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Effect of dietary seaweed (*Ulva lactuca*) supplementation on growth performance of sheep and on in vitro gas production kinetics

Ahmed EL-WAZIRY*, Ahmed AL-HAIDARY, Aly OKAB, Emad SAMARA, Khalid ABDOUN
Department of Animal Production, College of Food and Agriculture Sciences, King Saud University, Riyadh, Saudi Arabia

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Abstract: This study was carried out to determine the effect of dietary seaweed (*Ulva lactuca*) supplementation on growth performance of sheep, in vitro gas production, estimated energy, and microbial protein synthesis. A total of 18 Naimey male sheep with average live weight of 22.78 ± 0.24 kg were randomly allocated to 3 groups. Sheep in group 1 were fed a diet containing commercial feed without seaweed as a control diet, sheep in group 2 were fed the control diet with 3% seaweed, and sheep in group 3 were fed the control diet with 5% seaweed. The supplementation of seaweed had no effect ($P > 0.05$) on the average daily gain, feed intake, and feed conversion efficiency. The extent of gas production at 72 h was similar among the 3 groups ($P > 0.05$). There were no significant differences ($P > 0.05$) in the potential degradability, gas production rate, metabolizable energy, net energy, organic matter digestibility, and microbial protein synthesis among the experimental diets. This study concluded that dietary supplementation of seaweed (*Ulva lactuca*) has no effect on growth of sheep, in vitro gas production, potential degradability, estimated energy, organic matter digestibility, and microbial protein synthesis.

Key words: Seaweed, *Ulva lactuca*, growth, gas production, energy, microbial protein synthesis

1. Introduction

Seaweeds are accumulating in all world coast zones and are considered as an environmental hazard. Their collection and use as a nonconventional source for animal feeding may contribute in solving the environmental problem (1,2). Use of seaweed as a feed supplement for animals has been known by farmers for centuries, and thus the recent attempts to use it as a source of forage for livestock are not new (3–5). Seaweeds have higher protein, minerals, and vitamin levels and lower fat contents compared to some vegetables (6–8), and they are known as a useful feed supplement for sheep (3). Green seaweed (*Ulva lactuca*) has been described as a medium-quality forage for goats through in sacco and in vitro trials (5). Moreover, seaweeds have also shown positive effects on semen quality and fertility traits in ruminants (9,10) and nonruminant animals such as rabbits (11,12) under summer conditions. However, digestibility studies on seaweeds, and particularly *Ulva lactuca*, as a feed supplement to animals are scarce (3,13). More studies are needed to evaluate seaweed as a feed supplement in the diets of ruminants; therefore, the current study was conducted to evaluate the effects of feeding a diet supplemented with different amounts of seaweed (*Ulva lactuca*) on the growth performance of Naimey sheep and in vitro gas production, estimated energy, and microbial protein synthesis.

2. Materials and methods

2.1. Seaweed collection and preparation

Seaweed (*Ulva lactuca*) was collected from the sea and washed with fresh water. Thereafter, it was sun-dried and further dried at 60 °C for 72 h. Dried seaweed was grounded through a 1-mm stainless-steel screen using a Wiley mill grinder and was chemically analyzed. Finally, seaweed was incorporated into the experimental diets at 0%, 3%, and 5% DM. The experimental diets were then mixed through a feed mill and processed as pelleting diets.

2.2. Animals and diets

A total of 18 young lambs were weighed (average live weight of 22.78 ± 0.24 kg) and randomly allocated to 3 groups, each group consisting of 3 separately housed replicates of 2 lambs. Sheep were fed 3% of their body weight of commercial feed with and without different levels of seaweed (*Ulva lactuca*). The lambs in each group were fed as follows (Table 1): Sheep in group 1 were fed a diet containing commercial feed without seaweed as a control diet (CG), sheep in group 2 were fed the control diet supplemented with 3% seaweed (SW3), and sheep in

* Correspondence: aelwaziry@yahoo.com

Table 1. The experimental diets' composition.

Ingredients	Experimental diets (% of DM)[2]		
	CG	SW3	SW5
Alfalfa hay	40	37	35
Seaweed[1]	0	3	5
Barley	25	25	25
Corn	25	25	25
Soybean meal	7	7	7
NaCl	1	0.8	0.7
Lime stone	1	1	1
$NaHCO_3$	0.8	1	1.1
Vitamins	0.2	0.2	0.2
Total	100	100	100

[1]Green algae (*Ulva lactuca*).
[2]CG, control diet without seaweed; SW3, control diet with 3% seaweed; SW5, control diet with 5% seaweed.

group 3 were fed the control diet supplemented with 5% seaweed (SW5).

2.3. Growth trial

The experiment lasted for 60 days. Feed intake for each group was recorded weekly and daily feed intake was calculated. The animal's weights were recorded every week before the morning meal. The daily weight gains and feed conversion ratio were calculated.

2.4. In vitro trial

2.4.1. Gas production rate and potential degradability

The in vitro gas production technique was performed as described by Menke and Steingass (14). Rumen liquor was obtained from slaughtered sheep. Buffer solution was prepared according to Onodera and Handerson (15) and placed in a shaker water bath at 39 °C under continuous flushing with CO_2. Approximately 200 mg of air-dried of experimental diets was placed into syringes. Thirty-six syringes were divided into 3 treatment groups; each group consisted of 6 replicates with 2 syringes each. Thirty milliliters of rumen fluid and buffer mixture (1:2 v/v) was placed into each syringe containing the samples (16). The incubation procedure was repeated 3 times. The gas production was recorded after 3, 6, 9, 12, 24, 48, and 72 h of incubation. Cumulative gas production values were fitted to the potential equation according to the model of Ørskov and McDonald (17): Gas (Y) = a + b (1 – exp^{-ct}), where a = gas production from the immediately soluble fraction, b = gas production from the insoluble fraction, a + b = potential degradability, c = gas production rate constant for insoluble fraction b, and t = incubation time.

2.4.2. Estimation of energy, organic matter digestibility, and microbial protein synthesis

The energy values of experimental diets were calculated from the amount of gas produced at 24 h of incubation with supplementary analysis of crude protein, ash, and ether extract (14) as follows:

ME (MJ/kg DM) = 1.06 + 0.157 Gp + 0.084 CP + 0.22 CF – 0.081 CA,

OMD (%) = 14.88 + 0.889 Gp + 0.45 CP + 0.0651 CA,

where ME is the metabolizable energy, OMD is the organic matter digestibility, Gp is 24-h net gas production (m/200 mg DM), CP is crude protein, and CA is ash.

NE (Mcal/lb) = (2.2 + (0.0272 Gp) + (0.057 CP) + (0.149 EE)) / 14.64,

where NE is net energy, Gp is 24-h net gas production (mL/g DM), CP is crude protein, EE is ether extract, and the NE unit is then converted to MJ/kg DM.

Microbial protein (MP) was calculated as follows, according to Czerkawski (18):

MP (g/kg OMD) = OMD × 19.3 × 6.25,

where OMD is organic matter digestibility for 24 h.

2.5. Chemical analysis

Feeds were dried at 70 °C for 24 h and then ground through a 1-mm screen. Samples of feed were analyzed for dry matter (DM), crude protein (CP), ether extract (EE), and ash according to the AOAC (19). Neutral detergent fiber (NDF) and acid detergent fiber (ADF) were determined according to Van Soest et al. (20).

2.6. Statistical analysis

The data were statistically analyzed by ANOVA using the general linear models procedure of SAS (21). Means showing significant differences in ANOVA were tested using the PDIFF option. The probability value, which denotes statistical significance, was $P < 0.05$.

3. Results

The proximate analysis of the diets fed to the experimental animals is shown in Table 2.

3.1. Growth trial

The results of the growth performance trial are presented in Table 3. There were no significant differences ($P > 0.05$) among the 3 groups in the final weight of animals after 60 days. Dietary seaweed supplementation for lambs had no effect on the average daily gain (ADG) and feed intake (Table 3). The control group (CG) fed the diet without seaweed showed the numerical best feed conversion efficiency compared to the other groups (SW3 and SW5), although the difference was not significant ($P > 0.05$). Moreover, dry matter intake did not differ significantly among the experimental groups ($P > 0.05$).

Table 2. The proximate analysis of the 3 experimental diets.

Items[2]	Proximate analysis (% of DM)[1]					
	DM %	CP	EE	Ash	NDF	ADF
CG	93.38	15.87	2.52	8.74	27.59	16.62
SW3	93.18	15.75	2.47	9.72	27.16	16.38
SW5	93.47	16.07	2.43	10.30	26.46	16.14

[1]DM, dry matter; CP, crude protein; EE, ether extract; NDF, neutral detergent fiber; ADF, acid detergent fiber.
[2]CG, control diet without seaweed; SW3, control diet with 3% seaweed; SW5, control diet with 5% seaweed.

Table 3. Effect of seaweed (*Ulva lactuca*) additives on growth, feed intake, average daily gain and feed conversion (mean ± SE).

Parameters	Experimental diets[1]			P-value
	CG	SW3	SW5	
Period (days)	60	60	60	
Initial weight (kg)	22.99 ± 0.521	22.55 ± 0.583	22.78 ± 0.483	0.88
Final weight (kg)	38.25 ± 0.593	36.08 ± 1.383	36.75 ± 0.882	0.39
Gain weight (kg)	15.26 ± 0.170	13.53 ± 0.981	13.97 ± 0.453	0.19
Average daily gain (kg)	0.25 ± 0.003	0.23 ± 0.022	0.23 ± 0.013	0.19
Feed intake (kg)	1.26 ± 0.012	1.25 ± 0.014	1.26 ± 0.004	0.08
Feed conversion	4.97 ± 0.060	5.65 ± 0.341	5.43 ± 0.171	0.13

[1]CG, control diet without seaweed; SW3, control diet with 3% seaweed; SW5, control diet with 5% seaweed.

3.2. In vitro trial

3.2.1. Gas production rate and potential degradability

Cumulative gas production produced from the experimental diets during 72 h of incubation is shown in the Figure. There were no significant differences (P > 0.05) among the 3 diets on gas production; however, dietary seaweed supplementation at 2 levels (3% and 5%) had no effect on gas production during the incubation times.

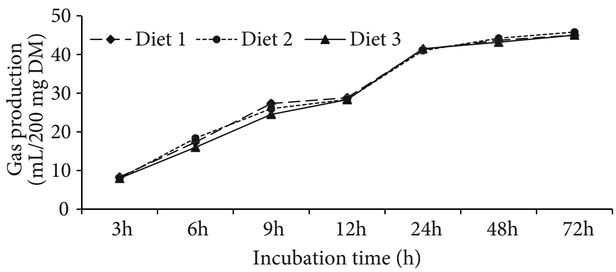

Figure. Cumulative gas production produced from the experimental diets during 72 h of incubation.

There were no significant differences (P > 0.05) among the experimental diets in potential degradability (a + b) (Table 4). The gas production rate (c) is shown in Table 4. There was also no significant difference (P > 0.05) among the experimental diets concerning gas production and potential degradability.

3.2.2. Estimation of energy, organic matter digestibility, and microbial protein synthesis

Predicted values of ME, NE, OMD, and MP are shown in Table 5. There were no significant differences (P > 0.05) among the experimental diets in ME, NE, OMD, and MP.

4. Discussion

4.1. Growth trial

Dietary seaweed supplementation for lambs had no effects (P > 0.05) on the final weight, ADG, feed intake, and feed conversion efficiency (Table 3). There were no differences (P > 0.05) in dry matter intake among the 3 groups; however, the control group had the best feed conversion

Table 4. Parameters of gas production produced from mixed diets contained seaweed during 72 h of incubation (mean ± SD).

Parameters	Experimental diets[1]			P-value
	CG	SW3	SW5	
a + b (mL)	44.80 ± 0.923	45.47 ± 0.664	44.85 ± 0.207	0.50
c (mL/h)	0.10 ± 0.013	0.10 ± 0.006	0.10 ± 0.004	0.25

[1]CG, control diet without seaweed; SW3, control diet with 3% seaweed; SW5, control diet with 5% seaweed.
Cumulative gas production data were fitted to the model of Ørskov and McDonald (17): Gas (Y) = a + b (1 – exp^{-ct}), where a = gas production from the immediately soluble fraction, b = gas production from the insoluble fraction, a + b = potential degradability, c = gas production rate constant for insoluble fraction b, t = incubation time.

Table 5. Predicted of metabolizable energy (ME), net energy (NE), organic matter digestibility (OMD), and microbial protein (MP) in vitro from mixed diets contained seaweed during 24 h of incubation (mean ± SD).

Parameters	Experimental diets[1]			P-value
	CG	SW3	SW5	
ME (MJ/kg DM)	7.26 ± 0.709	7.92 ± 0.550	7.75 ± 0.557	0.24
NE (MJ/kg DM)	5.44 ± 0.464	5.27 ± 0.422	5.18 ± 0.403	0.58
OMD (%)	55.51 ± 4.443	54.45 ± 4.034	53.09 ± 3.934	0.60
MP (g/kg OMD[2])	66.96 ± 5.359	65.68 ± 4.866	64.04 ± 4.748	0.60

[1]CG, control diet without seaweed; SW3, control diet with 3% seaweed; SW5, control diet with 5% seaweed.
[2]MP (g/kg OMD) = OMD × 19.3 × 6.25 according to Czerkawski (18), where OMD is organic matter digestibility for 24 h.

efficiency compared to the other groups (SW3 and SW5), which might be due to the higher ADG values in control group. The current study showed that the control group had the best weight gain, ADG, and feed conversion efficiency as compared to the other groups (SW3 and SW5), in agreement with the results reported by Allen et al. (22), who showed that brown seaweed extract supplementation did not affect the body weight of steers. Further, Al-Shorepy et al. (23) reported that supplementation of 1% seaweed meal had no significant influence on relative growth of body components of lambs. Seaweed extract supplementation did not increase the concentration of volatile fatty acids in the rumen of goats (22). However, a decrease in the proportion of propionate and increases in the proportions of butyrate and isobutyrate in the rumen of cattle (24) might be attributed to the observed numerical decrease in weight gain and ADG in the current study. In general, the use of seaweeds in agriculture research resulted in inconsistent findings. The discrepancies might be due to the variance in seaweed genera (*Palmaria*, *Ulva*, *Ascophyllum*), species (red algae, green algae, and brown algae), differences in harvesting and processing procedures (collecting, washing, and drying), or the levels used (25).

4.2. In vitro trial

4.2.1. Gas production rate and potential degradability

The supplementation of seaweed in mixed diet had no effect on gas production during the incubation times or the potential degradability (P = 0.50). Ventura and Castaňoń (5) reported that the potential degradability of seaweed using an in situ technique was 57.4%, which was higher than the potential degradability in the present study (44.80 to 45.47 mL). This discrepancy might be due to the difference of methods used, animal species, levels of seaweed used, or microbial utilization (16).

4.2.2. Estimation of energy, organic matter digestibility, and microbial protein synthesis

The supplementation of seaweed had no effect (P > 0.05) on ME and NE. Ventura and Castaňoń (5) estimated the digestible energy of the seaweed as 10.2 MJ/kg DM, which is equivalent to 8.26 MJ/kg DM for ME. This value is quite similar to the ME in the present study. There were no significant differences (P > 0.05) among the experimental diets in OMD and MP. The values of OMD reported in the current study were lower than that reported for brown algae mixture (*L. digitata* and *L. hyperborean*) in vitro (78.3%) by Hasen et al. (26) and for *U. lactuca* (62.1%) by Ventura and Castaňoń (5), and also less than that reported for *U. lactuca* (60%) in vivo using sheep (3). The results of MP were also lower than that reported by Hasen et al. (26), Ventura and Castaňoń (5), and Arieli et al. (3), who found values of 94.45, 74.91, and 72.38 g/kg OMD, respectively. As mentioned before, the differences between the various studies may be due to the different species of seaweed, harvesting time, species of experimental animals, processing procedures of seaweed, or the type of feeding.

The present study concluded that diets containing seaweed (*Ulva lactuca*) did not improve the ADG, feed conversion, gas production, potential degradability, estimated energy, organic matter digestibility, or microbial protein synthesis. This might be due to the lower levels used in the present study. Therefore, more studies using higher levels of seaweed supplementation to the diets of ruminants are needed.

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References

1. Okab AB. Risk and beneficial uses of sea algae (*Ulva lactuca* Linnaeus) in animal feedstuffs. In: 7th International Conference, Risk Factors of Food Chain, Nitra, Slovakia: Slovak University of Agriculture in Nitra; 2007. pp 152–158.
2. Oliveira MN, Freitas ALP, Carvalho AFFU, Sampaio TMT, Farias DF, Teixeira DIA, Gouveia ST, Pereira JG, Sena MMCC. Nutritive and non-nutritive attributes of washed-up seaweeds from the coast of Ceará, Brazil. Food Chem 2009; 115: 254–256.
3. Arieli A, Sklan D, Kissil G. A note on the nutritive value of *Ulva lactuca* for ruminants. Anim Prod 1993; 57: 329–331.
4. Applegate RD, Gray PB. Nutritional value of seaweed to ruminants. Rangifer 1995; 15: 15–18.
5. Ventura MR, Castaňoń JIR. The nutritive value of seaweed (*Ulva lactuca*) for goats. Small Ruminant Res 1998; 29: 325–327.
6. Beatrice DB. Nutritional aspects of the developing use of marine macro algae for the human food industry. Int J Food Sci Nutr 1993; 44 (Suppl. 1): 23–35.
7. Norziah MH, Ching CY. Nutritional composition of edible seaweed *Gracilria changgi*. Food Chem 2000; 68: 69–76.
8. Wong KH, Cheung PCK. Nutritional evaluation of some subtropical red and green seaweeds. Part 1. Proximate composition, amino acids profiles and some physico-chemical properties. Food Chem 2000; 71: 475–482.
9. Kellogg DW, Pennington JA, Johnson ZB, Anschutz KS, Colling DP, Johnson AB. Effects of feeding Tasco *Ascophyllum nodosum* to large and small dairy cows during summer months in central Arkansas. J Anim Sci 2006; 84 (Suppl. 1): 72.
10. Yates DT, Salisbury MW, Anderson H, Ross TT. Effects of Tasco-Ex supplementation on growth and fertility traits in male goats experiencing heat stress. Tex J Agric Nat. Resour 2010; 23: 12–18.
11. Okab AB, Ayoub MA, Ondruska L, Koriem AA. Dry biomass of Mediterranean sea algae in feed mixture of rabbits and its effects on semen characteristics. In: Proceedings of the 3rd Conference on Safety and Quality in Raw Material Foodstuffs. Nitra, Slovakia: Slovak University of Agriculture in Nitra; 2008. pp. 403–409.
12. Okab AB, Samara EM, Abdoun KA, Rafay J, Ondruska L, Parkanyi V, Pivko J, Ayoub MA, Al-Haidary AA, Aljumaah RS et al. Effects of dietary seaweed (*Ulva lactuca*) supplementation on the reproductive performance of buck and doe rabbits. J Appl Anim Res 2013; 41: 347–355.
13. Ventura MR, Castaňoń JR, McNab JM. Nutritional value of seaweed (*Ulva rigida*) for poultry. Anim Feed Sci Technol 1994; 48: 87–92.
14. Menke KH, Steingass H. Estimation of the energetic feed value obtained from chemical analyses and gas production using rumen fluid. Anim Res Develop 1988; 28: 7–55.
15. Onodera R, Henderson C. 1980. Growth factors of bacterial origin for the culture of rumen oligotrich protozoon, *Entodinium caudatum*. J Appl Bacteriol 2008; 48: 125–134.
16. Blümmel M, Ørskov ER, Comparison of *in vitro* gas production and nylon bag degradability of roughages in prediction of feed intake in cattle. Anim Feed Sci Technol 1993; 40: 109–119.
17. Ørskov ER, McDonald I. The estimation of protein degradability in the rumen from incubation measurements weighted according to rate of passage. J Agric Sci 1979; 92: 499–503.
18. Czerkawaski JW. An Introduction to Rumen Studies. Oxford, UK: Pergamon Press; 1986.

19. AOAC. Official Methods of Analysis. Washington, DC, USA: Association of Official Analytical Chemists; 2004.

20. Van Soest PJ, Robertson TB, Lewis BA. Methods for dietary fiber, neutral detergent fiber and non-starch polysaccharides in relation to animal nutrition. J Dairy Sci 1991; 74: 3583–3597.

21. SAS. SAS User's Guide: Statistics. Cary, NC, USA: SAS Institution; 2004.

22. Allen VG, Pond KR, Saker KE, Fontentot JP, Bagley CP, Ivy RL, Evans RR, Schmidt RE, Fike JH, Zhang X et al. Tasco: Influence of brown seaweed on antioxidants in forage and livestock—a review. J Anim Sci 2001; 79: E21–E31.

23. Al-Shorepy SA, Alhadrami GA, Jamali IA. Effect of feeding diets containing seaweed on weight gain and carcass characteristics of indigenous lambs in the United Arab Emirates. Small Ruminant Res 2001; 41: 283–287.

24. Han H, Hussein HS, Glimp HA, Saylor DH, Greene LW. Carbohydrate fermentation and nitrogen metabolism of a finishing beef diet by ruminal microbes in continuous cultures as affected by ethoxyquin and (or) supplementation of monensin and tylosin. J Anim Sci 2002; 80: 1117–1123.

25. Melton CSM. Influence of coated whole cottonseed on nutritional value and its potential for supplementation to ruminants. PhD, Texas Tech University, Lubbock, TX, USA, 2001.

26. Hansen HR, Hector BL, Feldmann J. A qualitative and quantitative evaluation of the seaweed diet of North Ronaldsay sheep. Anim Feed Sci Technol 2003; 105: 21–28.