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RUMINANT NUTRITION

Effect of adding *Spirulina platensis* algae to small ruminant rations on productive, reproductive traits and some blood components

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ABSTRACT. This experiment conducted using 20 Rahmani ewes at the last third of pregnancy in two equal groups. One group served as control, while the other group received *Spirulina platensis* (SP) at the rate of 0.5 gm 10 kg^{-1} live body weight. The objective was to find out the effect of adding *Spirulina platensis* algae to small ruminant rations on reproductive and productive traits and blood components of sheep. The experiments lasted for 120 days for both dams and their lambs after weaning. The findings proved that adding SP in ewes' diets had no effect on the average of live body weight change. Average milk yield was significantly (p <0.01) higher in the treatment group than the control. Lamb's birth weight and daily body gain of the treated group were significantly (p <0.01) higher than the control. Blood and serum picture profile of ewes were significantly higher when fed SP additive than the control. It could be concluded that the addition of SP to the ration of sheep positively preserved their health, productive and reproductive status as well as their lambs' growth rate. Also the additive improved the economic efficiency of treated animals by about 53.13%.

Keywords: blood, milk, productive traits, sheep, *Spirulina*.

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Introduction

Due to the attitude of several countries to diminish the addition of antibiotics in animal feeds, scientists started to use other health improving feed additives (Abou-Zeid, El-Damarawy, Mariey, & El-Mansy, 2015). Microalgae as feed additives proved to have a different positive influence on animal health (Holman & Malau-Aduli, 2013). Pulz and Gross (2004) found that there is a growing market for micro-algal biomass in animal nutrition in both aquaculture and animal husbandry. The amount of protein produced from algae found to be more valued in productivity and nutrition compared to that produced from traditional high-protein crops, and preserve the amount of fresh water used in traditional crops' cultivation as reviewed by Bleakley and Hayes (2017).

Sajilata, Singhal and Kamat (2008) reported that *Spirulina* is a rich source in proteins along with hypocholesterolemic γ-linoleic acid (GLA), B-vitamins and free-radical scavenging phycobiliproteins. Moreover, Capelli and Cysewski (2010) reported that *Spirulina* has 180, 670, 3100 and 5100% more calcium, protein, carotene and iron than those recorded for milk, tofu, carrots and spinach, respectively. In this concern, Carroll and Forsberg (2007) reported that, under oxidative stress conditions, demand for antioxidants is increased to reduce the adverse effects of free radicals on the immune system. Feeding, natural rather than synthetic, antioxidants could be beneficial to both animal welfare and consumer safety (Makkar, Francis, & Becker, 2007; Call, Davis, & Sawant, 2008). The works of Belay (2002), Khan, Bhadouria and Bisen (2005) and Abdel-Daim, Abuzead, and Halawa (2013) have shown that blue-green algae (*Spirulina platensis*; SP) are considered ideal natural antioxidant and immune stimulant for both humans and animals with higher cost effectiveness and less side effects compared to synthetic products.

On dry matter bases, algae contain comparable or even higher levels of crude protein, carbohydrates and fats adding a high content of polyunsaturated fatty acids as well as high levels of essential vitamins than conventional feed resources (e.g. soybeans). *Spirulina sp.* Has a digestibility coefficient value of 77.6 Vs. 95.1% and 94.2% recorded for casein and egg, respectively (Becker, 2007).

Earlier, Yamaguchi (1996) stated that high protein content of algae may be used as animal feed in aquaculture, farm animals and pets. Approximately 50% of *Spirulina* biomass, in fact, is used as a feed supplement due to its outstanding nutritional profile (Becker, 2004). An estimated 30% of global algal output found to be used for animal feeds (Gouveia, Batista, Sousa, Raymundo, & Bandarra, 2008). Several studies as reviewed and discussed by (Holman & Malau-Aduli, 2013) on poultry, sows and piglets, ewes and lambs and dairy cows showed that algae contain several types of antioxidants (chlorophyll and carotenoids pigments), which have anti-inflammatory effect and might prevent degenerative diseases. This immunity improvement, in case of infections, maintain the levels of daily gain, feed conversion ratio, reproduction capacity, healthy skin and a shiny coat.

Panjaitan, Quigley, McLennan and Poppi (2010) reported that cattle preferentially drink water contains 20% suspended *Spirulina* and enhanced their daily consumption of water by 24.8 g kg-1. They also stated that 20% of the *Spirulina* consumed bypasses degradation in the rumen, allowing for improved digestion and absorption of proteins and nutrients. Moreover, Kulpys, Paulauskas, Pilipavicius and Stankevicius (2009) reported that incorporation of 200 g day-1 *Spirulina* within cattle feed found to be economically effective in increasing animal body weight by 8.5-11% and daily milk production by 21%. *Spirulina* supplementation has also been demonstrated to increase milk quality by decreasing its content from saturated fatty acids, while increasing monounsaturated fatty acids and polyunsaturated fatty acids (Christaki, Karatzia, Bonos, Florou-Paneri, & Karatzias, 2012).

Heidarpour, Fourouzandeh-Shahraki and Eghbalsaied (2011) showed a significant reduction in plasma cholesterol, low density lipoprotein (LDL) and high density lipoprotein (HDL) concentration were recorded for 25 g *Spirulina* compared to other groups ($p < 0.05$). However, other blood parameters like blood-urea nitrogen, albumin and globulin were not affected by *Spirulina* ($p > 0.05$). Holman and Malau-Aduli (2013) stated that ruminants are the most promising in the digesting of high fiber with the highest extraction efficiency of algal proteins among all animals received algae supplementation.

Accordingly, the current work designed the effect of adding *Spirulina platensis* algae to small ruminant rations on reproductive and productive traits and some blood components as health indicators of Rahmani sheep.

Materials and methods

Experimental animals and management

Twenty healthy pregnant ewes with started live body weight of about 57.5 ± 1.4 kg on average were selected from the flock of El-Serw Experimental Research Station, located in the Northeastern part of the Nile Delta, Damietta governorate; belongs to Animal Production Research Institute, Agriculture Research Center, Ministry of Agriculture, Egypt. The selected ewes were at the last third of pregnancy period and divided to two equal groups (10 ewes each). The first group was the control one which fed concentrate feed mixture (CFM) with berseem hay (BH) at the ratios of 50:50 during late pregnancy period and 49:51 at the suckling period. The second group fed the same rations plus *S. platensis* (SP) algae extract powder at the ratio of 50:50 during the two experimental periods. The algal extract powder added to the second group rations at the rate of 0.5 gm 10 kg^{-1} live body weight daily during the 120 days of the experimental period using rice paper sacks. For ewes' experiment, each group was housed in a semi-roofed yard (4 x 3 x 5 meters). The animals were weighed at the beginning of the experiment and then biweekly. Ewes experimental period started about 60 days before lambing and lasted for 60 days post-lambing (weaning time of lambs).

The nutrients requirement was calculated according to NRC (National Research Council [NRC], 2007). Animals were fed the assigned ingredients of CFM which consists of 25% un-decorticated cotton seed meal, 43% yellow corn, 25% wheat bran, 3.5% molasses, 2.0% limestone, 1.0% common salt and 0.5% vitamin and minerals mixture (Contains per 3 kg: 1000000 IU Vit. A; 200000 IU Vit. D3; 10000 mg Vit. E; 1000 mg Vit B1; 5000 mg Vit. B2; 1500 mg Vit. B6; 10 mg Vit. B12; 50 mg Biotin; 250000 mg Colin chloride; 10000 mg Pentothenic; 30000 mg Niacin; 1000 mg Folic acid; 60000 mg Manganese; 50000 mg Zink; 3000 mg Iron; 4000 mg Copper; 300 mg Iodine; 100 mg Selenium and 100 mg Cobalt). Drinking water was available at all over the day times. Diets were offered twice daily at 8.00 am and 3.00 pm.

During the late pregnancy and suckling periods, average daily dry matter intake was recorded and calculated relative to live body weight as well as to metabolizable body weight ($W^{0.75}$). Live weight of the experimental ewes was recorded at 120, 135 and 150 days of pregnancy as well as their weight at lambing. The live body weight of ewes was measured every 15 days post-lambing tell 60 days post-lambing (weaning date) to study the changes in ewes' live body weight. After lambs weaning, at 60 days post-lambing, ewes were hand milked twice daily and daily total milk production were recorded along 8 weeks.

Chemical analysis of the experimental feed ingredients

Proximate chemical analysis of the feeds was carried out according to AOAC (Association of Official Analytical Chemists [AOAC], 2007). Crude fiber analysis of SP carried out according to the proposed method of Henneberg and Stohmann (1860-1864) using weak acid and alkali digestions which known commonly with Weende's method described as well as ash determination in the Analytical Techniques in Aquaculture Research (Analysis of Feed & Feed Ingredients, Proximate Analysis). For water soluble vitamins determination, ten grams of SP powder were homogenized with methanol for extraction, while acetone-chloroform (30:70 v v^{-1}) was used for extraction of fat soluble vitamins. The mixtures after shaken on a vortex mixer for 5 min was centrifuged at 4000 rpm for 5 min. and filtered. The filtrates were evaporated under nitrogen and the residues were re-dissolved in 1ml water for water soluble vitamins and in 1 ml butanol for fat soluble vitamins tell quantified by HPLC (Manz & Vuilleumier, 1988). The β-carotene level was determined by spectrophotometric method according to AOAC (Association of Official Analysis Chemists [AOAC], 2000) method number 2005.07.

Mineral content of SP was determined according to AOAC (2000) at 550-600oC for ashing process and prepared samples was diluted with 1:1 (10% HCL: Water) for measuring in Atomic Absorption Spectroscopy Shimadzu Model (AA-6650).

Total Digestible Nutrients (TDN) was calculated using the equation (129.39- 0.9419 (CF+NFE); Digestible energy (DE, Mcal kg^{-1} DM) using the equation (% TDN x 0.04409) and Metabolizable energy (ME, Mcal kg^{-1} DM) was calculated according to the equation (- 0.45 + 1.01 DE) according to National Research Council [NRC] (1978). The chemical composition of the experimental ingredients presented in Table 1.

Table 1. Chemical composition of feedstuffs, calculated composition and feeding values of the experimental rations.

	Chemical composition (on DM basis, %)							TDN (%)	DE (Mcal kg^{-1} DM)	ME (Mcal kg^{-1} DM)
Ingredients	DM	OM	CP	EE	CF	NFE	Ash			
CFM	91.29	91.41	14.47	3.29	14.41	58.70	8.52	60.52	2.67	2.25
BH	89.13	86.71	12.19	1.74	35.51	38.69	14.81	59.50	2.62	2.20
Spirulina OM constituents			65.00	18.00	5.00	9.00	7.50	--	--	3.15
Vitamins, minerals and pigments (in 10 gm of *Spirulina*)										
β-carotene	B_1 (mg)	B_2 (mg)	B_3 (mg)	B_5 (μg)	B_6 (μg)		B_9 (μg)		B_{12} (μg)	
32000	0.31	0.35	1.46	10.00	80.00		1.00		32.00	
Vit. A (μg)	Choline (mg)	Vit. C (mg)	Vit. E (mg)	Vit. K (μg)	Ca (mg)		P (mg)		K (mg)	
29.0	66.0	10.1	5.0	25.5	100.0		90.0		120.0	
Fe (mg)	Mn (mg)	Zn (mg)	Se (mg)	Cu (mg)	Na (mg)		Phycothian (mg)		Chlorophyll (mg)	
15.0	0.16	0.3	0.003	120.0	60.0		1500		115	

DM= dry matter; OM= organic matter; CP=crude protein; EE=ether extract; NFE=nitrogen free extract; TDN=total digestible nutrients; DE=digestible energy; CFM=concentrate feed mixture and BH=Egyptian clover hay.

Reproductive and productive traits measurements of Rahmani ewes

Some productive traits of ewes were measured in terms of:

- Litter size (fetus weight/ewe);
- No. of still birth lambs;
- No. of alive lamb at 0 day;
- No. alive lambs at weaning;
- Kilogram lambs born/ewe.;
- Kilogram weaned/ewe;
- Mortality %;
- Average daily milk yield at 2, 4, 6 and 8 weeks of lactation.

Blood profile measurements of Rahmani ewes

In order to estimate the health status indicators of the experimental animals, some blood hematological and biochemical parameters were studied. For this purpose, blood samples were collected from the jugular vein of 3 ewes in each group once before feeding, at the end of experimental period. Part of the whole blood was immediately used for hematological estimation. The other part of blood samples was centrifuged at 4000 rpm (round per minute) for 20 min., and separated serum stored frozen at -20°C till the biochemical analysis. Hematological analyses including hemoglobin (Hb, g dL^{-1}), hematocrit (Hct, %), red blood cells (RBCs, × 106 μL^{-1}) and mean cell hemoglobin concentration (MCHC, %) were conducted on the heparinized samples. The serum samples used for the determination of glucose (mg dL^{-1}), total protein (g dL^{-1}), albumin (g dL^{-1}), globulin (g dL^{-1}), urea nitrogen (Urea-N, mg dL^{-1}), AST (u L^{-1}), ALT (u L^{-1}), cholesterol (mg dL^{-1}) and total lipids (mg dL^{-1}). Appropriate commercial kits (Diamond Diagnostics, Egypt) were used for colorimetric biochemical determinations according to the procedure outlined by the manufacturer.

Rahmani lambs growing trial

For growing lambs experiment, 5 male weaned lambs were selected from each group and fed the same two tested rations of ewes. Feeding requirements were calculated according NRC (2007), since the two groups received 90% CFM + 10% BH. The algal powder was added to the diets of the second group only at the same rate used with ewes. Each group was housed in a semi-roofed yard (3 x 3 x 5 meters).

Economic efficiency

To judge the application of algal extract in as feed additive in rations of ewes and their lambs the economic efficiency was calculated by using the following Equation 1:

$$\text{Economic efficiency (estimated for 4 months)} = \frac{\text{kg lambs x kg price (LE)}}{\text{Feed cost during 120 days}} \times 100 \quad (1)$$

With the following assumptions:

Price of sale kg of live weight is 50 (LE).

Price in year 2018 for CFM, BH and SP were 5600, 3700 (LE ton^{-1}) and 3.00 LE g^{-1}, respectively.

Statistical analysis

A mixed model (SAS Institute, 2003) with a repeated measurements design was used to analyze ewes and lamb growth data of the whole experimental period. The model considered the variation between animals in litter size and gender. Litter size values used as a co-variate in the mixed model used for milk production data analysis. Duncan multiple range test used to determine the significance of the results were considered at $p < 0.05$ (Duncan, 1955).

Results and discussion

Feed intake of Rahmani ewes

The results of feeding Rahmani ewes algal extract additive in their rations clearly indicated that average daily dry matter intake (g h^{-1}) was higher during the two experimental periods (Late pregnancy and suckling period) (Table 2). Regarding average of total dry matter intake, its percentage from body weight and as a % of metabolic weight during the two experimental stages (being 75.57 Vs. 75.77 and 104.50 Vs. 106.50, respectively), the data revealed that adding *Spirulina* to rations of the experimental animals gave almost similar values to those recorded in the control group.

Due to rumen restriction at late pregnancy period, the ewe increases food passage rate and protein absorption by 15%. High energy content of the diet is critical since lower ME supply decreased feed efficiency. The minimum metabolizable energy in a compound recommended to be 12 MJ kg^{-1} DM by using good quality ingredients without dependence on low energy by-products (Jameson, 2020).

Similar results were recorded by Heidarpour et al. (2011) who showed that the *Spirulina* treatment was not significantly ($p > 0.05$) affected daily feed intake and feed efficiency of Holstein's calves. On contrary, Peiretti and Meineri (2008) found that *Spirulina* supplementation at 10% increased the feed intake of rabbits as well as improve the quality of rabbit meat.

Table 2. Average feed intake (gm dry matter, DM head^{-1} day^{-1}) of Rahmani ewes during late pregnancy and suckling periods.

Item	Experimental Groups	
	Control	SP
The 1st experimental period before lambing (90 days of pregnancy):		
Average daily DM intake (gm) from		
CFM	801	800
BH	792	808
Average total DM intake (gm head^{-1} day^{-1})	1593	1617
Average DM intake as % of body weight	2.73	2.73
Average DM intake as % of metabolic weight (g kg$^{-0.75}$)	75.57	75.77
Roughage : Concentrate ratio	50 : 50	50 : 50
The 2nd experimental period after lambing (Suckling period)		
Average daily DM intake (gm) from:CFM	990	1001
BH	960	992
Average total DM intake (gm head^{-1} day^{-1})	1950	1993
Average DM intake as % of body weight	3.94	4.01
Average DM intake as % of metabolic weight (g kg$^{-0.75}$)	104.50	106.50
Roughage : Concentrate ratio	49 : 51	50 : 50

Body weight of Rahmani ewes

Data in Table 3 indicated that average initial weight (at 90 days of pregnancy) was 57.4 and 57.5 kg for both experimental groups (the control and *Spirulina*), respectively. Ewes weight gradually increased without significant differences in both groups at 120, 135 and 150 days of pregnancy compared to their initial weight. At lambing, the control group recorded 52.4 Vs. 60.0 kg at 150 days of pregnancy, while the treatment group recorded 52.6 Vs. 62.4 kg for the same period.

Table 3. Average live body weight (LBW; kg) of Rahmani ewes during the two experimental periods (Late pregnancy and suckling).

Item	Experimental Groups		SEM	Probability of significance
	Control	SP		
No. of ewes	10	10	-	-
The 1st experimental period before lambing (90 days of pregnancy)				
Initial weight	57.4	57.5	1.53	NS
LBW at 120 days of pregnancy	57.8	58.9	1.68	NS
LBW at 135 days of pregnancy	59.1	60.2	1.66	NS
LBW at 150 days of pregnancy	60.0	62.4	1.72	NS
The 2nd experimental period after lambing (Suckling period)				
LBW at lambing	52.4	52.6	1.45	NS
LBW at 15 days post-lambing	50.4	50.7	1.33	NS
LBW at 30 days post-lambing	48.3	49.6	1.24	NS
LBW at 45 days post-lambing	47.4	48.7	1.26	NS
LBW at 60 days post-lambing (Weaning)	46.5	48.2	1.25	NS

NS: Not significant. SEM: Standard Error of mean.

Post lambing, the treatment group ewes were superior in live body weigh since they recorded the highest values at 15, 30 and 45 days as well as at 60 days post-lambing (at weaning). The records of the two experimental groups showed that adding *Spirulina* to the diets of Rahmani ewes seemed to have no effect ($p = 0.28$) on the average live body weight change (being 9.3 ± 0.76 Vs. 10.9 ± 1.39 kg) for the whole experimental period (Figure 1). Although there was no significant increase in average dry matter intake in both groups, the addition of SP to the treated animals kept their weight loss less than that of the control ones. This may be due to the high values of SP from CP and ME (Table 2), which may be reflected on the nutritional value of the diets. Such preserve effect of daily supply from minerals and vitamins via adding SP to ewe's diets is supported by Jameson (2020) suggestion that such supplying sources ensuring the maintenance of body functions with limited available body reserves during late pregnancy.

This result confirms with the findings of Holman, Kashani and Malau-Aduli (2012) who reported an increase in the weight of sheep with dietary *Spirulina* along with an increase in body condition and other body conformation traits. Notably, an enhancement in the rate of growth of the fed SP ration was correlated with an increase in the digestibility coefficients of most nutrients and nutritional values of this ration as compared to other none-received SP rations. This corresponds to the opinion of Panjaitan, Quigley, McLennan, Swain and Poppi (2014) who stated that *Spirulina* intake with 5.7 g could be provided greater increases microbial crude protein (MCP) production, feed intake, could also be fed safely at higher levels of nitrogen (N) intake, increasing rumen degradable protein (RDP) and growth rate in cattle.

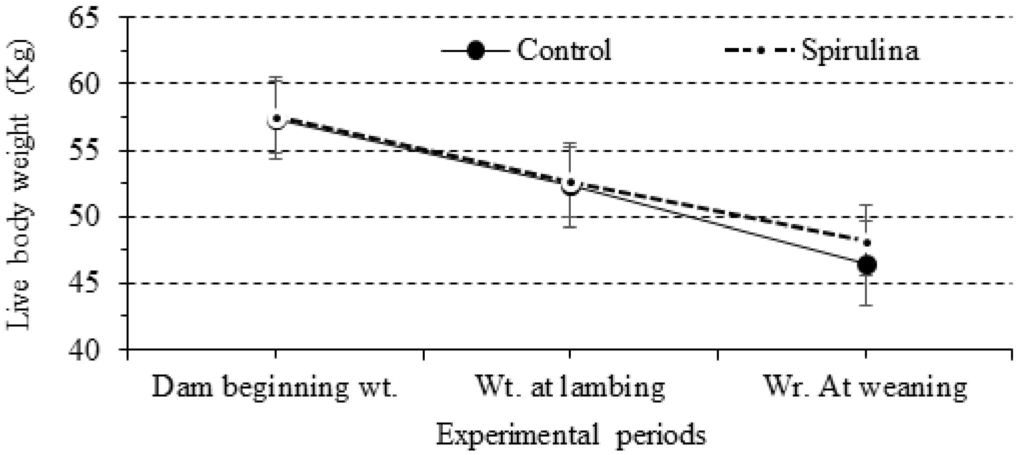

Figure 1. Live body weight changes of Rahmani ewes during the two experimental periods (Late pregnancy and suckling).

In support of the present experiment results, the findings from Khalifa, Hassanien, Mohamed, Hussein, and Azza (2016) study established that kids nursed by the SP group showed higher average body weight and daily gain without significant difference than those auspices in the control group.

Productive and reproductive performance of Rahmani ewes

A perusal of data in Table 4 indicated that both groups maintained its born lambs (10 for the control and 13 for the treated group) alive at 0 days and at 60 days (weaning) and there were no stillbirth lambs.

Regarding the average birth weight of lambs, the treated group recorded significantly (p <0.01) heavier weights than the control one with an average of 3.13 vs. 2.65 kg, respectively. Jameson (2020) stated that meeting the rapid increase in energy and protein requirements of ewes during the last eight weeks of pregnancy via good nutritional management, assure that mortality is increased in lambs with a low weight at birth and/or those born to poor body condition's ewe. Khalifa et al. (2016) recorded positive correlation coefficients between feeding and does body weight, kids' body weight, udder size, suckling milk flow and energy of suckling milk. They also observed that the noticed improvement in milk yield of does fed SP ration was associated with increasing growth rate of dams and their kids (Vishnu & Sumathi, 2014, Akporhuarho, 2015; Hafez et al., 2015).

Table 4. Average litter weight (LW; kg) of Rahmani ewes during the suckling period.

Item	Experimental Groups		SEM	Probability of significance
	Control	SP		
No. of ewes	10	10	-	-
No. of stillbirth lambs	0	0	-	-
No. of alive lambs at 0 day	10	13	-	-
No. of alive lambs at 60 days (at weaning)	10	13	-	-
Average birth weight, kg	2.66^{b}	3.14^{a}	0.14	0.0210
AVERAGE LW AT 15 DAYS OF AGE, kg	4.79^{b}	6.19^{a}	0.29	0.0055
Average LW at 30 days of age, kg	6.80^{b}	8.83^{a}	0.33	0.0006
Average LW at 45 days of age, kg	9.00^{b}	11.50^{a}	0.39	0.0003
Average LW at 60 days of age, kg (weaning)	11.39^{b}	13.85^{a}	0.37	0.0001
Average daily body gain, gm	146.2^{b}	178.6^{a}	4.18	0.0000
Average Kilogram lambs born / ewe	2.65^{b}	4.08^{a}	0.29	0.0031
Average Kilogram weaned / ewe	11.40^{b}	18.20^{a}	1.32	0.0019
Mortality, %	0	0	-	-
Relative Economic efficiency, %	1.28	1.96	-	-

a, b: Means within the same raw with different superscripts are significantly different. SEM: Standard Error of mean.

The beneficial effects of additive SP related to the highest protein (El-Sabagh, Abd Eldaim, Mahboub, & Abdel-Daim, 2014), vitamin as β-carotene (Meza-Herrera et al., 2014), minerals mixture (Ahmad Fazel et al., 2014) and energy (Kumar, De, Saxena, & Naqvi, 2015). Khalifa et al. (2016) found that Zaraibi kids at birth in *Spirulina* group nanny goats showed significant ($p < 0.05$) higher average body weight than kids patronage by the control group as a result of improvement in milk production (quality and quantity). The last authors added that feeding of SP to pregnant does provide adequate energy, protein, minerals, vitamins to support embryonic, fetal growth, maintenance of metabolic processes, mammary gland growth, colostrum and milk yield. In this concern, Mahboub, Ramadan, Helal and Enas Aziz (2013) noticed that the best nutrition during fetal life affects postnatal growth, reproductive performance and metabolism. Moreover, Jameson (2020) reported that providing sufficient energy in the diet is one of the insurance factors of having good milk production after lambs born.

Data in the same Table 4 showed also that ewes of the treated group reared their lambs and gave them more weight during the suckling period, since their lambs weight from birth till weaning was significantly ($p < 0.01$) higher than those in the control group. The average daily weigh gain increased significantly ($p < 0.01$) from 146.2 gm day^{-1} in the control group to 178.6 gm day^{-1} in the treated group.

Moreover, ewes in the treated group significantly ($p < 0.01$) exceeded those in the control group in kilogram lambs born / ewe by about 53.96% and in kilograms weaned / ewe by about 59.65%. Thus, from an economic point of view, it is clear that adding *Spirulina* to the diets of ewes positively enhanced the economic efficiency for the treated group from 1.28 (Control) to 1.96%. From an economic point of view, Khalifa et al. (2016) found that the cost of kg milk was the lowest (1.45 L.E) for the doe in the SP group and the highest (1.84 L.E) for the control does. Interestingly, such trend was reflected in the highest economic efficiency (%) of milk production 55.96 and 44.15 in the SP group followed by those in the control group, respectively. Furthermore, SP group recorded higher economic efficiency relative (127.27 %) than that of the control. Abd Eldaim, Ramadan, Elsabagh, and Mahboub (2018) concluded that supplementation of pregnant ewes with SP and vitamin A improved their health at lambing and enhanced their lambs' survivability and performance.

Regarding the average daily milk yield of ewes, Figure 2 showed that there were significant ($p < 0.01$) differences between the two tested groups. The addition of *Spirulina* to the second group increased average daily milk yield from 215 to 326, 218 to 333, 214 to 316 and 212 to 334 gm/head/day compared to the control group.

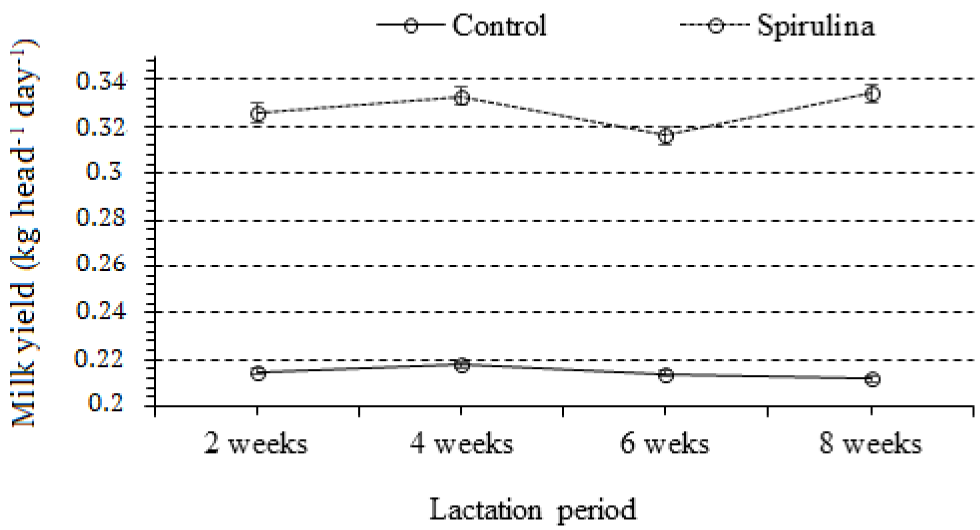

Figure 2. Average daily milk yield of Rani ewes during the lactation period.

Yaakob, Ali, Zainal, Mohamad and Takriff (2014) reported that *Spirulina* has been commonly used in food supplements due to its exceptional nutrient compositions and digestibility, also showed that the *Spirulina* has shown considerable effectiveness and increased milk production. Khalifa et al. (2016) found that the overall means of milk production throughout seven weeks of lactation was statistically significant ($p < 0.05$) higher in the group fed *Spirulina* during the first three weeks of lactation. While, advancing of lactation curve another four weeks Zaraibi does in the *Spirulina* group was appeared non-significantly booster in milk harvest than does in the control group.

Some blood components of Rahmani ewes

Table 5 explored the results of blood and serum tests as some health indicators. From the obtained figures, it is clear that hemoglobin, hematocrit %, RBCs count as well as MCHC% were significantly ($p < 0.01$) higher in the treated group than those of the control. Moreover, serum tests recorded also significantly ($p < 0.01$) higher values of glucose, total protein, globulin, Urea-N, cholesterol and total lipids in the treated group than those in the control ones. While, albumin as well as liver enzymes (AST and ALT) were not significantly differed between the two experimental groups. The positive results in some blood hematological parameters obtained herein can be attributed to the rich content of SP from crude protein, vitamin B_{12}, Fe as well as other essential macro- and micro-elements.

Blood urea levels recorded in this study were within the reference of urea values (12-28 mg dL^{-1}) for normal goats reported by Kalio, Okafor and Ingweye (2014). On the other hand, Liping, Li-an, Yiquan and Guorong (2011) found that the urea concentration was 8.68, 6.25, 6.01, 5.84 mmol L^{-1} when rat received SP at levels at 0, 50, 100 and 200 mg kg^{-1}, respectively. The parameters of AST and ALT were consistent with the references reported that normal range of liver enzymes. The AST level was varied from 167 to 513 U L^{-1} while, ALT between 9 and 19 U L^{-1} (Rumosa-Gwaze, Chimonyo, & Dzama, 2012). In this study, the SP group showed a significant decrease in AST and ALT compared with the control ones. This result is symmetrical with Azab, Abdel-Daim and Eldahshan (2013) who indicated that SP may play a protective role against liver dysfunctions. Moreover, Holman and Malau-Aduli (2013) reported that the enhanced serum levels of triglycerides, cholesterol and glucose after lambing with feeding SP might be due to its rich contents of various nutrients with several health benefits.

Table 5. Blood profile of Rahmani ewes after 120 days of the algal extract addition to their diets.

Item	Experimental Groups		SEM	Probability of significance
	Control	SP		
Hemoglobin (gm dL^{-1})	11.50^{b}	13.75^{a}	0.19	0.0001
Hematocrit (%)	32.27^{b}	35.00^{a}	0.18	0.0237
Red blood cells × 10^{6} μL^{-1} (RBCs)	12.7^{b}	14.9^{a}	0.08	0.0221
Mean Cell Hemoglobin Concentration (MCHC, %)	35.7^{b}	39.3^{a}	0.10	0.0014
Glucose (mg dL^{-1})	63.60^{b}	72.37^{a}	0.37	0.0001
Total protein (gm dL^{-1})	6.67^{b}	7.83^{a}	0.06	0.0002
Albumin (gm dL^{-1})	2.98	3.19	0/04	0.0224
Globulin (g dL^{-1})	3.69^{b}	4.64^{a}	0.02	0.0000
Urea-N (mg dL^{-1})	15.68^{b}	17.49^{a}	0.21	0.0034
AST (u L^{-1})	47.69	47.26	0.23	0.2655
ALT(u L^{-1})	17.05	16.53	0.15	0.0699
Cholesterol (mg dL^{-1})	103.83^{b}	106.20^{a}	0.37	0.0105
Total lipids (mg dL^{-1})	308.13^{b}	313.30^{a}	0.30	0.0003

a, b: Means within the same raw with different superscripts are significantly different. SEM: Standard Error of mean.

El-Sabagh et al. (2014) reported that there were significant differences ($p < 0.05$) in the serum globulin, AST, ALT, cholesterol, triglycerides, blood urea nitrogen and glucose between the treatment groups, while there was no significant difference in the concentrations of total protein, albumen and A/G ratio. The SP group recorded significant elevation ($p < 0.05$) in plasma globulin, while their AST, ALT, cholesterol and blood glucose levels slightly decreased ($p < 0.05$) than that of the control group. Furthermore, lambs fed SP supplemented diets recorded a significant increase in blood urea nitrogen with increased levels of triglycerides. Abd Eldaim et al. (2018) post lambing, found a significant ($p < 0.05$) decrease in the ewes' serum alanine aminotransferase (ALT) activity and increased the serum creatinine level of the control group. While, supplementation with SP and vitamin A normalized these parameters. This supplementation also improved serum levels of glucose, triacylglycerol and total cholesterol.

These results are in agreement with previous report by Riss et al. (2007) who stated that treatment with *Spirulina* could reduce oxidative stress with a consequent decrease in lipid peroxidation. Sine, this *Spirulina's* antioxidative effect is related to several active ingredients, e.g. phycocyanin, polysaccharides, α-tocopherol and ß-carotene that have potent antioxidant activities working, individually or in synergy, directly on free radicals (Riss et al., 2007). Gershwin and Belay (2008) reported that the antioxidant activity of phycocyanin had been estimated to be nearly 20 times more efficient than vitamin C. In addition, *Spirulina* according to Belay (2002) contains superoxide dismutase, which works indirectly by slowing down the rate of reactions produced by oxygen radicals.

Rahmani lambs growing trial

Figure 3 illustrated that lambs fed algal extract additive in their diets improved significantly (p <0.01) their average live body weight. The lambs started with a similar average live body weight of 13.6 ± 0.7 kg for both experimental groups. The significant difference between the two tested groups started to appear at 90 days of age and continued in increasing tell the end of the trial (at 180 days of age). It seems that the *Spirulina* addition to the second group enriched the energy content that used efficiently in the growing of the treated group compared to those in the control group. The results of better growth performance in lambs fed SP supplemented diets obtained herein can be explained by the subsequence of high nutrient density of SP which may stimulate the secretion of gut microflora for extracellular enzymes as suggested by Tovar-Ramírez et al. (2002). Due to the rich structure of *Spirulina* from several nutrients, especially vitamins, minerals, essential fatty acids, amino acids and other nutrients it was suggested to may induce faster growth (Gershwin & Belay, 2008).

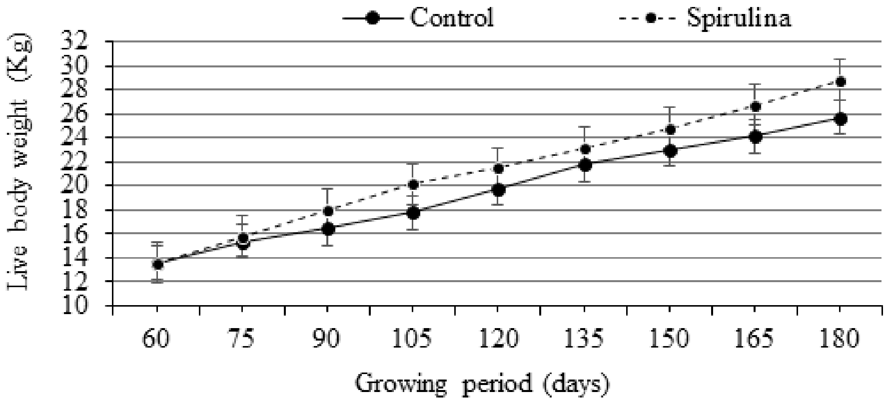

Figure 3. Live body weight of growing Rahmani lambs after weaning till 180 days of age with and without SP supplementation in their diets.

Furthermore, *Spirulina* in steers showed to decrease rumen protein degradation and produced changes in rumen bacterial diversity with increasing the efficiency of rumen microbial crude protein synthesis (Panjaitan et al., 2010). Moreover, *Spirulina* exhibited not only to increase the production of microbial crude protein, but also to decrease its retention time within the rumen (Quigley & Poppi, 2009). Quigley and Poppi (2009), Panjaitan et al. (2010) and Zhang et al. (2010) added that approximately 20% of dietary *Spirulina* bypasses rumen degradation and became available for direct absorption within the abomasum. El-Sabagh et al. (2014) concluded that SP increased body weight gain, plasma globulin, vitamin A and reduced glutathione concentration, while decreased liver enzymes activities, cholesterol, glucose and plasma malondialdehyde concentration. The potential application of *Spirulina* in fattening lambs diet as antioxidants to protect against free radicals' cellular damage from stress, to enhance growth, and as an immune-modulator is worth exploring.

Conclusion

It could be concluded that the addition of algae extract powder (SP) as a feed additive to the ration of sheep is of positive return on the health and productive status since it improved ewe/lamb performance. Also the additive improved the economic efficiency of the experimental animals of the present study by about 53.13%.

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