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Use of a geographic information system to evaluate morphometric variations of rumen papillae related to diet and pasture vegetative cycle

Paola Scocco[1], Piero Ceccarelli[2], Renata Gatti[1] & Andrea Catorci[1]

Summary

The morphometric variations of the rumen papillae due to different alimentary diets has been analysed using a geographic information system (GIS), as the preliminary stage of a wider study aimed at creating a geo-database to link environmental data (pasture structure and composition, pastoral value) with parameters measuring animal welfare (body condition score, volatile fatty acids concentration, haematochemical profile) both during a pasture vegetative cycle and in different conditions of animal load on pastures, with the ultimate goal of contributing to grassland management. A first step was to collect samples of rumen wall tissue from different groups of sheep (lambs to milky and mixed diet, and adult at the maximum of flowering and at the end of pasture vegetative cycle) to verify morphometric differences in rumen papillae due to different diets. Wall tissues of rumen samples were removed from the dorsal and ventral sac and preserved in a formalin solution. Twenty papillae from the dorsal and ventral sac were taken from each sample and their images were elaborated with ArcGIS™ software. Results show that the morphometric variation of papillae is related with the pasture productivity trend: the maximum size of rumen papillae occurs immediately after the phytomass and flowering spike; in this phase the animals utilise a very nourishing and quantitatively abundant pasture. After this phase, a deterioration of pasture occurs and the surface of rumen papillae surface decreases rapidly. Results obtained further confirm the existence of a close relationship between quality and quantity of phytomass and the extent of rumen papillae absorptive surface, demonstrating the effects of this relationship during a pasture vegetative cycle.

Keywords

Diet, Geographic information system, Grassland, Pastures, Rumen papillae, Sheep, Surface enlargement.

Uso del sistema informativo geografico per la valutazione delle variazioni morfometriche delle papille ruminali in relazione alla dieta e al ciclo vegetativo del pascolo

Riassunto

Utilizzando il GIS sono state analizzate le variazioni morfometriche delle papille ruminali legate a differenti diete, come stadio preliminare di uno studio più ampio finalizzato alla creazione di un geo-database per integrare dati ambientali (struttura e composizione del pascolo, valore pastorale) con parametri indicativi del benessere animale (body condition score, concentrazione degli acidi grassi volatili, profilo ematochimico) sia durante il ciclo vegetativo del pascolo che in

(1) Department of Environmental Sciences-UNICAM, via Pontoni 5, 62032 Camerino, Italy
(2) Department of Veterinary Biopathological Sciences and Hygiene of Animal and Food Production, Perugia University, via S. Costanzo 4, 06126 Perugia, Italy

differenti condizioni di carico di animali sul pascolo, con lo scopo finale di contribuire alla gestione delle praterie. Un primo step è stato quello di raccogliere campioni di parete ruminale da gruppi differenti di pecore (agnelli da latte e a dieta mista e adulti sacrificati nel momento di massima fioritura e alla fine del ciclo vegetativo del pascolo) per verificare le differenze morfometriche delle papille ruminali legate a differenti diete. I campioni di parete ruminale sono stati prelevati dal sacco dorsale e ventrale del rumine e conservati in formalina. Venti papille sono state rimosse da ciascun campione, fotografate e le immagini sono state elaborate con il software ArcGIS™. I risultati mostrano che le variazioni morfometriche delle papille sono legate al trend produttivo del pascolo: la dimensine massima delle papille si ha immediatamente dopo il picco di produzione di fitomassa e fioritura del pascolo; in questa fase gli animali utilizzano un pascolo molto nutriente e quantitativamente abbondante. Dopo questa fase, si assiste ad un impoverimento del pascolo e la superficie assorbente delle papille ruminali subisce un rapido decremento. I risultati ottenuti confermano quindi l'esistenza di una stretta relazione tra qualità e quantità di fitomassa prodotta ed estensione della superficie assorbente delle papille ruminali, dimostrando gli effetti di questa relazione durante il ciclo vegetativo del pascolo.

Parole chiave

Dieta, Fattore di ingrossamento della superficie, Papille ruminali, Pascoli, Pecora, Praterie, Sistema informativo geografico.

Introduction

According to Burrough, geographic information systems (GIS) are composed of different tools to acquire, store, extract, transform and visualise spatial data (1).

GIS integrates two main types of information, as follows:

- geometry of features: (point, line, polygon) and geographic position
- topology: the set of rules that models how points, lines and polygons share geometry (connection, adjacency, inclusion, etc.).

GIS is widely used in veterinary activities for the epidemiological surveillance of infectious diseases. Other veterinary activities can also be evaluated by means of GIS.

By applying an integrated methodology, we present an experimental approach finalised to the evaluation of the morphometric variations of sheep rumen papillae, in relation to different diets, using GIS. It is well known that the nutritional contribution of grassland plant communities changes during the vegetative season at both quantitative and qualitative levels (3); this fact possibly affects animal welfare and consequently the productive and economic aspects of farm.

Materials and methods

To evaluate the difference in the rumen papillae size in four groups of sheep (5 suckling lambs, 8 weaning lambs and two groups of 10 adult sheep each, sampled during the flowering season [July] and at the end [October] of the pasture vegetative cycle), rumen papillae from the 33 sheep were removed and the morphometric variations were evaluated.

Sections of rumen wall tissue (approximately 5 cm × 5 cm) (6, 7), were cut from the dorsal and ventral sac of sheep. Samples were preserved in buffered 10% formalin solution; a 1 cm × 2 cm section was cut from each of the rumen wall samples and the number of papillae was counted. Twenty papillae from dorsal and ventral sacs were randomly removed and placed on paper near a metric reference (Fig. 1).

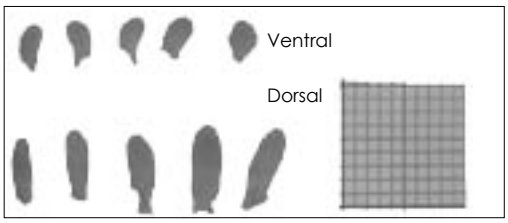

Figure 1
Ventral and dorsal sac rumen papillae

Five digital photos for each sample were taken and then developed the ArcGIS™ software to calculate the area of rumen papillae. The surface enlargement factor (SEF) was

calculated on the basis of the following formula:

SEF = 2MPSA x D + 1

where D is the density of papillae and MPSA is mean papillary surface area (cm^2) (7).

Even if the study is in a preliminary stage, an analysis of variance (ANOVA) was performed to test both the differences among various diets and between rumen dorsal and ventral wall samples and *post hoc* analysis was conducted using the Tukey's b and Hochberg test to determine sensitivity. Statistical significance was set at $p \leq 0.01$.

Ecological and productive data of grasslands were collected in a phyto-ecological study (2) of seasonal phytomass growing using the Gratani methods (5).

Results

The results of dorsal and ventral rumen sac papillae measurements are shown in Figure 2 and descriptive statistics are given in Table I, in which the SEF values are also shown. The density of papillae was 80/cm^2 in the milky diet lambs and 65/cm^2 in both dorsal and ventral sacs of the other subjects.

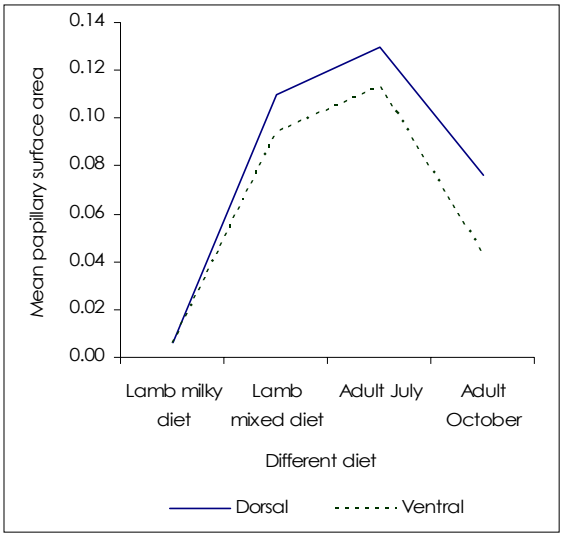

Figure 2
Mean papillary surface area of sheep rumen papillae from the milking stage to the end of the pasture vegetative cycle

Morphometric measurements showed differences among the different samples in relation to different diet. ANOVA and *post hoc* analysis showed significant differences among all groups, with the exceptions of the comparison between dorsal and ventral papillae of milky diet lamb rumen. The Hochberg test did not show a significant difference between the ventral wall sac papillae of mixed diet lambs and adults at the peak of flowering (Table I).

Seasonal phytomass growing referred to the study area is shown in Figure 3.

Discussion

The morpho-physiological variation of the digestive system of ruminants depends on the co-evolution of animals and specific selected forage plants. Therefore, different ruminants show a species-specific optimum link to a range of tolerances revealing an adaptive ability in acute situations of quality and availability of food, feeding and digestion. The rumen papillae at the foetal stage do not differ among animal species. In optimal feeding conditions, after weaning, the rumen foetal papillae assume a leaf or tongue-like shape. Development is affected by alimentary condition and, in cases of imbalanced food intake (qualitative and/or quantitative), instead of presenting an adult shape stage they can have a morphological and physiological involution to the foetal stage, affecting the absorptive capacity of the volatile fatty acids (VFA) derived from cellulose digestion with effects on the general condition of the animal.

Previous studies (7) on the seasonal changes of rumen papillae were performed measuring their mean length and width, but the accuracy of measurements were questionable because:

- the papillae were considered as perfect rectangles
- a long time was required to measure the parameters.

The use of GIS for papillae measurements proved to be rapid, precise and inexpensive and appears to give statistically significant data at lower *p* value compared to those reported by Jiang *et al.* (7).

Table I
Descriptive statistics of papillary surface area

Subject	Mean papillary surface area				Surface enlargement factor	
	Dorsal		Ventral			
	Mean	95% CI	Mean	95% CI	Dorsal	Ventral
Lamb milky diet	0.00624	0.0060-0.0064	0.00612°	0.0059-0.0063	1.9976	1.9792
Lamb mixed diet	0.109514	0.1042-0.1149	0.093847*	0.0907-0.0969	15.2368	13.2001
Adult July	0.129704	0.1262-0.1332	0.112915*	0.0987-0.1272	17.8615	15.6789
Adult October	0.076464	0.0710-0.0819	0.042526	0.0405-0.0446	10.9403	6.5283

CI confidence interval
* no significant difference

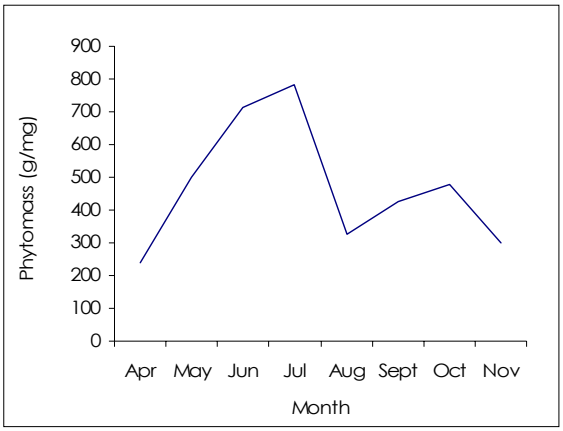

Figure 3
Seasonal phytomass production

Our data confirmed that grass diet promotes the development of rumen papillae due to the effect of VFA produced by cellulose digestion and showed that VFA mainly affect the development of dorsal sac papillae. While the introduction of grass in the diet at the beginning similarly affects the development of both dorsal and ventral sac papillae, which do not show significant differences in the absorptive surface extent, the exclusively grass diet further promotes papillae development until July (Fig. 2), i.e. until the peak of the pasture flowering and growth. In particular, dorsal sac papillae develop more than ventral ones, showing statistically significant differences when compared with dorsal sac papillae of mixed diet subjects. In October, a decrease in absorptive papillae surface occurs with significant differences in both dorsal and ventral sac papillae in comparison to the previous period.

From an ecological point of view, the Apennine grasslands show a productive annual trend with highest production occurring to the peak flowering period (Fig. 3). The graph shows a gradual increase of phytomass during spring until the highest peak at the end of June which corresponds to the flowering peak (4). In the summer, the quantity of phytomass available for flock feeding decreases, due to the death of flowering plants and to the drying (partial or total) of vegetative plants. Only at the beginning of autumn is new productivity observed, due to a brief phase of vegetative renewal which occurs between the end of September and October. Subsequently, in addition to a phytomass decrease, a forage biochemical modification also occurs, due to the increase of lignin (polysaccharide undigested from rumen micro-organisms) percentage with the consequent decrease of both forage digestibility and nutritional supply (3). With the end of the flowering season, a worsening of nutritional value from pastures is seen, at both qualitative and quantitative levels.

A comparison of Figures 2 and 3 shows a similar trend in the development of papillae and the productivity cycle of pastures. The largest rumen papillae are observed immediately after the phytomass and the flowering peak (end of June-July). After this phase, the deterioration of pastures occurs and, simultaneously, the rumen papillae surface extent suffers a rapid decrease which continues for the rest of the summer.

Our results confirm the existence of a close relationship between quality and quantity of phytomass and rumen papillae absorptive surface extent.

Research is in progress to use GIS to correlate several parameters indicating animal welfare (morphometric variations of rumen papillae, dosage of VFA, haematochemical profile, body condition score evaluation) of extensively bred sheep with environmental parameters (landscape patterns, pasture structure and composition, pastoral value of pasture, soil exposure, etc.) both during a pasture vegetative cycle and in different pasture conditions, finalised to build a GIS database designed to contribute to the standardisation of best practices of mountain grassland management.

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