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Potential use of *Spartina alterniflora* as forage for dairy cattle

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ABSTRACT

This study evaluates the potential use of halophyte *Spartina alterniflora* (SA) as forage for ruminants by detecting the effect of plant maturity on organic and mineral compositions as well as the effect of increasing dietary inclusion of *S. alterniflora* on rumen fermentation in dairy cattle. Crude protein (CP), ash content, and *in vitro* dry matter (DM) digestion of *S. alterniflora* exhibited a negative correlation with increasing maturity; however, biomass, DM, neutral detergent fiber (NDF) content, and acid detergent fiber (ADF) content showed a positive correlation. Mineral composition drastically changed with increasing plant maturity. Compared with conventional diets, *S. alterniflora* mixed diets showed higher ash, NDF, ADF, ether extract, and Na, Ca, and P contents, and similar organic matter (OM), CP, and gross energy contents. DM and water intake of dairy cattle linearly increased from 0% to 25% SA in the diet. The mean values of the concentration of total volatile fatty acids (TVFA); the molar percentage of acetate, propionate, butyrate, and isobutyrate; and the acetate-to-propionate ratio did not significantly change at 12:00 h with increasing inclusion level of *S. alterniflora* in the diet. The initial findings obtained from the feed and rumen fermentation analysis of dairy cattle demonstrate that *S. alterniflora* can be utilized as potential forage for dairy cattle at less than 25% of the animal's diet. Overall, *S. alterniflora* could be provided with the potential to improve the sustainability of ruminant production as alternative feeds to replace partially common roughages, alleviate feeding cost and partially control the rapid spread of the invasive plant in salt marsh of China.

1. Introduction

Milk demand in China has increased in recent years. This scenario has resulted in substantially intensified dairy cattle production in the coastal regions of China. Roughage for dairy cattle in these regions is provided mainly by maize silage and Chinese wildrye (*Leymus chinensis*) hay. However, the availability of maize and Chinese wildrye hay cannot meet the current demand and production cost in the abovementioned regions. Hence, exploring unconventional feed resources with sufficient nutrients to balance diets and reduce cost is necessary.

Halophytes are drought-resistant plants that have the ability to survive in saline and alkaline soils. In many areas of the world, native and introduced halophytes are significant forage resources, especially for sustaining grazing livestock when other feeds are scarce (El-Shatnawi and Turuk, 2002; Ben Salem et al., 2004). *Spartina alterniflora* is a perennial saltmarsh grass native to the Atlantic and Gulf Coasts of North America. It is introduced to many coastal and estuarine regions worldwide, including China, as a species for erosion control. Given its enormous seed production and root fragments, *S. alterniflora* has adapted well and spread rapidly over the last 30 years in intertidal flats along the coastal regions of China, including Jiangsu, Shanghai, Zhejiang, and Fujian. In Jiangsu Province, *S. alterniflora* saltmarshes amounted to 15,000 ha in 2004 (Liu et al., 2007). Its average net primary production in native regions varies within 1–1.5 kg (m^{-2} $year^{-1}$) dry matter (Pomeroy and Wiegert, 1981). However, in the Jiangsu coastal region, this exotic species exhibits strong growing power, with biomass production of over 3 kg (m^{-2} $year^{-1}$) DM, and is an attractive plant feedstock for potential food and fodder production (Qin and Xie, 1998). *S. alterniflora* utilization in green manure,

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fish feed, biomineral liquid, and biofuel (Chung, 2006) has been investigated; however, reports on its feeding value in ruminants are limited. Recently, Wu et al. (2011) found that *Elaphurus davidinus* (Père David's deer) released in Dafeng Milu National Nature Reserve of China prefers *S. alterniflora* communities and consumes the aboveground parts of *S. alterniflora* as its main source of food. Wang et al. (2008) reported that *S. alterniflora* in the diet of dairy cattle has no drastic effects on milk production and composition. Given these valuable findings, *S. alterniflora* should be evaluated as a potential ruminant feed resource.

However, similar to most halophytes, high concentrations of minerals exist in the stem and leaves of *S. alterniflora*. NaCl is the principal constituent that affects the feeding value of halophyte forage for ruminants. Concern has been expressed over the finding that feeding saltbushes (e.g., *Atriplex*) to small ruminants drastically affects milk production and composition, reduces the efficiency of energy use in sheep production (Gihad and El Shaer, 1994; Arieli et al., 1989), and produces non-ideal results when included as the sole dietary component or energy supplement (Swingle et al., 1996). The incorporation of halophyte feedstuff into mixed diets minimizes the potential adverse effects of high salt content and can probably yield higher economic returns than direct grazing of halophyte resources (Swingle et al., 1994). The general nutritional characteristics of halophyte forages have been well defined in previous studies (Gihad and El Shaer, 1994). Their nutrient composition varies by species, plant part, stage of maturity, and salinity of the irrigation source. However, reliable information on the nutritive value (i.e., organic composition, mineral composition, and digestibility) of *S. alterniflora* in different maturity stages is still lacking.

This study aims to (i) investigate nutritive values and mineral contents of *S. alterniflora* in different stages of maturity and in diets with different *S. alterniflora* inclusion levels; (ii) assess the effect of using graded levels of *S. alterniflora* as dietary inclusions on feed intake, voluntary water intake, and ruminal fermentation in dairy cattle; and (iii) evaluate the strengths and weaknesses of the use of *S. alterniflora* in ruminant production and subsequently provide systematic data on the feeding of this unconventional halophyte.

2. Materials and methods

2.1. Plant materials

Test plant materials were collected from the upper intertidal area of a *S. alterniflora* plantation located in Sheyang County, Yancheng, Jiangsu Province, China (Fig. 1). Stems of *S. alterniflora* in different stages of maturity were sampled according to a randomized complete block design with three replicates and were hand-harvested from at least three 2.5 m × 2 m replicate plots established in the experimental field in April (stage 1), May (stage 2), June (stage 3), July (stage 4), August (stage 5), September (stage 6), and October (stage 7) 2010. Sampling was suspended in the middle of October, when the plant growth cycle ended. The samples were dried at 65 °C for 48 h, ground to pass through a 0.425 mm screen, and then stored in dry bags for analysis.

2.2. Test animals and feeding test

This study was conducted in a cattle farm located in Yancheng city, 27 km west of the *S. alterniflora* plantation in the summer of 2010. Four late-lactating Holstein dairy cattle (5–6 years of age, 437 ± 23 kg BW) outfitted with ruminal cannulas were utilized. The experimental design was a 4 × 4 Latin square (Khejornsart et al., 2011; Anantasook et al., 2015) with 18 d periods, each of which consisted of a 15 d feeding prophase followed by a 3 d collection period

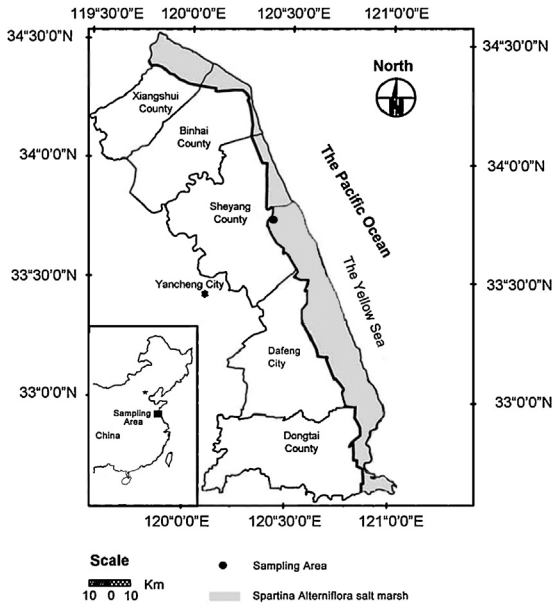

Fig. 1. Sampling area located in northern Jiangsu, China.

Table 1
Feed ingredients of experimental diets distributed to dairy cattle (DM basis).

Ingredients	Diet[a] (%)			
	0% SA	5% SA	15% SA	25% SA
Maize silage	30.00	28.50	25.50	22.50
Chinese wildrye	20.00	19.00	17.00	15.00
S. alterniflora	0.00	2.50	7.50	12.50
Sugar beet pulp	10.00	10.00	10.00	10.00
Concentrate mix[b]	40.00	40.00	40.00	40.00

[a] Level of *S. alterniflora* replacing maize silage and Chinese wildrye in dairy cattle diets.
[b] The following was provided in the diet (g kg): maize grain, 54.00; wheat bran, 10.50; cottonseed meal, 10.00; distillers dried grains with solubles, 9.00; soybean meal, 6.00; sesame meal, 5.00; calcium bicarbonate, 1.50; salt, 1.50; dicalcium phosphate, 1.50; 97100A, 1.00.

of rumen liquid. The total experiment comprised four periods. The cattle were housed in a well-ventilated cement-floored barn with individual feeding facilities (indoor temperature = 29.1 °C ± 4.3 °C). All subjects were kept under strict hygiene and uniform management protocols throughout the experiment.

Each cow was randomly offered one of the four maintenance rations formulated to incorporate different amounts of *S. alterniflora* in the diet: 0% (0% SA, control diet), 5% (5% SA), 15% (15% SA), or 25% (25% SA) with *S. alterniflora* as forage proportionally replacing an equal amount of conventional maize silage and Chinese wildrye hay. The dietary ingredients of each diet are shown in Table 1. A commercial feed concentrate was offered in all treatments to meet the nutritional requirements of the animals and was fed approximately at the level of 1% BW.

The aboveground parts of *S. alterniflora* were harvested daily in the morning from the *S. alterniflora* plantation throughout the experimental period and cut into small pieces (3–4 cm) with a manual chopper to reduce selective feeding by animals and maximize intake. *S. alterniflora* was given to cattle as a fresh material mixed into maize silage and Chinese wildrye hay. Roughage and concentrate were separately fed, and the roughage portion was offered before the concentrate three times a day at approximately 08:00, 14:00, and 20:00 h. Throughout the experiment, the cattle had free access to water, and the volume of daily water intake was