Nutritive value of 5 genera of West Australian chenopods for livestock

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Abstract

Planting chenopods such as *Atriplex* species (saltbush) on saline land, leads to greater whole farm profitability, increased livestock carrying capacity in autumn and a range of environmental benefits. While digestible energy is often limited, chenopods have the potential to be used as a high value, standing supplement of crude protein, minerals and antioxidants such as vitamin E. With the exception of several *Atriplex* and *Maireana* species, little is known about the variation in nutritive value of chenopods.

The aim of this project was to explore the potential of a range of native chenopods to add value to ruminant production systems in southern Australia. Fifty-seven samples of edible biomass (leaves and small stems), representing 5 genera and 10 species were collected in autumn at 15 sites across the northern wheatbelt of Western Australia. Biomass was subject to analysis of *in vitro* organic matter digestibility (OMD), organic matter (OM), fibre, N, nitrate, oxalate and a range of other minerals. The results indicate that there is considerable diversity within the samples for nutritive value traits. Variation in nutritive value was linked to both genus and the site of collection. No single genus would offer a balanced diet for ruminants, however, there is an opportunity to increase the diversity of chenopods within commercial plantations to allow grazing animals the potential to select a diet that optimises their nutritional needs for growth while balancing anti-nutritional factors.

Key Words

Feeding value, sheep, salinity, *Rhagodia*, *Enchylaena,* Bluebush

Introduction

Climate change (leading to greater variability in rainfall) and dryland salinity are major challenges for agriculture in southern Australia (Howden et al. 2008; Macfarlane et al. 2004). Native perennial chenopods such as A*triplex nummularia* and *A. amnicola* (old man and river saltbushes) and *Maireana brevifolia* (small-leaved bluebush) are currently used in saline and semi-arid livestock systems to reduce seasonal feed shortages (Masters et al. 2007; Ben Salem et al. 2010).

The nutritive profiles of chenopods are unique when compared to other forages and this is a partial consequence of their need for drought tolerance and osmotic-regulation. *Atriplex* species tend to have low to moderate OMD, moderate to high crude protein and high levels of minerals (Norman et al. 2010). Plant secondary compounds such as vitamin E and betaine are known to accumulate in chenopods and have been identified as playing a role in animal health and meat quality (Pearce et al. 2010).

A significant opportunity exists to explore the potential of other locally adapted chenopods for use in grazing systems. Whole farm economic modeling by O'Connell et al. (2006) indicates that a 10% increase in digestibility of *Atriplex* shrubs can lead to a doubling of profitability from the revegetated paddocks. The economic model indicates that improving digestibility by 10% is three times more profitable than increasing biomass production by 10% or reducing the cost of establishment by 10%. Additionally diversifying the feed base will allow grazing animals to balance their diets, maximizing intake of nutrients whilst balancing the intake of minerals and toxins. The aim of this study was to investigate the nutritive profiles of a range of 'wild' chenopods that are adapted to the low to the medium rainfall wheatbelt of Western Australia.

Methods

Collection of biomass

In autumn 2009, an 800 km survey was conducted to locate remnant stands of chenopods across the northern wheatbelt of Western Australia (encompassing an area between Jurien Bay, Kalbarri, Yalgoo and Wubin). Biomass samples (comprising a bulked sample of leaves and small stems with a diameter < 3mm from 5 individual shrubs per species) were collected from sites that had a minimum diversity of 3 species. In total 57 biomass samples were collected from 15 sites representing 10 species and 5 genera (*Atriplex, Enchylaena, Halosarcia, Maireana* and *Rhagodia*).

Laboratory analysis

Plant samples were oven dried at 65^{o}C for 48 h and ground to pass through a 1-mm screen. Concentrations of OM, neutral detergent fibre (NDF), acid detergent fibre (ADF), N, nitrate, oxalate, P, K, S, Na, Ca, Mg, Cu, Zn, Mn, Fe and B were determined using laboratory methods outlined in Norman et al (2004). Predicted *in vivo* OMD was determined by pepsin cellulase digestion calibrated using *in vivo* data as described in Norman et al (2010).

Statistical analyses

Differences in nutritive value traits associated with genera and sites of collection were compared using an unbalanced ANOVA (based on regression). Principal Components Analysis (based on the correlation matrix) was used to illustrate differences in nutritive traits between species. All statistical analyses were conducted using GenStat 12th Edition (VSN International Limited U.K.).

Results

Means of nutritive value traits of the 5 genera are presented in Table 1. The mean predicted OMD of genera range from 42 (*Rhagodia*) to 54 % (*Enchylaena*). Significant differences were associated with genera ($P < 0.001$) and sites of collection ($P < 0.001$). Differences in OM and soluble salt (represented by Na, K & Cl) were linked to genera ($P < 0.001$) but not to collection site. *Halosarcia* had the lowest OM of 66% with 23 % of DM comprising Na, K and Cl. *Rhagodia* (88%) and *Enchylaena* (81%) had the highest OM concentrations. *Maireana* and *Enchylaena* had significantly higher N and nitrate concentrations than other genera ($P < 0.01$) and both N and nitrate concentrations were also associated with collection site ($P < 0.01$). *Maireana* had the highest oxalate levels (13.81%; $P < 0.001$). *Rhagodia* and *Halosarcia* had significantly lower oxalate (1.93 to 2.18 %) and higher S levels (0.60 to 0.66%) than the other genera ($P < 0.001$). Of the remaining minerals, there were significant differences between genera in P, Mg, Mn and B. Of these minerals, P and Mn were also associated with site of collection and there was a significant genus x site interaction term. There were no significant differences between genera or sites of collection for fibre (NDF and ADF), Ca, Cu, Fe and Zn.

Table 1. Mean nutritive characteristics of 57 chenopod samples from 5 genera, collected from 15 sites in Western Australia. Significance of differences associated with genus, site of collection and the interaction are presented with the average standard error of differences.

	Atriplex	*Enchylaena*	*Halosarcia*	*Maireana*	*Rhagodia*	Significance of differences[1]			Average s.e. of difference
n[2]	24	8	9	8	8	genus	site	genus x site	

Predicted OMD (%)	50.59	54.25	51.60	52.47	42.48	***	***	ns	6.0
OM (%)	73.33	81.02	65.61	73.93	88.13	***	ns	ns	9.2
NDF (%)	41.62	40.79	33.69	38.95	47.67	ns	ns	ns	
ADF (%)	23.93	23.25	18.01	21.33	29.62	ns	ns	ns	
N (%)	1.79	2.26	1.82	2.67	1.76	***	**	ns	0.50
S (%)	0.41	0.23	0.60	0.30	0.66	***	*	ns	0.22
P (%)	0.15	0.14	0.20	0.14	0.13	**	**	*	0.04
Oxalate (%)	3.66	5.01	2.18	13.81	1.93	***	*	ns	1.4
Nitrate (g/kg)	0.50	1.12	0.64	1.07	0.41	**	**	ns	0.62
Na, K & Cl (%)	16.48	11.92	23.06	13.71	6.54	***	ns	ns	7.5
Mg (%)	0.85	0.43	1.17	0.33	0.60	***	ns	ns	0.35
Ca (%)	1.21	0.39	0.77	0.54	0.63	ns	ns	ns	
Mn (mg/kg)	51.71	172.91	31.22	161.74	207.30	***	***	***	40
B (mg/kg)	51.13	41.53	48.46	59.08	31.76	**	ns	ns	19.5
Cu (mg/kg)	6.77	8.97	9.72	11.48	6.53	ns	ns	ns	
Fe (mg/kg)	741.59	731.86	308.96	690.18	417.73	ns	ns	ns	
Zn (mg/kg)	33.68	20.96	33.32	27.37	24.15	ns	ns	ns	

[1]Significance of differences; ns is not significant; * P < 0.05; ** P < 0.01; *** P < 0.001

[2]number of samples from each genus

The principal components biplot (Figure 1) has the location of each species plotted as a mean of principal components. Standard errors of the means are presented to indicate the amount of variation within the species for PC1 and PC 2 scores. Both *Rhagodia* species have highly negative PC2 scores, indicating relatively high fibre and low OMD. The species differ in their S content with *R. preisii* having higher S than *R. drumondii.* The *Atriplex* species split into two groups. The first group are characterised by higher OM and fibre (*A. amnicola, A. semibaccata* and *A. vesicaria*) while the second group have higher soluble salts. The *Halosarcia* species sits with the second *Atriplex* group on the PCA biplot. The *Enchylaena* and *Maireana* samples cluster in the top left of the biplot and are relatively different from other samples due to higher N, nitrate, oxalate, OMD and lower S. There is greater variation within the *R. Preisii*, *A. amnicola* and *M. brevifolia* clusters.

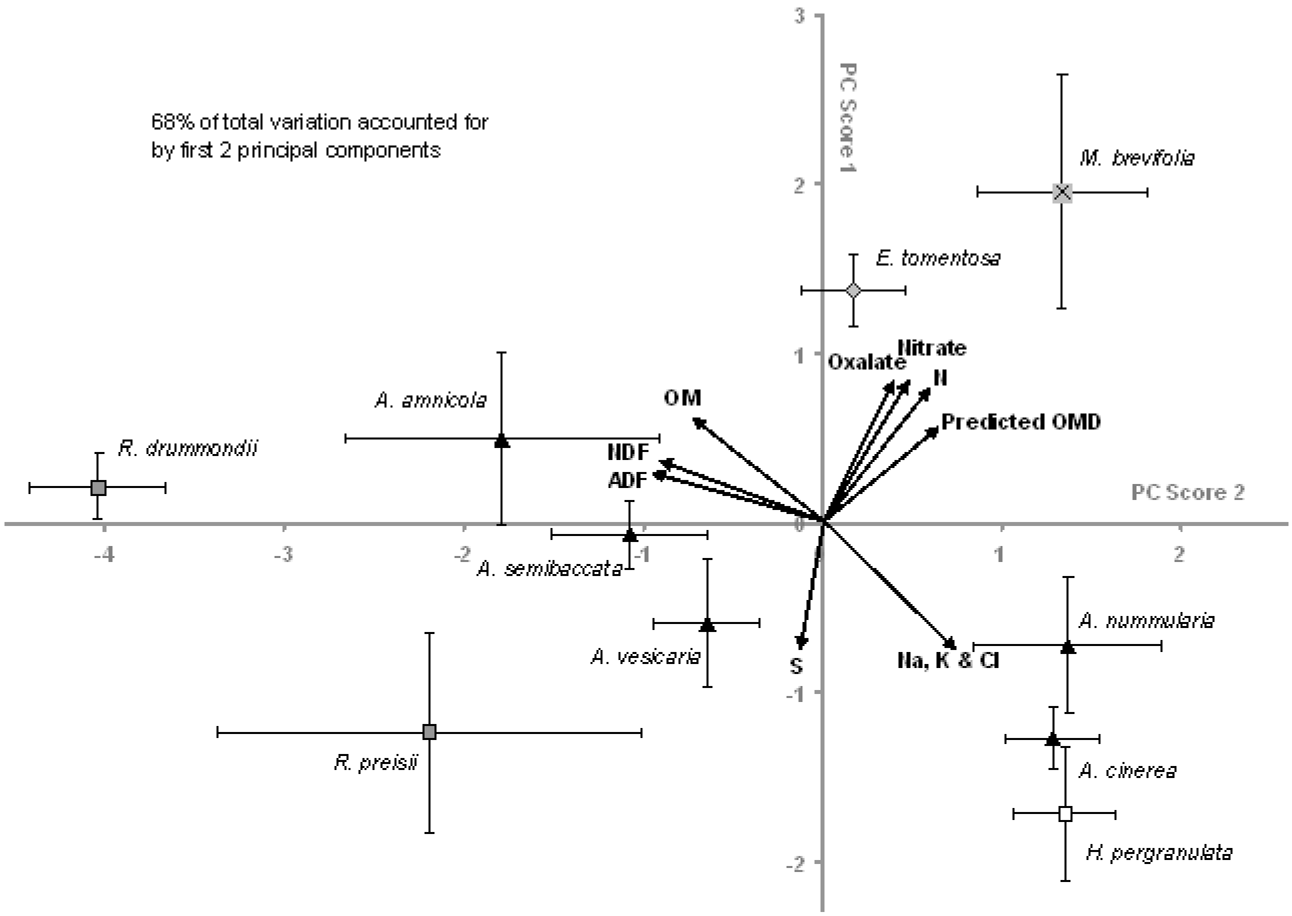

Figure 1. Biplot of the first and second principal components from a PCA analysis based on nutritive traits for 57 shrub samples representing 10 species collected across 15 sites in Western Australia. Vector loadings are presented on the biplot as arrows, the length of arrows indicate the relative contribution of each trait and the direction of the arrow indicates the direction of trait increase.

Discussion

Whole farm economic modeling by O'Connell et al. (2006) suggests that digestibility should be a focal trait for shrub improvement. None of the genera had a significantly higher OMD than the *Atriplex* genera (the current benchmark) however there was some variation within genera and species that may offer opportunities to improve OMD. Of the samples tested, it was clear that the *Rhagodia's* had a lower OMD than the other species. *Rhagodia* does have one advantage over the other species due to its relatively low salt content. All of the other genera had more than 11% of biomass comprising Na, K and Cl. These salt levels will depress feed intake and lead to reduced digestibility of the diet (Masters et al. 2007). All 5 genera had mean levels of N that would appear to meet the protein requirement for maintenance of mature wethers (with > 11% CP), however, much of this N is likely to comprise non-protein nitrogen which is only converted to microbial protein in the rumen when a good supply of energy is available (Masters et al. 2007). The high nitrate levels in *Enchylaena* and *Maireana* account for some of this non-protein nitrogen and may influence palatability of the forage. The levels of oxalates within *Enchylaena* and *Maireana* (means of 5 and 13% respectively) are of concern. Burritt and Provenza (2000) found that lambs offered a diet containing 3% oxalate ate half the amount of DM as lambs offered a control diet and James (1977) stated that plants containing 10% oxalate should be considered toxic to ruminants. It is interesting to note that field observations of grazing preference have consistently revealed that sheep preferentially graze *Maireana brevifolia* over *Atriplex* species despite potential aversion to oxalate (H. Norman, unpublished). The chenopods have all accumulated a range of minerals at levels in excess of dietary recommendations that could induce specific mineral imbalances or deficiencies in livestock (Masters et al. 2007). For example, diets containing 0.25 to 0.35 % S are deemed to be high for sheep (Standing Committee on Agriculture, 1990) and it is, therefore, possible that sheep grazing *Rhagodia, Atriplex* or *Halosarcia* monocultures could suffer S toxicity or induced Cu deficiency.

While no individual genus of chenopod offers an ideal diet for ruminants, it is possible that the diversity of chemical characteristics displayed on the PCA biplot, offers an opportunity to improve productivity and animal health through mixed plantings. In a recent review Villalba and Provenza (2009) discuss how herbivores select diets from an array of plant species that vary in nutrients and plant secondary metabolites (PSM), leading to a diet higher in nutrients and lower in PSM than the average available in the environment. The chenopods also offer an opportunity to complement crop stubbles or senesced pastures that are often deficient in protein and minerals.

Conclusion

There were differences in nutritive traits among the 5 genera of Australian native chenopods examined in this survey. While it appears that no single genus of the 5 tested offers a complete, nutritionally balanced diet for livestock, diversity in nutritive profile offers the opportunity for animals to select a diet higher in nutrients and lower in toxins than a monoculture of any species.

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