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Protein value of different seaweed species in dairy cows

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Introduction

Limited land resources and increasing food demand puts pressure on agriculture and especially protein supply restricts increase in animal production. Indeed, it is no longer environmentally sustainable to increase the area of land used for farming, as this will further contribute to climate change (Steinfeld *et al.,* 2007). In order to support the needs of the rising world's population, farming has to intensify drastically so that more products are produced more rapidly from the same land area. On the other hand, marine waters hold the majority of the total world area and possess potential biomass, e.g. seaweeds, that could be utilized for feeding animals. These alternative feedstuffs can be used to decrease the dependency on conventional feedstuffs like soybeans. Use of seaweeds in animal feeding is not new; people living on coastal areas have fed their animals with seaweeds especially during lean feed seasons (Dunlop, 1953; Evans & Critchley, 2013). In the past, studies have focused on individual seaweeds or seaweed meal fed to small ruminants with respect to their nutritional value (Ventura & Castañón, 1998). In certain seaweed species, the crude protein (CP) content can reach 47% of the dry matter (DM) (Arasaki & Araski, 1983; Burtin, 2003). The nutritive value of seaweeds for ruminants varies widely and depends upon species, composition, and animal adaptation to that specific species. However, *in vivo* studies on protein digestibility of seaweed in dairy cows are scarce. The aim of this study was to evaluate the effect of season and seaweed species on the protein value for ruminants.

Materials and Methods

Three seaweed species (the green *Acrosiphonia sp*., the brown *Pelvetia canaliculata* and the red *Porphyra sp*.; hereafter *Acrosiphonia, Pelvetia* and *Porphyra,* respectively) were sampled in spring (March) and autumn (October and November) 2014 at the coast of Bodø in northern Norway.

Three dry rumen fistulated (#1C, Bar Diamond Inc., Parma, ID, USA) Danish Holstein cows were fed a standard ration (67:33 forage to concentrate ratio) at maintenance level and used for rumen incubations. Three duodenally canulated Danish Holstein dairy cows maintained on a 60:40 forage (grass and maize silage) to concentrate ratio (DM basis) diet were used for intestinal incubations of mobile bags. All cows had free access to fresh drinking water.

The samples were freeze dried before milling on a 1.5-mm screen with a cutter mill. The CP values were estimated as N×6.25 after N analysis by the Kjeldahl method. The samples were incubated in the rumen for *in situ* protein degradation at 8 time intervals (0, 2, 4, 8, 16, 24, 48 and 96 hours) using Dacron bags (38 µm pore size) according to the standard NorFor procedure (Åkerlind *et al.,* 2011). For the total tract digestibility, mobile bags (Dacron, 12 µm pore size) were ruminally pre-incubated for 16 h before pepsin-HCl treatment and incubation in the small intestine through the duodenal cannula, where after the bags were recovered in the faeces (Hvelplund & Weisbjerg, 2000).

Degradation profiles of CP were fitted assuming an exponential degradation profile including a lag time using PROC NLIN in SAS (9.4 version, SAS Institute Inc.).

Rumen degradable CP was estimated as effective rumen protein degradability (EPD) at 5% rumen fractional passage rate (Åkerlind *et al.*, 2011), but also including lag time:

EPD = a + (b(c/(c+kp)))×(exp(-(c+kp)×lt)), where a is soluble fraction, b is degradable but not soluble fraction, c is fractional rate of degradation, kp is fractional rate of passage (0.05/h), and lt is lag time (h).

Indigestible CP was estimated as the CP residue in mobile bags after faecal recovery. Intestinally degradable CP was estimated as rumen degradable CP minus indigestible CP. Rumen degradable, intestinal degradable and indigestible CP was reported as g per kg of original DM.

All data were analysed using PROC Mixed Model by SAS 9.4 version (SAS Institute Inc.) with species and season as fixed effects and cow as a random effect.

Results and Discussion

Crude protein concentrations in the seaweed, and CP (as g/kg original DM) degraded in the rumen and in the small intestine, and fully indigestible, are given in Table 1. The ash concentration in all three species was generally high and differed among species (P<0.0001), the high concentration was probably due to growing in sea water with high salt concentration. Concentrations of CP showed a large variation among species and season. Samples collected in the spring had higher (P<0.0001) CP contents than in autumn. The highest CP in DM was measured in *Porphyra* sampled in spring (37%) and lowest in *Pelvetia* sampled in autumn (8%). Both *Acrosiphonia* and *Porphyra* provided a high supply of rumen degradable protein, however *Acrosiphonia* had a higher indigestible part and thereby *Porphyra* had the highest supply of intestinally degradable protein. About 50% of total protein intake from *Porphyra* was degraded in the small intestine. *Pelvetia* had low rumen degradability (33%, average across both seasons) and, together with the low protein concentration, it only supplied ~~90~~ 30 g rumen degradable CP/kg original DM. Pelvetia showed a negative small intestinal degradability.

Table 1 The ash and protein concentration in seaweed, and the amount of protein degraded in the rumen, in the small intestine, and indigestible (g/kg original DM)

Species	Season	Ash	CP	CP		
				Rumen degraded	Small intestinal degraded	Indigestible
Acrosiphonia	Autumn	126.7	285.9	120.1	82.7	83.1
Acrosiphonia.	Spring	170.8	333.1	153.2	102.5	77.4
Pelvetia	Autumn	210.1	75.0	21.8	-20.5	73.7
Pelvetia	Spring	218.5	105.3	37.9	-9.1	76.5
Porphyra	Autumn	106.5	320.6	121.8	162.5	36.3
Porphyra	Spring	149.2	372.2	152.6	185.0	34.6
P value	Specie	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
	Season	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

This might be due to methodological differences between the methods used for rumen and total tract mobile bag degradability, as e.g. pore size of the bags. *Pelvetia* did not fit the exponential curve model, which also might have affected the estimation of the effective rumen CP degradability. Species and season affected ($P<0.0001$) seaweed CP concentration and degradability.

Different *Porphyra* species are traditionally used by humans especially in Asia because of their high nutritive values. Crude protein concentrations found in the present study are in accordance with Hasan and Chakrabarti (2009). On the other hand, *Pelvetia* has been fed to pigs (Chapman & Chapman, 1980) but there is no evidence of earlier studies in cows. There is scarcely any information available in the literature about CP values and protein digestibility values of these seaweed species in dairy cows.

Conclusion

The three seaweed species investigated had higher protein content in spring than in autumn. Both *Porphyra* and *Acrosiphonia* can supply the rumen with high amounts of rumen degradable protein but, due to both a high protein concentration and a low indigestible part, *Porphyra* can also supply a high amount of digestible protein to the small intestine. *Pelvetia* protein had a very low degradability in the rumen and the rumen escapable protein was not degradable in the small intestine, therefore, *Pelvetia* should not be used to feed dairy cows.

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