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A multivariate approach in the analysis of the nutritional quality of woody pastures in NW Spain

M.P. González-Hernández, M.R. Mosquera-Losada, N. Ferreiro-Domínguez and A. Rigueiro

University of Santiago de Compostela, Department of Crop Production
Benigno Ledo, s/n, 27002, Lugo (Spain)

Abstract. Nutritive quality and productivity assessment of food resources in pastures is essential in developing efficient and environmentally friendly management strategies. In this study, 12 nutritional parameters have been compared for 26 plants commonly found in scrublands and understory of forest communities in Galicia (Northwest Spain). Energy and protein available in range forages were analyzed in terms of dry matter (DM), crude protein, *in vitro* digestibility (OMD), structural carbohydrates (acid detergent fiber (ADF), lignin, cellulose, and silica) and nitrogen-complexing compounds (condensed and hydrolysable tannins). Mineral content in forages are crucial in animal health as well, thus phosphorus (P), calcium (Ca), magnesium (Mg), and potassium (K) concentrations were considered. Principal Components Analysis (PCA) was used to assess similarities among plant species and to reduce a large number of nutritional parameters into a small set that could explain the variability of the data. Four variables, namely ADF, OMD, DM and Mg, showed the highest percent of variance that was accounted for by the two retained principal components. The first component, represented by ADF and DM in the positive side of the axis, and by K and OMD in its opposite, separated plants with low digestibility and small content of available crude protein (i.e. heathers) from a group of plants with better nutritional quality mostly represented in oak forests understory. This was categorized as the "nutritional quality component. Three variables loaded heavily on the second component (Mg noticeably stronger than Ca and total tannins) explaining the data variability only to some extent. This was categorized as the "nutritional disorders component".

Keywords. Principal Component Analysis – ADF – Digestibility – Tannins – Ericaceae.

Une approche multivariée pour l'analyse de la qualité nutritionnelle des pâturages ligneux dans le NO de l'Espagne

Résumé. *L'évaluation de la qualité nutritive et de la productivité des ressources alimentaires des pâturages est essentielle pour développer des stratégies de gestion efficientes et respectueuses de l'environnement. Dans cette étude, 12 paramètres nutritionnels ont été comparés pour 26 plantes couramment rencontrées dans les broussailles et l'étage inférieur des communautés forestières en Galice (nord-ouest de l'Espagne). L'énergie et les protéines disponibles dans les fourrages des parcours ont été analysés en termes de matière sèche (MS), protéine brute, digestibilité in vitro (DMO), hydrates de carbone structurels (fibre acido-détergente (ADF), lignine, cellulose, et silice) et composés de complexation d'azote (tannins condensés et hydrolysables). La teneur minérale des fourrages est cruciale pour la santé animale, donc on a considéré les concentrations en phosphore (P), calcium (Ca), magnésium (Mg), et potassium (K). L'analyse en Composantes Principales (ACP) a été utilisée pour évaluer les similarités entre espèces végétales et pour réduire un large nombre de paramètres nutritionnels à un petit ensemble qui puisse expliquer la variabilité des données. Quatre variables, à savoir ADF, DMO, MS et Mg, ont montré le plus fort pourcentage de variance qui correspondent aux deux composantes principales retenues. La première composante, représentée par ADF et MS du côté positif de l'axe, et par K et DMO du côté opposé, séparaient les plantes à faible digestibilité et faible teneur en protéine brute disponible (c.-à-d. bruyères) par rapport à un groupe de plantes ayant une meilleure qualité nutritionnelle représentées notamment par le sous-étage forestier des chênes. Ceci était catégorisé comme "composante de qualité nutritionnelle". Trois variables pesaient lourdement sur la deuxième composante (Mg nettement plus fort que Ca et tannins totaux) expliquant seulement en partie la variabilité des données. Ceci était catégorisé comme "composante de désordres nutritionnels".*

Mots-clés. *Analyse en Composantes Principales – ADF – Digestibilité – Tannins – Ericaceae.*

I – Introduction

Plant species composition determines the nutritional quality of range forages as nutritional quality may vary greatly among plants (Van Soest, 1982). Alternatively, nutritional quality of vegetation can be explained using multiple nutritional parameters. For both reasons, nutritional quality assessment of range forages may involve a substantial number of correlated variables and plant species, making data interpretation a difficult task. Multivariate analysis, as a dimension-reduction tool, can facilitate the understanding of relationships (distance) among a large number of plant species defined by a variety of nutritional parameters. Principal Components Analysis (PCA) in particular, has been proved very useful, as it reduces a large number of nutritional parameters into a small set that still contains most of the information. Our main objective was to give an overall approach on the similarities and differences on nutritional quality of plants frequently present in forest communities in Northwest Spain. We also wanted to evaluate to what extent the information on 12 nutritional parameters could be reduced to the most relevant and still explain the variability of the data.

II – Materials and methods

1. Material

Data on nutritional parameters of plants from oak woods, conifer stands and scrublands (broom, gorse and heather lands) in Galicia (Northwest of Spain) for which contents in P, Ca, Mg, K, ADF, lignin, cellulose, silica, DM, OMD, CP and total tannins (TA) were reported before (González-Hernández and Silva-Pando, 1999, González-Hernández *et al.*, 2000, González-Hernández *et al.*, 2003) were subjected to a PCA. Detailed information of extraction procedures and techniques applied for chemical analysis can be found in the above studies.

2. Methods

PCA was performed for 12 original nutritional parameters across 26 plant species (a 26 x 12 data matrix). To solve the matter on "number-of-components" to retain we tested various criteria such as the eigenvalue-one criterion, the scree test, the cumulative percent of variance accounted for, and the interpretability criterion; combining all four in a structured sequence. Components extraction was followed by a varimax (orthogonal) rotation, with the aim of determining what is measured by each of the retained components. This involved identifying the variables that contribute most to the component (i.e. high factor loadings on a given component), determining what these variables have in common, and labeling each retained component. To perform the data analysis, we used the software STATGRAPHICS Plus Version 5.0.

III – Results and discussion

The purpose of the PCA was to obtain a small number of linear combinations of the nutritional parameters which account for most of the variability in the data. As PCA is normally conducted in a sequence of steps, three correlated parameters, namely lignin, cellulose and silica (which accounted for the total ADF), were removed from the 26 x 12 original data matrix after initial analysis. Accordingly, subsequent PCA analysis was performed for a final 26 x 9 data matrix. Table 1 shows the strength of the linear relationship between the variables measured by Pearson's correlation coefficient analysis.

Table 1. Pearson's correlation matrix between nutritional parameters. ADF: Acid Detergent Fiber, DM : dry matter, OMD : organic matter digestibility, CP : crude protein, TA : total tannins

	P	Ca	Mg	K	ADF	DM	OMD	CP	TA
P									
Ca	-0.1030								
Mg	-0.1442	**0.5077†**							
K	**0.4646†**	0.2156	**0.4316†**						
ADF	-0.2941	**-0.3934†**	-0.3691	**-0.5551†**					
DM	-0.3442	-0.3572	-0.3794	**-0.801†**	**0.7333†**				
OMD	0.3674	0.3281	0.2008	**0.6269†**	**-0.8310†**	**-0.751†**			
CP	0.2822	-0.0638	0.1503	**0.4411†**	**-0.5842†**	**-0.573†**	**0.6478†**		
TA	-0.1618	0.1239	**0.5062†**	-0.0708	0.0551	0.0784	-0.3466	-0.1614	

† indicate statistically significant non-zero correlations at the 95% confidence level.

PCA extracted 2 major components of variation based on eigenvalues ≥1 and the results of a scree test; consequently, only the first two components were retained for rotation. Combined, components 1 and 2 accounted for 66.8 % of the total variance. In interpreting the rotated factor pattern, a nutritional parameter was said to load on a given component if the factor loading was 0.60 or greater for that component, and was less than 0.60 for the other. Using these criteria, five nutritional parameters were found to load on the first component and only three loaded on the second component (Table 2). Estimated communality indicated that four variables, ADF, OMD, DM and Mg explained the highest percent of variance that was accounted for by the two retained components.

Table 2. Factor loading matrix after varimax rotation and final communality estimates from PCA of nutritional parameters. Parameters consider to load on a given component are shown in bold case

Variable	Factor 1	Factor 2	Estimated communality
P	0.54125	-0.3565	0.42002
Ca	0.25559	**0.67471**	0.52056
Mg	0.24958	**0.87340**	**0.82512**
K	**0.79977**	0.19707	0.67847
ADF	**-0.8388**	-0.2527	**0.76747**
DM	**-0.8782**	-0.2412	**0.82942**
OMD	**0.91904**	0.00805	**0.84470**
CP	**0.73736**	-0.1134	0.55657
TA	-0.2941	**0.69613**	0.57112

The first component explained 45.8% of the variability of the data. It showed that ADF and DM loaded most heavily on positive values, whereas K content and OMD had the highest weight in the negative values. Although CP is an essential figure for the nutrition of the animal, this nutritional variable did not account greatly in explaining the data variability. Thus, component 1 separated plant species of low digestibility and high ADF content, such as heathers, from plants of high digestibility for browsers (González-Hernández and Silva-Pando, 1999) as *Lonicera periclymenum*, *Hedera helix*, *Frangula alnus* and *Asphodelus albus* (Fig. 1). As a result, component 1 was labeled as "nutritional quality component".

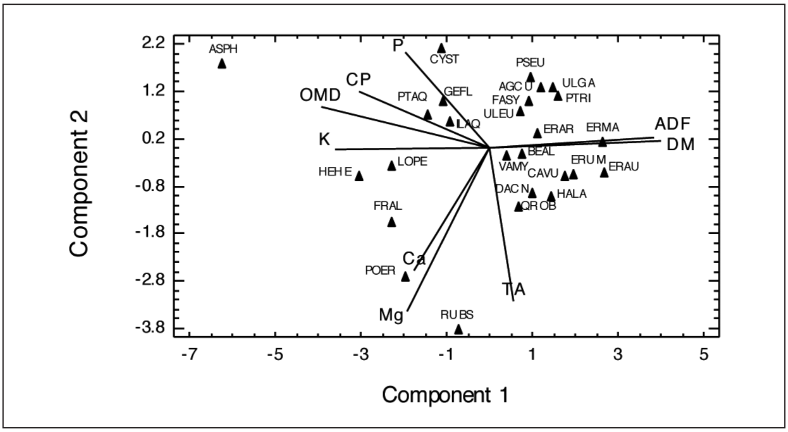

Fig. 1. Two-dimensional biplot with rays that represent the magnitude and direction for each variable.

(AGCU: *Agrostis curtissii*, ASPH: *Asphodelus albus*, BEAL: *Betula alba*, CAVU: *Calluna vulgaris*, CYST: *Cytisus striatus*, DACN: *Daboecia cantabrica*, ERAR: *Erica arborea*, ERAU: *Erica australis*, ERMA: *Erica mackaiana*, ERUM: *Erica umbellata*, FASY: *Fagus sylvatica*, FRAL: *Frangula alnus*, GEFL : *Genista florida*, PTRI: *Pterospartum tridentatum*, HALA: *Halimium lasianthum*, HEHE: *Hedera helix*, ILAQ: *Ilex aquifolium*, LOPE: *Lonicera peryclimenum*, POER: *Potentilla erecta*, PSEU: *Pseudarrhenatherum longifolium*, PTAQ: *Pteridium aquilinum*, QROB: *Quercus robur*, RUBS: *Rubus* sp., ULEU: *Ulex europaeus*, ULGA: *Ulex gallii*, VAMY: *Vaccinium myrtillus*).

The second component accounted for 21% of the total variance and explained a Mg-Ca-tannin gradient. It separated plants with higher content in Ca (*Fangula alnus*, *Hedera helix*), Mg and total tannins (*Rubus* sp., *Potentilla erecta* and *Quercus robur*) in negative axis from leguminose and grasses displayed in the positive axis. It is widely known that low levels of Mg or Ca, as well as high K intake relative to Ca and Mg intake, may induce hypomagnesemia (grass tetany). Plant species in this study had low Mg content (< 2g Mg/kg DM) but an optimum K (Ca+Mg) ratio (< 2.2) (González-Hernández *et al.*, (2000). Legumes that contain leaf tannins help break up the foam when bloat problems occur, and beneficial antimicrobial properties from tannins are also acknowledged. On the other hand, tannins are widely recognized as important factors influencing feeding by mammals on woody plants and may reduce digestion of protein and fiber (Hagerman *et al*., 1992; Starkey *et al*., 1999, González-Hernández *et al.*, 2003). As a result, component 2 was identified as the “nutritional disorders component”. Magnesium should be included to prevent grass tetany, and potasium is often deficient in dormant warm-season grasses (Holecheck *et al.*, 2004). Because Ca/P ratios for nearly all forages fall within an optimum range in terms of animal performance they are not an important factor influencing grazing animal productivity (Holecheck *et al.*, 2004, González-Hernández *et al.*, 2000).

Although Mg, tannin and Ca defined component 2, and therefore accounted for some of the variance, they slightly supported organizing the species by similarities. As an example, *Betula alba* and *Vaccinium myrtillus*, showed lower tannin content than *Fagus sylvatica* (González-Hernández *et al*., 2003), but this was not consistent with their distribution in Fig. 1. We also included hydrolysable and condensed tannins in the PCA, but they did not facilitate interpretation. Tree species displayed closer to the intersection of both components as nutritional parameters showed intermediate values in the overall ranges.

IV – Conclusions

PCA analysis can be a useful tool that minimizes the complexity of correlated data reducing a number of observed variables into a smaller number of artificial variables that account for most of the variance in the data set. In this study, PCA showed that four nutritional parameters, ADF, OMD, DM and Mg explained the highest percent of variance that was accounted for by the two retained components. Component 1 neatly separated heathers (poor nutritional quality) from plant species very frequent in oak forests understory (rich nutritional quality) and consequently was categorized as "nutritional quality component". Component 2 reflected, to some extent, a Mg-Ca-tannin gradient and, as a result, was identified as "nutritional disorders component".

References

González-Hernández M.P. and Silva-Pando F.J., 1999. Nutritional attributes of understory plants known as components of deer diets. *Journal of Range Management,* 52 (2), 132-138.

González-Hernández M.P., Silva-Pando F.J., Mosquera-Losada R. and Rigueiro A., 2000. Contenido mineral de especies componentes del monte gallego (NW España). Importancia en la gestión de ecosistemas pascícolas. *Actas de la XL Reunión Ibérica de Pastos y Forrajes. Xunta de Galicia.* ISBN 84-453-2775-5.

González-Hernández M.P., Starkey E.E. and Karchesy J., 2003. Research observation: Hydrolyzable and condensed tannins in plants of northwest Spain forests. *Journal of Range Management*, 56 (5), 461-465.

Hagerman A.E., Robbins C.T., Weerasuriya Y., Wilson T.C. and McArthur C., 1992. Tannin chemistry in relation to digestion. *Journal of Range Management,* 45 (1), 57-62**.**

Holecheck J.L., Pieper R.D. and Herbel C.H., 2004. *Range management. Principles and practices*. Fifth edition. Pearson Prentice Hall, NJ USA, 607 pp.

Starkey E.E., Happe P.J., Gonzalez-Hernandez M.P., Lange K. and Karchesy J., 1999. Tannins as nutritional constraints for elk and deer of the coastal Pacific Northwest. In: *Plant polyphenols 2: Chemistry, biology, pharmacology, ecology*, pp. 897-908. Gross GG, Hemingway RW, and Yoshida T. Kluwer Academic/ Plenum Publishers. USA. ISBN 0-306-46218-4.

Van Soest P.J., 1982. *Nutritional ecology of the ruminant. Ruminant metabolism, nutritional strategies, the cellulolytic fermentation and the chemistry of forages and plant fibers*. Cornell University Press.