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Effect of dietary supplementation of *Spirulina* (*Spirulina platensis*) on growth performance, carcass traits and economy in Nellore Ram Lambs

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Abstract
A growth trial was conducted for 90 days with 18 Nellore brown ram lambs with average body weight of 15±0.37 kg which were randomly divided into three groups containing six animals in each group and were evaluated with/without supplementation of *Spirulina platensis* on growth performance, and carcass characteristics in a CRD model. To a basal diet acting as control (T_1) the *Spirulina* was supplemented at 1 g and 2 g/10 kg body weight to 2nd and 3rd groups to make them as T_2 and T_3, respectively. The animals were stall fed with the concentrate mixture and super napier green fodder. The initial and final body weights were found to be non-significant among treatments with a significant effect ($p<0.01$) on the weight gain, T_2 recording the highest weight gain followed by T_3 and T_1. *Spirulina* supplementation at 1 g/10 kg body weight showed a marked significant difference among ADG (g) and a gain of 148 g was recorded for T_2 followed by T_3 and T_1, ADG was 26.5% and 13.6 % higher in T_2 and T_3 as compared to T_1 in the present study. Feed efficiency was higher for T_2 as compared to T_1 and T_3 indicating that the efficiency in utilising the feed was efficient for *Spirulina* supplementation at 1 g/10 kg body weight. A significant increase ($p<0.05$) in ADFI (g/day) was recorded for T_2 group as compared to T_3 and T_1. None of the parameters like preslaughter weight, empty body weight, hot carcass weight, dressing % (PSW) and dressing % (EBW) were found to be significant among the treatments. The total feed cost/kg weight gain was significantly lower ($p<0.05$) for T_2 and it was 5.6 % and 19.5% lower as compared to T_1 and T_3 respectively. It was concluded that supplementation of *Spirulina* at 1 g/10 kg improved the performance of animal with positive growth rate. Owing to it's high protein content and quality protein *Spirulina* can be added as a feed additive in the rations of sheep with improved efficiency.

Keywords: Growth trial, *Spirulina*, ADG, carcass characteristics, feed efficiency

Introduction
The demand for the consumption of livestock products is increasing day by day because of the consumer preferences for tastes, awareness about consumption of quality protein through livestock products and also urbanization is also one of the major factor for this demand. But 2 reasons strongly oppose the working conditions for meeting this animal product demand: increased competition for the land and the climate change which negatively affects water and animal feed availability (Poppi and McLennan, 2010) [24]. The identification of other alternate resources is therefore important for sustainable animal production which has high nutritive value and conversion efficiency, be able to optimise animal product quality. Consequently, *Spirulina* is emerging as a potential alternate to meet these criteria.
It contains all essential amino acids, vitamins and minerals. It also is a rich source of carotenoids and fatty acids (Holman and Malau -Aduli, 2013) [12]. Intensive livestock production systems may be associated with multiple stressful incidents that
negatively impact immune response and animal performance. The high metabolic rate during intensive feeding is accompanied by an increased production of free radicals, and any imbalance between production of these molecules and their safe disposal may end in oxidative stress, which can damage cells and tissues (Lykkesfeldt & Svendsen, 2007) [19]. Therefore, under oxidative stress conditions, there is an increased demand for antioxidants to reduce the deleterious effects of free radicals on the immune system (Carroll & Forsberg, 2007) [9]. Interestingly, feeding natural, rather than synthetic, antioxidant could be advantageous to animal welfare and consumer safety.

The blue-green algae, *Spirulina platensis*, have been considered as a suitable natural antioxidant and immune-stimulant to humans and animals with fewer side effects and more cost effectiveness than synthetic products (Abdel-Daim *et al*., 2013) [4]. The present trial was conducted to study the effect of optimum level of supplementation of *Spirulina* in the diet of growing ram lambs and also, it's effect on carcass traits

Materials and Methods

The present study was conducted at the Department of Animal Nutrition, College of Veterinary Science, Tirupati, to study the effect of dietary supplementation of *Spirulina* in Nellore ram lambs on their growth performance, nutrient digestibility, serum biochemical and carcass characteristics. The laboratory analysis was carried out at the Department of Animal Nutrition and Department of Veterinary Biochemistry, College of Veterinary Science, Tirupati and the animal experimentation was carried out at the Department of Livestock Farm Complex, College of Veterinary Science, Tirupati. Feed ingredients were procured from the local market, *Spirulina* was procured from Inway *Spirulina* private limited, fresh super napier green fodder was harvested at optimum stage from the fodder plots, Department of Livestock Farm Complex, Tirupati was used for feeding experimental animals after cutting and chopping each day. Eighteen Nellore brown ram lambs (age-3-5 months old, Avg body wt. 15±0.37 kg) were purchased from a local shandy. The ram lambs were adapted for stall feeding conditions, dewormed and vaccinated against F&M disease before the commencement of the study. The animals were randomly allotted to three treatment groups with six animals per treatment. A basal diet with *ad libitum* feeding of super napier and concentrate mixture @ 1.5 % of body weight was fed for all the three groups and were named as T_1, T_2 and T_3. The basal diet with no supplementation of *Spirulina* was the control (T_1), T_1 with *Spirulina* supplementation in concentrate mixture @ 1 g/10 kg bodyweight is T_2 and @ 2 g/10 kg bodyweight is T_3. A growth trial was conducted for a period of 90 days under intensive system of rearing and the ram lambs were housed in a pucca shed in individual pens of 2.1 x 1.2 x 1m dimensions having facilities for feeding and watering. The ram lambs were fed with weighed quantities of concentrate mixture according to the experimental diets at 9:00 AM daily and *ad libitum* feeding of super napier was done twice daily at 12:00 PM and 4:00 PM and the leftover super napier if any was recorded next day morning to calculate dry matter intake (DMI). The animals had free access to fresh and clean drinking water throughout the day. Deworming was done once in a month during the experimental period. Periodical weighing of the animals was practiced before feeding at fortnightly intervals to know the effect of experimental diets on growth performance. At the end of experiment, 5 lambs per treatment were slaughtered to study effect of treatments on carcass traits. Animals were slaughtered by "Halal" method and sticking, legging, dressing and evisceration were performed as per the procedures described by Gerrard (1964) [28].

Results

Growth performance

The growth performance and feed efficiency of ram lambs fed with concentrates supplemented with *Spirulina* is presented in Table 1. The initial body weight (kg) of ram lambs were 15.13, 15.13 and 15.02 for T_1, T_2 and T_3, respectively and was not significantly different among treatments. The final body weight (kg) was higher in T_2 than in T_1 and T_3 and the values were 25.73, 28.48 and 27.05 in T_1, T_2 and T_3, respectively and were not significantly different ($p<0.05$). The weight gain (kg) of ram lambs during the 90-days growth trial was 10.6, 13.35 and 12.03 for T_1, T_2 and T_3, respectively which was significantly ($p<0.01$) higher in T_2 than T_1 and T_3. The average daily gain (g) was 117.78, 148.33 and 133.70, in T_1, T_2 and T_3, respectively which was significantly ($p<0.01$) higher in T_2 than in T_1 and T_3, fed lambs. The feed efficiency was significantly ($P<0.01$) better in T_2 compared to other treatments, and the values were 5.98, 5.14 and 5.64 in T_1, T_2 and T_3, respectively. The average daily feed intake g/day was 702.19, 762.26 and 754.93 in T_1, T_2 and T_3, respectively and which was significantly higher ($p<0.05$) in T_2 and T_3 than T_1.

Carcass Characteristics

The carcass characteristics of ram lambs are presented in Table 2. No significant ($p>0.05$) effects were noticed for carcass characteristics *viz.*, preslaughter weight, empty body weight, hot carcass weight, dressing % (PSW) and dressing % (EBW) among the ram lambs fed three dietary treatments. The pre slaughter weight (kg) was 25.73, 28.48 and 27.05; empty body weight (kg) was 21.33, 24.05 and 22.78; hot carcass weight was 12.90, 14.32 and 13.69; dressing % on pre slaughter weight was 50.17, 50.29 and 50.62; dressing % on empty body weight was 60.65, 60.56 and 60.13 in T_1, T_2 and T_3 respectively.

Cost economics

The effect of dietary supplementation of *Spirulina* on Cost economics of ram lamb production per animal is represented in Table 3. The feed cost (Rs.)/kg live weight gain obtained was 91.51, 86.23 and 102.63 for T_1, T_2 and T_3 fed groups, respectively, and were significantly low in T_2 as compared to T_1 and T_3. Total feed cost (Rs) was significantly ($p<0.05$) higher in T_3 and T_2 than in T_1 and the values were 966.13, 1146.69 and 1228.21 in in T_1, T_2 and T_3 respectively. But, there was no significant difference in total returns (Rs) and the values were 7743, 8592, and 8217 in in T_1, T_2 and T_3, respectively. Net Profit (Rs) was significantly higher ($p<0.05$) in T_2 than in T_1 and T_3 and the values were 2236.87, 2905.31 and 2483.79 in T_1, T_2andT_3, respectively.
Supplementation of *Spirulina* showed a remarkable effect on the cost economics of the trial. The cost incurred on super napier and concentrate mixture was significantly higher ($p<0.05$) in T_2 and T_3 as compared to control and the values were 219.31, 238.07 and 235.78 for super napier; 746.83, 810.72 and 802.93 for concentrate mixture; for T_1, T_2 and T_3, respectively. Significant changes ($p<0.05$) were also noticed for total feed cost (Rs), total feed cost : gain ratio and net profit (Rs) for T_1, T_2 and T_3 and the values were 966.13, 1146.69 and 1228.21 for total feed cost; 91.51, 86.23 and 102.63 for feed : gain ratio; 2236.87, 2905.31 and 2483.79 for net profit (Rs) in T_1, T_2 and T_3, respectively. The values in table 3 for net profit and total feed consumed per kg body weight gain clearly depict that supplementation of *Spirulina* showed a marked influence on the cost economics in a positive way.

Table 1: Effect of dietary supplementation of *Spirulina* on growth performance

Treatment	Initial weight (kg)	Final weight (kg)	Weight gain (kg)**	ADG (g)**	Feed efficiency** (kg DMI/kg gain)	ADFI g/day*
T_1	15.13±0.98	25.73±1.17	10.6^{a}±0.44	117.78^{a}±4.95	5.98^{b}±0.13	702.19^{a}±18.36
T_2	15.13±0.55	28.48±0.76	$13.35^{b\pm}$0.55	148.33^{b}±6.10	$5.14^{a\pm}$0.09	762.26^{b}±17.58
T_3	15.02 ±0.32	27.05±0.43	$12.03^{ab\pm}$0.49	133.70^{ab}±5.45	$5.64^{b\pm}$0.14	754.93^{b}±14.20
P value	0.990	0.102	0.005	0.005	0.001	0.046

ab values in a column bearing different superscripts differ significantly **(p<0.01), *(p<0.05)

Table 2: Effect of dietary supplementation of *Spirulina* on slaughter studies

Treatment	Preslaughter weight (kg)	Empty bodyweight(kg)	Hot carcass weight (kg)	Dressing % (PSW)	Dressing % (EBW)
T_1	25.73±1.17	21.33±1.19	12.90±0.59	50.17±0.26	60.65±0.65
T_2	28.48±0.76	24.05±0.68	14.32±0.38	50.29±0.13	60.56±0.31
T_3	27.05±0.43	22.78±0.5	13.69±0.27	50.62±0.21	60.13±0.26
P value	0.102	0.107	0.102	0.30	0.254

Table 3: Effect of dietary supplementation of *Spirulina* on Cost economics per animal

Parameter	T_1	T_2	T_3
a) Animal cost (Rs)	4540±293.70	4532±165.89	4505±96.25
b) Super Napier cost (Rs)*	219.31^{a}±5.74	238.07^{b}±5.49	235.78^{b}±4.44
c) *Spirulina* cost (Rs)	---	97.9±3.03	189.51±1.99
d) Concentrate mixture cost (Rs)*	746.83^{a}±19.53	810.72^{b}±18.7	802.93^{b}±15.11
e) Total feed cost (Rs)*	966.13^{a}±25.27	1146.69^{b}±25.39	1228.21^{c}±20.22
f) Weight gain (kg)*	10.6^{a}±0.44	$13.35^{b\pm}$0.55	$12.03^{ab\pm}$0.49
g) Total feed cost (Rs)/kg wt. gain*	91.51^{a}±1.93	86.23^{a}±1.68	102.63^{b}±2.75
h) Returns by sale (by sale of meat & offals Rs)	7743±354.21	8592±227.64	8217±161.46
i) Net Profit/Loss (Rs)*	2236.87^{a}±123.38	2905.31^{b}±135.32	2483.79^{a}±148.69

^{abc} values in a column bearing different superscripts differ significantly*(p<0.05)

Discussion

Growth performance

Though the initial weight (kg) were not significant among the treatments, the final body weight was higher in T_2 than T_1 and T_3 and were not significantly different. These findings are in accordance with Mokhtar *et al*. (2023) [21] who reported non-significant increase in final body weight in *Spirulina* supplemented group. Hanafy (2023) [13] also reported significant increase (p<0.01) in final bodyweight in *Spirulina* supplemented group at 1 g/10 kg weight. Mansour *et al*. (2023) [22] reported a significant increase (p<0.05) in final bodyweight in *Spirulina* supplemented lambs at 10 g/day, Alghonaim *et al*., (2022) [5] found significant (p<0.05) increase in final body weight in *Spirulina* supplementation at level of 8 ppm and the weight gain was found significantly different (p<0.01). In the present findings, *Spirulina* supplementation at 1 g/10kg body weight recorded highest weight gain of 13.35 kg followed by *Spirulina* supplementation at 2 g/10kg body weight (12.03 kg) and the group without *Spirulina* with 10.6 kg, which are 25.9% and 13.5% higher for T_2 as compared to T_1 and T_3, respectively. These findings are in agreement with Hanafy (2023) [13]; Assar *et al*., (2023) [2]; Mansour *et al*., (2023) [22]; Alghonaim *et al*., (2022) [5], who reported significant increase (p<0.05) in weight gain in *Spirulina* supplemented lambs. Mokhtar *et al*. (2023) [21] reported non-significant increase in weight gain in *Spirulina* supplemented groups. Similar trend was noticed in ADG (p<0.01) in which it was found that T_2 was 26.5% and 13.6 % higher as compared to T_1 and T_3, respectively which agree with Hanafy (2023) [13]; Mansour *et al.* (2023) [22].

The feed efficiency was significantly higher (p<0.01) for T_2 followed by T_3 and T_1. These findings agree with Hanafy *(*2023) [13]; Mansour *et al.* (2023) [22]; El-sabagh *et al*. (2014) [10]; Mokhtar *et al*. (2023) [21] reported non-significantly better FCR in *Spirulina* supplemented group.

The ADFI (g/day) was significantly higher (p<0.05) for T_2 and T_3 than T_1. These findings agree with Hanafy (2023) [13]; Assar *et al.* (2023) [2]; Mokhtar *et al*. (2023) [21]; Alghonaim *et al.* (2022) [5]. *Spirulina* supplementation resulted in enhanced growth performance, including final weight, total weight gain, average daily gain (g), and improved feed efficiency. Several factors contribute to the improved performance in ram lambs. The high protein content of *Spirulina* used in the trial at 56.7%, is a potential factor contributing to enhanced growth performance which are consistent with findings by Karlsson *et al*. (2011) [15]; Hanafy (2023) [13]. Additionally, the higher crude protein digestibility in T_2 may contribute to the improved performance. Increased protein digestion in the rumen leads to enhanced microbial protein synthesis, making it more available to the animals, thereby contributing to better growth performance.

The high nutrient density of *Spirulina*, coupled with the secretion of extracellular enzymes by gut microflora (Tovar-Ramirez *et al*., 2002) [27], may be responsible for improvements in body weight gain, average daily gain (ADG), and dry matter intake (DMI) in growing lamb rams (Lamminen *et al.*, 2019) [20]. *Spirulina* supplementation is known to enhance production by increasing rumen microbial crude protein production and altering bacterial community composition in steers (Panjaitan *et al*., 2010) [23]. The improvement in ADG partially explains the enhanced feed efficiency observed in lambs fed *Spirulina* diets, associated with increased nutrient utilization, improved microbial nitrogen supply and body nitrogen retention (Abdel-Wahed *et al*., 2023) [3].

It is to be noted that the trial was conducted from April to June which is said to be a peak stress period for the animals.

But it was reported that *Spirulina* is a natural antioxidant and immune stimulant with minimal side effects and this property of *Spirulina* could be one of the contributing factor in minimizing the reduced feed intake and improve performance. This reported statement is in agreement with Abdel-Daim *et al*. (2013) [4] who reported that *Spirulina* contains a property of natural immune system. *Spirulina* emerges as a natural supplement promoting growth, immunity, and productivity in lambs (Bezerra *et al.*, 2010; El-sabagh *et al.*, 2014; Kashani *et al.*, 2015; Alghoniam *et al*., 2022) [7, 10, 16, 1], owing to its high concentrations of Linoleic acid and Linolenic acid, essential constituents in animal metabolism. It was reported that *Spirulina* contains several types of antioxidants (chlorophyll and carotenoid pigments), having anti-inflammatory effect and might prevent degenerative diseases. This immunity improvement maintains the levels of daily gain, feed conversion and reduces the disease incidence in lambs (Holman and Malau-Adauli, 2013) [12]. *Spirulina's* antioxidant effect is related to many dietary active ingredients like phycocyanin, polysaccharides, α-tocopherol and β-carotene which also have potent antioxidant activities. *Spirulina* with its antioxidant property would work on free radicals to prevent cell damage either individually or in synergism with these dietary active ingredients (Riss *et al*., 2007) [26]. Antioxidant activity of phycocyanin had been estimated to be nearly twenty times more efficient than vitamin C (Gershwin & Belay.,2008) [11].

Another potential reason for improved performance with *Spirulina* supplementation is its enhancement of microbial protein synthesis in the rumen and reduced retention time, making nutrients more available at the intestinal level. Approximately 20% of dietary *Spirulina* escapes rumen degradation and becomes available at the abomasum during digestion (Quingley and Poppi, 2009) [25]. It was further reported that the amount of protein produced from algae was found to be more valued in terms of productivity and nutrition compared to protein from traditional plant sources (Bleakley and Hayes, 2017) [8].

Excessive dietary protein intake in T_3 (2 g/10kg body weight) may have suppressed optimal growth in lambs (Holman *et al.*, 2012) [13]. A higher dose of *Spirulina* (2 g/10kg body weight) could lead to nutrient saturation, potentially causing digestive issues. Increased *Spirulina* supplementation may result in dietary interactions, leading to decreased average daily gain (ADG) due to individual variability and nutrient saturation, as observed in T3 (2 g/10kg body weight *Spirulina* supplementation). The negative correlation between protein accretion and fat deposition could also contribute to the decreased ADG in T3. Excessive protein may get deaminated and lost in urine or broken down in the liver, leading to conditions such as fatty liver and ketosis.

Therefore, feeding 1 g *Spirulina*/10 kg body weight may provide better tolerance, allowing more consistent feed consumption and leading to increased ADG in T_2 (1 g/10kg body weight). Further research on fractional dosage between 1 g and 2 g/10 kg body weight is recommended to optimize *Spirulina* dosage in growing ram lambs.

Carcass studies

The supplementation of *Spirulina* did not exert any influence on the carcass characteristics. Although the pre-slaughter weight of animals in T_2 and T_3 was numerically higher than that of the control group, no statistical significance was observed. The observed increase in pre-slaughter weights for the *Spirulina*-supplemented groups may be attributed to the enhanced body weight gain at the end of the trial and a higher average daily feed intake (ADFI) in grams per day. The lack of a significant difference in dressing percentage among treatments could be due to the understanding that slaughter yield tends to improve with age and is higher in animals raised for faster and increased growth rates (Lebas and Colin, 1992) [18]. The non-significant differences in both hot and cold carcass weights in the current study align with the findings of Al-Yahyaey *et al.* (2023) [6] and Hafez *et al.* (2013) [14]. Additionally, the weight of the empty digestive tract was higher in the *Spirulina*-supplemented groups which are consistent with the results reported by Al-Yahyaey *et al.* (2023) [6] in an experiment conducted with Omani goats.

Cost economics

Since all animals in the treatment groups were procured based on body weight at the same cost, no statistically significant differences ($p>0.05$) were observed in the initial weights. However, there was a significant variation ($p<0.05$) in the cost of green super napier and concentrate mixture among the treatments. In the current trial, the average daily feed intake (ADFI) was higher for T_2 and T_3, potentially contributing to the increased cost of these two parameters. The total cost of feed/kg gain was lowest ($p<0.05$) for T_2 as compared to T_1 and T_3. It was 5.6% and 19.5% lower as compared to T_1 and T_3, respectively. The reason for an increased total feed cost/kg wt. gain for T_3 attributed to a higher cost involved in feeding higher amount of *Spirulina* which is expensive as seen from table-3. *Spirulina* supplementation at a rate of 1 g per 10kg body weight proved to be more efficient in producing a kilogram of meat at a lower cost ($p<0.05$), aligning with the findings of Mokhtar *et al*. (2023) [21]. This also aligns with findings of Kulpy's *et al*. (2009) who reported that incorporation of *Spirulina* was found to be economically efficient in increasing animal body weight by 8.5- 11% in cattle and also Abdel-Daim *et al*. (2013) [4] who reported that blue green algae are considered as ideal natural antioxidant and immune stimulant for both human and animals with higher cost effectiveness. This cost efficiency in T_2 may be attributed to increased protein digestibility, enhanced weight gain, and higher average daily gain (ADG).

Conclusion

Finally, it was concluded that in general addition of algae extract powder as feed additive to the ration of sheep will show the positive result on the health and production. From the present trial, it was concluded that supplementation of *Spirulina* at 1 g/10 kg could improve the performance of animal with positive growth rate. However supplementation of *Spirulina* at higher level as discussed in the present study could not be proved economical. Owing to it's high protein content and quality protein *Spirulina* can be added as a feed additive in the rations of sheep with improved efficiency.

References

1. Alghonaim AA, Alqahtani MF, Al-Garadi MA, Suliman GM, Al-Baadani HH, Al-Badwi MA, *et al*. Effects of different levels of spirulina (*Arthrospira platensis*) supplementation on productive performance

nutrient digestibility blood metabolites and meat quality of growing Najdi lambs. Trop Anim Health Prod. 2022;54(2):124.
2. Assar DH, Al-Wakeel RA, Elbialy ZI, El-Maghraby MM, Zaghlool HK, El-Badawy AA, *et al*. Spirulina platensis algae enhances endogenous antioxidant status, modulates hemato-biochemical parameters, and improves semen quality of growing ram lambs. Adv Anim Vet Sci. 2023;11(4):595-605.
3. Abdel-Wahed AM, Khattab IM, Zaher M, Khattab AS, El-Damrawy SZ, El-Keredy A, *et al*. Growth performance, nutrient utilization, rumen fermentation, blood biochemistry and carcass traits of lambs fed Atriplex nummularia L. hay-based diet supplemented with yeast or bacterial direct-fed microbial. Anim Biotechnol. 2023;34(7):2132-2140.
4. Abdel-Daim MM, Abuzead SM, Halawa SM. Protective role of Spirulina platensis against acute deltamethrin-induced toxicity in rats. PLoS One. 2013;8(9):e72991.
5. Alghonaim AA, Alqahtani MF, Al-Garadi MA, Suliman GM, Al-Baadani HH, Al-Badwi MA, *et al*. Effects of different levels of spirulina (*Arthrospira platensis*) supplementation on productive performance nutrient digestibility blood metabolites and meat quality of growing Najdi lambs. Trop Anim Health Prod. 2022;54(2):124.
6. Al-Yahyaey F, Al-Marzooqi W, Shaat I, Smith MA, Al-Sabahi J, Melak S, *et al*. Effect of Spirulina platensis supplementation on carcass characteristics, fatty acid profile and meat quality of Omani goats. Animals (Basel). 2023;13(18):2976.
7. Bezerra LR, Silva AMA, Azevedo SA, Mendes RS, Mangueira JM, Gomes AKA. Performance of Santa Inês lambs submitted to the use of artificial milk enriched with Spirulina platensis. Ciência Animal Brasileira. 2010;11:258-263.
8. Bleakley S, Hayes M. Algal proteins: extraction, application, and challenges concerning production. Foods. 2017;6(5):33.
9. Carroll JA, Forsberg NE. Influence of stress and nutrition on cattle immunity. Vet Clin North Am Food Anim Pract. 2007;23:105-149.
10. EL-Sabagh MR, Abd Eldaim MA, Mahboub DH, Abdel-Daim M. Effects of Spirulina platensis algae on growth performance, antioxidative status and blood metabolites in fattening lambs. J Agric Sci. 2014;6(3):92.
11. Gershwin ME, Belay A. Spirulina in human nutrition and health. Boca Raton, FL: CRC Press; c2008.
12. Holman BWB, Malau-Aduli AEO. Spirulina as a livestock supplement and animal feed. J Anim Physiol Anim Nutr. 2013;97(4):615-623.
13. Hanafy A. Enhancing fattening lamb performance with Spirulina platensis: Insights into growth, blood metabolism and antioxidant status. J Appl Life Sci Int. 2023;26(1):31-38.
14. Hafez YH, Mahrous AA, Hassanien HAM, Khorshed MM, Youssef HFH, Abd El-All AAM. Effect of algae supplementation on growth performance and carcass characteristics of growing male lambs. Egypt J Nutr Feeds. 2013;16(3):419-426.
15. Karlsson L, Martinsson K. Growth performance of lambs fed different protein supplements in barley-based diets. Livest Sci. 2011;138:125-131.
16. Kashani A, Holman BWB, Nichols PD, Malau-Aduli AEO. Effect of level of Spirulina supplementation on the fatty acid compositions of adipose, muscle, heart, kidney and liver tissues in Australian dual-purpose lambs. Ann Anim Sci. 2015;15:945-960.
17. Kulpys J, Paulauskas E, Pilipavicius V, Stankevicius R. Influence of cyanobacteria Spirulina platensis biomass additive towards the body condition of lactation cows and biochemical milk indexes. Agron Res. 2009;7(2):823-835.
18. Lebas F, Colin M. World rabbit production and research. In: Proceedings of the 5th World Rabbit Congress, Corvallis; c1992. p. 29-54.
19. Lykkesfeldt J, Svendsen O. Oxidants and antioxidants in disease and oxidative stress in farm animals. Vet J. 2007;173:502-511.
20. Lamminen M, Halmemies-Beauchet-Filleau A, Kokkonen T, Vanhatalo A, Jaakkola S. The effect of partial substitution of rapeseed meal and faba beans by Spirulina platensis microalgae on milk production, nitrogen utilization and amino acid metabolism of lactating dairy cows. J Dairy Sci. 2019;102(8):7102-7117.
21. Mokhtar MH, Suliman AIA, Abdou SG. Effect of macro and microalgae supplementation on productive performance, some blood constitutes and economic efficiency of growing Farafra male lambs. Arch Agric Sci J. 2023:73-83.
22. Mansour MM, Zeitoun MM. Influence of Spirulina supplementation on growth performance, puberty traits, blood metabolites, testosterone concentrations and semen quality in Barki male lambs. Open Vet J. 2023;13(6):772-781.
23. Panjaitan T, Quigley SP, McLennan SR, Poppi DP. Effect of the concentration of Spirulina (Spirulina platensis) algae in the drinking water on water intake by cattle and the proportion of algae bypassing the rumen. Anim Prod Sci. 2010;50(6):405-409.
24. Poppi DP, McLennan SR. Nutritional research to meet future challenges. Anim Prod Sci. 2010;50:329-338.
25. Quigley SP, Poppi DP. Strategies to increase growth of weaned Bali calves. Canberra: Australian Centre for International Agricultural Research; c2009.
26. Riss J, Ecordé KD, Sutra T. Phycobiliprotein C-phycocyanin from Spirulina platensis is powerfully responsible for reducing oxidative stress and NADPH oxidase expression induced by an atherogenic diet in hamsters. J Agric Food Chem. 2007;55:7962-7967.
27. Tovar-Ramírez DJ, Zambonino C, Cahu FJ, Gatesoupe R, Vázquez-Juárez R, Lésel R. Effect of live yeast incorporation in compound diet on digestive enzyme activity in sea bass (*Dicentrarchus labrax*) larvae. Aquaculture. 2002;204:113-123.
28. Gerrard JH. A disturbance-sensitive Reynolds number range of the flow past a circular cylinder. Journal of Fluid Mechanics. 1965 May;22(1):187-196.