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Can Nordic hemisphere macroalgae reduce emission of methane from ruminant livestock?

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Introduction:
Methane (CH_4) is a potent greenhouse gases (GHG) with 25 times more global warming potential than carbon dioxide (CO_2) (Eckard *et al.,* 2010; Jeyanathan *et al.,* 2014). Emission of CH4 from livestock contributes to climate change accounting for roughly 28% of global anthropogenic CH4 emission (Beauchemin *et al.*, 2008). Enteric CH_4 production also results in a significant energy loss to the animals which amounts to 2 to 12% of the gross energy intake (Martin *et al.*, 2010; Benchaar and Greathead, 2011; Patra, 2012). Therefore, safe and effective enteric methane mitigation strategies will have a positive contribution to both the environment and animal productivity.

Hypothesis:
Seaweed products can reduce enteric methane emission from ruminant livestock.
Seaweed products do not affect rumen degradability of co-fermented basal feed.

Objectives:
To assess the effect of intact and purified seaweed extracts on the enteric methane emission
To assess the effect of intact and purified seaweed extracts on total gas production.
To investigate the impact of intact and purified seaweed extracts on feed degradability during *in vitro* rumen fermentation.

Materials and Methods

Intact, dried seaweed of the species *Alaria esculenta* (AE), *Ascophyllum nodosum* (AN), *Saccharina latissima* (SL), and a commercial seaweed mix (OceanFeed™, Ocean Harvest Technology, Milltown, Ireland), and purified seaweed extracts (Extract-I and extract-II) were incubated alone (except for extract-I and extract-II) or together with either sugar beet pulp or maize silage (basal feeds). The products and basal feeds were fermented anaerobically in buffered rumen fluid for 48 hours. The volume of gas produced was detected continuously by an automatic wireless pressure sensor in the Ankom™ system (Ankom Technology, USA). Gas production is an indicator of microbial activity and therefore, digestion. Two of the three bottles per sample were fitted with gas tight bags (SKC, Flex Foil PLUS, USA) to collect all gases produced during in vitro fermentation to subsequently assess end-point methane using gas chromatography. Expected volumes for total gas and methane were calculated by adding the proportional gas produced per gram organic matter by the pure feeds or compounds in the mixes.

Results and Discussion

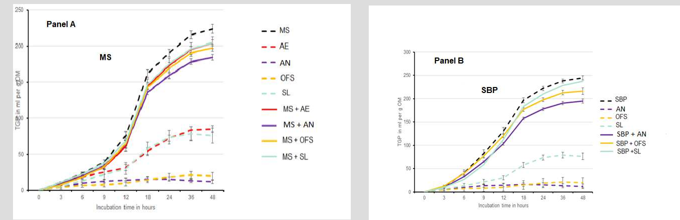

Figure 1. Effects of intact seaweed on total gas produced per gram organic matter when fermented with MS (Panel A) or SBP (Panel B) during 48 hours of incubation. Dashed lines represent pure compounds or feeds; solid lines represent mixes. MS, maize silage; SBP, sugar beet pulp; AE, *Alaria esculenta*; AN, *Ascophyllum nodosum*; SL, *Saccharina latissima;* OFS, oceanfeed swine

Basal feeds	Additives	Observed TGP	Predicted TGP	% Reduction
MS	AE	203.89	240.66	15.28%
	AN	184.25	225.99	18.47%
	OFS	197.24	227.54	13.32%
	SL	204.38	238.83	14.43%
SBP	OFS	216.02	248.39	13.03%
	SL	237.00	259.68	8.73%
	AN	194.53	246.84	21.19%

Table 1 Observed and expected TGP production per gram degraded organic matter. MS, maize silage; SBP, sugar beet pulp; AE, *Alaria esculenta*; AN, *Ascophyllum nodosum*; SL, *Saccharina latissima;* OFS, oceanfeed swine

Intact seaweeds fermented with SBP or MS
• Pure MS and SBP produced large amount of gas but the pure seaweeds produced much less amounts. AN and OFS produced a negligible amount of gas while AE and SL showed moderate gas production (Figure 1).
•Fermentation of seaweeds with either MS or SBP reduced total gas produced (Table 1) with AN exerting more significant inhibition.
•Endpoint methane production (Table2) was also inhibited by intact seaweed fermentation with MS or SBP. Maximum inhibition was observed with addition of AN (21%).
•AE significantly increased dry matter degradation when incubated with MS but did not affect dry matter degradation when incubated with SBP. All other intact seaweeeds did not affect dry matter degradability when fermented with either SBP or MS (Figure 3).

Purified seaweed extracts (Extract-I and -II) fermented with MS
•Total gas and methane production had a tendency to decrease while with increasing doses of extract-I when fermented with MS (Figure 2).
•Dry matter degradability had a tendency to increase when inceasing doses of extract-I were fermented with MS.
•Extract-II affected neither total gas, methane production nor dry matter degradation.
Maia et al. (2016) reported that Saccharina can reduce methane production when included up to 25% . In vitro studies with seaweed has also reported reduction of methane synthesis by AN but increased SCFAs in response to SL (Belanche et al., 2015). Similarly, the current study reported reduced methane production in response to seaweed inclusion but increased digestibility with AN which could be an indicator for increased SCFAs was observed.

Feed with additives		Observed	Expected	Reduction (%)
Maize Silage	AE	25.07	30.89	18.8
	AN	22.15	27.95	20.8
	OFS	22.41	27.95	19.8
	SL	23.22	28.94	19.8
Sugar Bett Pulp	OFS	25.54	27.20	6.1
	SL	25.15	28.19	10.8

Table 2. Observed and expected methane production per gram degraded organic matter in the incubated sample. MS, maize silage; SBP, sugar beet pulp; AE, *Alaria esculenta*; AN, *Ascophyllum nodosum*; SL, *Saccharina latissima;* OFS, oceanfeed swine

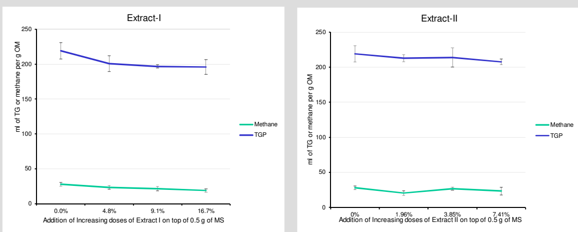

Figure 2. Effects of Extract-I and -II on the total and methane production when fermented with maize silage in increasing doses during the 48 hours incubation.

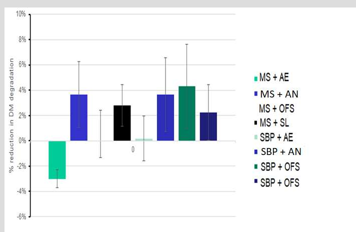

Figure 3. Dry matter degradation changes. MS, maize silage; SBP, sugar beet pulp; AE, *Alaria esculenta*; AN, *Ascophyllum nodosum*; SL, *Saccharina latissima;* OFS, oceanfeed swine

Conclusion

- AE, AN, OFS and SL reduced both total gas and methane production when fermented with SBP or MS without negatively affecting dry matter degradation.
- AE increased MS dry matter degradation while reducing total gas production and methane, suggesting that this seaweed has changed the profile of the short-chain fatty acids produced during fermentation
- AL showed tendency for reducing total gas and methane production while inceasing the dry matter degradability but extract-II lacked both attributes.
- Increasing doses of extract-I may have antimethanogenic activity.

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