively.

Table 2: Chemical composition of the experimental diets, soya bean and Azolla (% on DM basis)

Items	Groups			*Azolla Pinnata*	Soya bean
	G1	G2	G3		
DM	87.90	88.08	88.26	9.10	91.80
OM	96.08	94.82	93.56	84.65	94.16
CP	15.96	13.65	11.35	20.60	46.50
CF	5.32	6.18	7.03	12.15	6.70
NFE	70.88	70.82	70.77	40.20	36.50
EE	3.92	4.16	4.41	3.70	2.20
ASH	3.92	5.18	6.44	19.80	6.90

DM= dry matter, OM=organic matter, CP=crude protein, CF=crude fiber, NFC= nitrogen free extract, EE=either extract
G1= control group, does fed on basal ration contain soya bean as a source of ration protein.
G2= does fed on the basal ration with the *Azolla pinnata* replaced by 50 % soya bean.
G3= does fed on the basal ration with the *Azolla pinnata* replaced by 100 % soya bean.

Table 3: Effect of feeding different rations on reproductive performance Baladi goats.

Items	Groups			Chi-Square value
	G1	G2	G3	
No. of does	15	15	15	--
No. of does conceived	15	14	15	--
Conception rate (%)	100.00	93.33	100.00	2.45^{NS}
Gestation length (day)	152.0±1.54	150.0±1.31	151.0±1.42	--
Kidding rate (%)	100.00	93.33	100.00	1.11^{NS}
No. of kids born alive	22	19	21	--
Litter size at birth (%)	146.60	135.70	140.00	0.74^{NS}
Twining rate (%)	1.46	1.37	1.40	0.74^{NS}
No. of kids weaned	20	17	20	--
Weaning rate (%)	90.90	89.47	95.23	0.44^{NS}
Mortality rate from birth to weaning (%)	9.09	10.52	4.76	8.87^{*}

G1= control group, does fed on basal ration contain soya bean as a source of ration protein.
G2= does fed on the basal ration with the *Azolla pinnata* replaced by 50 % soya bean.
G3= does fed on the basal ration with the *Azolla pinnata* replaced by 100 % soya bean.

These results are agreed with those reported by Abdalla *et al.* (2015) and El-Harairy *et al.* (2006), they reported that conception rate was not affected by feeding ration contained different sources of ration protein.

Number of kids born alive, percentage of litter size at birth and twining rate were insignificantly increased in the does of control and G3 groups than the does in G2 group. On the other hand, mortality rate was significantly lower in the does of G3 group (4.76%), while the does of G2 and control groups recorded highest rate (9.09 and 10.52%, respectively). These results might indicate that *Azolla pinnata*

can improved does efficiency and doesn't have any adverse effects on reproductive performance of Baladi goats with reduced feed cost when concentrate mixture or protein meal are partially replaced by *Azolla pinnata*. The above results were in harmony with those reported by Indira *et al.* (2009); Kumar *et al.* (2012) and Murthy *et al.* (2013).

Mandal *et al.* (2012) reported that *Azolla pinnata* contain beneficial components such as β-carotene, protein, vitamin C, calcium and potassium, which have been shown to improve reproductive performance. These effects can be attributed to the high levels of beta-carotene, protein, and other valuable compounds (Al-Mufarji and Mohammed. 2022). However higher kidding rate observed may be attributed to the inclusion of these supplements in their diet. Supplementary feed that is rich in protein and energy has been shown to have a significant positive impact on reproduction in general, and specifically on ovulation rate (Blache *et al.,* 2008). Conversely, the offspring born to goats that are fed *Azolla pinnata* exhibited low mortality rates. This outcome could potentially be influenced by the presence of therapeutic compounds found in *Azolla pinnata*, as reported by Alalade and Iyayi (2006).

3.3. Productive performance

3.3.1. Body weight changes of Baladi doe goats

The experimental Baladi doe goats remained apparently in good health throughout the experimental period irrespective of dietary protein. Data presented in Table (4), showed the effect of experimental rations on the changes of does weights before and after kidding. There was no significant difference in initial body weight of the experimental animals among the different groups. Also, there were insignificant differences between groups in weights before and after kidding. Does of control and G3 groups recorded an increase in body weights with values being 39.38 and 39.75 kg, respectively, while the does of G2 group recorded 37.95 kg. Similar trend of weights was observed after kidding (32.5, 31.25 and 32.5 kg for control, G2 and G3 groups, respectively).

Moreover, weight gain from initial weight to after kidding was higher in control and G3 groups than the does of G2 group (4.15, 4.28 and 3.49 kg, respectively). These results are consistent with those reported by Hassanein *et al.* (2023) who found that weight gain of Zaraibi goats was increased when fed on rations contain 25 and 50% *Azolla* replacement sunflower meal.

Table 4: Effect of feeding different rations on body weight changes of Baladi goats

Items	Groups			SEM	P value
	G1	G2	G3		
Initial body weight (kg)	28.38	28.76	28.12	1.65	0.234
Body weight before kidding (kg)	39.21	37.95	39.75	1.34	0.251
Body weight after kidding (kg)	32.50	31.25	32.40	0.78	0.083
Weight gain (kg)	4.15	3.49	4.28	0.33	0.076

G1= control group, does fed on basal ration contain soya bean as a source of ration protein.
G2= does fed on the basal ration with the *Azolla pinnata* replaced by 50 % soya bean.
G3= does fed on the basal ration with the *Azolla pinnata* replaced by 100 % soya bean.

On the other hand, Abdullah *et al.* (2024) found that body weight gain and average daily gain were insignificantly affected with partial substation crude protein of concentrate feed mixture with *Azolla* by 12.5 and 25%. However, Ahmed *et al.* (2016) noticed that final body weights were lowest with increased level of *Azolla* in the diet.

3.3.2. Body weight changes of new born kids

Data in Table (5) showed that the kids birth weight didn't affect by type of ration protein. New born kids of control group showed slightly increase in birth weight (2.35 kg) followed by G3 (2.21 kg) then G2 which recorded the lowest value (2.13 kg). The obtained results showed that weaning weight and daily gain had significant higher in *Azolla pinnata* groups as compared to the control group. These

results showed that replacement of soya bean in concentrate mixture with dried *Azolla pinnata* meal did not have any adverse effect on growth performance of Baladi goat kids.

On the other hand, these results were in accordance with Ghodake *et al.,* (2012) in Osmana badi kids, who replaced 15 percent concentrate mixture with *Azolla* meal. The inclusion of 10% *Azolla* had 2.5 times higher weight gain as compared to reported on rearing lambs under semi-intensive system and reduced the feed cost by 22% as compared to control diet without adverse effect on feed intake (Wadhwani *et al.* 2010).

Table 5: Effect of feeding different rations on body weight changes of kids goat

Items	Groups			SEM	P value
	G1	G2	G3		
Birth body weight (kg)	2.35	2.13	2.21	0.17	0.076
Weaning body weight (kg)	10.11[b]	12.05[a]	12.85[a]	0.56	0.001
Daily body weight gain (g/d)	86.22[b]	110.22[a]	118.22[a]	6.18	0.001

G1= control group, does fed on basal ration contain soya bean as a source of ration protein.
G2= does fed on the basal ration with the *Azolla pinnata* replaced by 50 % soya bean.
G3= does fed on the basal ration with the *Azolla pinnata* replaced by 100 % soya bean.
[a-b] Means bearing different superscripts within the same row are significantly different (P<0.05).

Moreover, Sihag *et al.* (2018) concluded that a concentrate mixture of goat diets can be replaced with sundried *Azolla* up to 15% without any adverse effect with economic feeding. Also, there were no significant differences in DM intake, average daily gain, and feed efficiency of Mecheri lamb groups when 10% protein of concentrate mixture was replaced by *Azolla* meal (Sankar *et al.* 2020). Bhatt *et al.* (2021) found that the average daily gain among Sahiwal female calves was higher for groups with 15% followed by 30% feed content of *Azolla*. Similarly, it was noted that the growth rate was improved when replacing the concentrate with 5% *Azolla*.

3.3.3. Milk yield and composition

Data in Table (6) illustrated that milk yield was significantly increased in groups fed diet contain *Azolla pinnata* as compared with control group with values being 787, 734 and 665 ml/day for G3, G2 and control group, respectably. The percentage of increase in milk yield was 10.37 and 18.34% for G2 and G3 as compared to control group. These results are in agreement with those reported by Dongare *et al.* (2019) who studied the effect of feeding different levels of *Azolla* plus basal diet on milk production of Konkan kanyal goat. They found that daily milk production was increased by about 22.83% in goats fed basal diet plus 100 g concentrate plus 300 g fresh *Azolla*, and 13.98% in goats fed on basal diet plus 0 g concentrate plus 400 g fresh *Azolla* as compared to control group which fed on basal diet plus 400 g concentrate with 0 g *Azolla*.

In dairy cattle, Pillai *et al.* (2005) found that incorporating 1.5 -2 kg of fresh *Azolla* with regular feed/day in the diet increased milk yield by 15%. Moreover, Gouri *et al.* (2012) found that replacing 20% commercial feed with *Azolla* of diet dairy cows, increased milk yield by about 15–20%. Incorporating 1.5–2 kg fresh *Azolla* in cow diets led to increase milk yield by 20.96% and 16.9% in buffalo (Mathur *et al.* 2013). Moreover, Kumar *et al.* 2020 found that fresh *Azolla* can be used as a feed supplement for dairy cows up to 1 kg per day which could increase milk production by 7–13%. This increasing in milk yield might be due to the low lignin and high protein content of *Azolla*.

On the other hand, milk fat, ash and solid not fat didn't affect by treatments (Table 6). While, milk protein level was significantly increased in the does of G3 followed by does of G2 then the does of control group, which recorded the lowest level of milk protein with values being 32.91, 29.22 and 25.32%, respectively. Similar trend was also observed in lactose and total solids (40.04 and 121.2 for G3, 38.76 and 116.3 for G2 and 34.71 and 104.8 for control group), respectively. These results are in harmony with previous studies conducted by Kholif *et al.* (2015), which demonstrated that supplementing goat diets with vitamins and minerals resulted in improved milk production and composition. The inclusion of *Azolla* in the goat diets had a significant positive impact on both the

quantity and quality of their milk. This enhancement in milk yield can be attributed to the higher metabolizable energy content present in *Azolla pinnata*.

Table 6: Effect of feeding different rations on milk yield and composition of Baladi goats

Items		Treatments			SEM	P value
		G1	G2	G3		
Milk yield (ml/ day)		665.00[b]	734.00[a]	787.00[a]	1.03	0.001
Milk components (g/kg)	**Fat**	33.40	36.45	37.30	0.71	0.076
	Protein	25.32[b]	29.22[ab]	32.91[a]	1.03	0.001
	Lactose	34.71[b]	38.76[a]	40.04[a]	0.83	0.031
	Ash	6.94	6.98	7.01	0.017	0.127
	Total Solids	104.8[b]	116.30[a]	121.20[a]	0.031	0.001
	Solids not fat	71.39	79.85	81.09	0.012	0.270

G1= control group, does fed on basal ration contain soya bean as a source of ration protein.
G2= does fed on the basal ration with the *Azolla pinnata* replaced by 50 % soya bean.
G3= does fed on the basal ration with the *Azolla pinnata* replaced by 100 % soya bean.
[a-b] Means bearing different superscripts within the same row are significantly different (P<0.05).

3.3.4. Blood biochemical parameters

The blood biochemical profile is a primary parameter in determining feeding efficiency, which is subsequently used in assessing livestock health, physiological condition, possible pathological events and nutritional adequacy (Hocine *et al.,* 2023). The results of blood metabolite analysis are shown in Table (7). Concerning the effect of different rations on blood metabolites, it could be observed that total proteins and albumin were significantly increased in *Azolla pinnata* groups, while globulin concentration slightly increased in control group followed by G2 then G3. Total protein recorded the highest (P< 0.05) value in the does of G3 (6.91 g/dl) then G2 (6.74 g/dl), while the lowest value observed in control group (6.38 g/dl).

Total blood protein and its fractions are considered as a biological index reflecting productive performance and health status of the animal. Significant increasing values of total proteins and albumin agree with previous findings (Hassanein *et al.,* 2023, Kahn *et al.,* 2010) and indicate normal ranges for goats. Moreover, similar results were observed in buffalo calves fed rations contain *Azolla* which partially replaced by 12.5 and 25% crude protein in concentrate feed mixture (Abdullah *et al.,* 2024). The present results and those of other studies confirmed that *Azolla pinnata* is a good source of protein in animal rations. The observed range of total serum protein in experimental goats was within the normal range of 6.0 to 7.5 g/dl (Kaneko 1997) showing no adverse effect of replacement.

On the other side, glucose concentration was not affected (P> 0.05) by dietary with *Azolla pinnata* (Table 7) and the values are within the normal range (50-75mg/dl) for goats, as reported by Kaneko *et al.* (1997). Glucose concentrations insignificantly increased in the does of control and G3 than the does of G2 with values being (59.09, 60.71 and 56.23 g/dl, respectively). Our findings support those of Al-Suwaiegh (2023), they noticed that glucose concentration didn't affected by feeding 10 and 20% *Azolla* in animal diets.

The values of cholesterol and triglycerides were not affected by feeding different types of ration protein. Cholesterol concentration tended to insignificantly increase in the does of control group than the does of G2 and G3 with values being 45.77, 43.89 and 44.14 mg/dl, respectively (Table 7). While, triglyceride concentration was insignificantly higher in the does of G2 than other groups with values being 16.33, 18.71, 16.98 mg/dl for control, G2 and G3, respectively (Table 7). These results are in agreement with those reported by Ravindra *et al.* (2015) who found no differences in cholesterol and triglycerides of goats fed control and concentrate mixture were replaced with 25% *Azolla* meal. The values were within the normal range as suggested by Kaneko (1997).

The positive effects of *Azolla pinnata* on blood metabolites values might be due to several factors including nutrient digestibility, antioxidative properties, and regulating pathways involved in the metabolism (Das *et al.,* 2017 and El-Naggar and El-Mesery, 2022).

Table 7: Effect of feeding different rations on blood biochemical parameters of Baladi goats.

Items	Groups			SEM	P value
	G1	G2	G3		
Total proteins (g/dl)	6.38^{b}	6.74^{ab}	6.91^{a}	0.01	0.050
Albumin (g/dl)	3.12^{b}	3.57^{a}	3.16^{b}	0.03	0.001
Globulin (g/dl)	3.26	3.17	3.05	0.13	0.061
Glucose (g/dl)	59.09	58.23	60.71	0.98	0.072
Cholesterol (mg/dl)	45.77	43.89	44.15	1.023	0.071
Triglyceride (mg/dl)	16.33	18.71	16.98	0.08	0.063

G1= control group, does fed on basal ration contain soya bean as a source of ration protein.
G2= does fed on the basal ration with the *Azolla pinnata* replaced by 50 % soya bean.
G3= does fed on the basal ration with the *Azolla pinnata* replaced by 100 % soya bean.
$^{a-b}$ Means bearing different superscripts within the same row are significantly different (P<0.05).

3.3.5. Kidney and liver function

Data in Table (8) showed that urea and creatinine concentrations did not affected by treatment. Level of urea was 29.18 mg/dl in control group, 29.01 mg/dl in G2 and 28.33 mg/dl in G3. Creatinine values were 0.79, 0.74 and 0.76 mg/dl for control, G2 and G3, respectively. The positive changes in blood urea and creatinine values were obtained by *Azolla pinnata* feeding goats could be attributed to increase of feed conversion (Al-Suwaiegh, 2023). Hassanein *et al.* (2023) found that urea concentration did not affected when *Azolla* was introduced into ration at levels of 10 and 20%. While, creatinine values were significantly increased when *Azolla* levels increased in rations. They suggested that the increase in the urea content in blood has been reported to result from increasing intake of digestible crude protein (Balikci *et al.,* 2007). The value of creatinine in the present study was within the normal range and is also comparable with previous findings (Khan *et al.,* 2016). Since the results are within the normal range, it has no detrimental impact on the kidney. As a result, incorporating *Azolla pinnata* into a diet is safe for kidney health and has no negative consequences.

Table 8: Effect of feeding different rations on kidney and liver functions of Baladi goats.

Items	Groups			SEM	P value
	G1	G2	G3		
Urea (mg/dl)	29.18	29.01	29.63	0.768	0.321
Creatinine (mg/dl)	0.79	0.74	0.76	0.182	0.077
ALT (IU/L)	11.61	10.42	10.10	0.813	0.109
AST (IU/L)	50.21	52.87	51.67	2.058	0.091

G1= control group, does fed on basal ration contain soya bean as a source of ration protein.
G2= does fed on the basal ration with the *Azolla pinnata* replaced by 50 % soya bean.
G3= does fed on the basal ration with the *Azolla pinnata* replaced by 100 % soya bean.

In relation to the ALT and AST levels (Table 8), the data clearly indicates that there were not affected by the experimental treatment. Similar results were observed by Al-Suwaiegh (2023). Measurements of hepatic enzymes (AST and ALT) are considered as a reliable indicator of liver function in ruminant animals (Liu *et al.,* 2012; Noro *et al.,* 2013), and the liver enzymes values were unchanged due to *Azolla pinnata* supplementation in the diets. Levels of ALT and AST observed in our study were within the normal physiological ranges, which are crucial indicators of liver activity and function. This suggests that there were no pathological lesions in the liver due to the feeding *Azolla pinnata*, as supported by Hassanein *et al.* (2023). In dairy cattle, Ghallab *et al.* (2023) reported that ALT and AST values didn't affected by feeding control ration with replacing 1.2 kg of *Azolla* instead of 1.5 kg of CFM and 2.4 kg instead of 3 kg of CFM. In general, including 50 and 100% *Azolla pinnata* as a source of ration protein resulted in no harmful effects to biochemical parameters in Baladi goats.

3.3.6. Immunological parameters

As shown in Table (9), immunoglobulin concentration of IgA was significantly increased in control and G2 as compared to G3 with values being 0.031, 0.033 and 0.029 mg/dl for control, G2 and G3, respectively. While, IgG concentration was insignificantly increased in control and G3 than G2 with values being 0.042, 0.041 and 0.040 mg/dl, respectively. On the other hand, IgM concentration observed significantly higher in the does of G3 than the does of control and G2 with values being 0.034, 0.030 and 0.029 mg/dl, respectively. These results indicated that *Azolla pinnata* supplementation improved immunological responses. The green *Azolla pinnata* contains beta-carotene and antioxidant vitamin A with antioxidant activity that might help in immune health (Al-Suwaiegh (2023).

Table 9: Effect of feeding different rations on immunological parameters of Baladi goats.

Items	Groups			SEM	P value
	G1	G2	G3		
IgA (ng/dl)	0.031[a]	0.033[a]	0.029[b]	0.001	0.014
IgG (ng/dl)	0.042	0.040	0.041	0.001	0.074
IgM (ng/dl)	0.030[b]	0.029[b]	0.034[a]	0.002	0.011

G1= control group, does fed on basal ration contain soya bean as a source of ration protein.
G2= does fed on the basal ration with the *Azolla pinnata* replaced by 50 % soya bean.
G3= does fed on the basal ration with the *Azolla pinnata* replaced by 100 % soya bean.
[a-b] Means bearing different superscripts within the same row are significantly different (P<0.05).

4. Conclusion

The inclusion of *Azolla pinnata* as a source ration protein of Baladi goats has shown promising results in enhancing their reproductive and productive performance as well as blood biochemical parameters. These positive effects have been observed without any adverse effect on kidney and liver function. These findings suggest that there is a great potential for reduce the ration cost by using *Azolla pinnata* in animal ration.

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