

ANATOMY OF FORAGE PLANT PARTS IN RELATION TO DIGESTION

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ABSTRACT

The objective of this study was to contribute some quantitative information regarding the proportion of cell types and the thickness of cell walls in different plant parts of three major forage species, lucerne (*Medicago sativa* L.), tall fescue (*Festuca arundinacea* Schreb.) and maize (*Zea mays* L.). All plant parts examined contained a significant proportion of cell types with walls which appeared too thick to be completely degraded during the time which plant particles are likely to spend in the rumen; this applied particularly to lucerne stems and maize leaf blades.

KEYWORDS

anatomy, lucerne, tall fescue, maize, digestibility

INTRODUCTION

The thickness and accessibility to microbes of forage cell walls has a major effect on the rate and extent of digestion of forage by ruminants (Wilson and Mertens, 1995). There are large, but as yet inadequately quantified, differences between forage species and between different parts of plants in the proportion of thick-walled cells and in the thickness of the walls. In order to contribute some quantitative data, we have recorded the proportion of different cell types and the thickness of their walls in plant parts of eight of the twelve forage species grown by Wilman et al. (1996). In the present paper we refer to three of the eight species.

METHODS

The three species referred to here are *Medicago sativa* L. cv. Europe, *Festuca arundinacea* Schreb. cv. Dovey and *Zea mays* L. cv. LG2080. The species were grown in identical conditions in a heated glasshouse (mean daily minimum and maximum temperatures 15 and 31 °C, respectively) in each of two years. The experimental treatments comprised all combinations of the species and early v. later harvesting. A randomized block design was used, with two blocks. The results presented here are means of early and later harvesting and of two years and two blocks. The standard errors are derived from the years x treatments interaction.

Seven plant parts are referred to in the present paper: green leaflets and green stems of *M. sativa* (these were 35 and 55%, respectively, of harvested dry matter), green leaf blades and green leaf sheaths of *F. arundinacea* (70 and 24% of dry matter) and green leaf blades, green leaf sheaths and green stems of *Z. mays* (29, 18 and 42% of dry matter). The plant parts were examined in cross-sections 10-15 mm thick, stained with safranin and fast green. The cells in the cross-sections were identified as being either thick-walled but not epidermal (i.e. sclerenchyma and xylem) or thin-walled (parenchyma, including mesophyll, and phloem) or epidermal. When measuring the thickness of the epidermal cell walls, the outer wall measurement included cuticle and was recorded separately from the inner wall measurement because of the big difference in thickness.

RESULTS AND DISCUSSION

The epidermal cells were a small proportion of cross-sectional area in stems, an intermediate proportion in leaf sheaths and a relatively large proportion in leaf blades, particularly those of *Z. mays* (Table 1). The outer walls of the epidermal cells (including cuticle) were the thickest walls recorded in each of the three species and in each plant part (Table 2). These walls are likely to be only partially

digested, partly because of the presence of cuticle, which may be almost indigestible (Monson et al., 1972), and partly because the walls seem much too thick to be fully digested during the time the forage particles remain in the rumen. The estimates of Wilson and Mertens (1995) suggest that less than 1 mm of wall thickness will be digested even if a particle remains in the rumen for 48 hours; on this basis, at least four fifths of the thickness of the outer walls of the epidermal cells of *Z. mays* would pass through the animal undigested. In addition the outer walls of the epidermal cells delay and restrict the access of microbes to the internal tissues of the leaves and stems.

The proportion of thick-walled cells, excluding the epidermis, was lowest in *M. sativa* leaflets and highest in *M. sativa* stems (Table 1). In *F. arundinacea* and *Z. mays* the proportion of these thick-walled cells was higher in the leaf blades than in the other plant parts recorded. The walls of these thick-walled cells were thicker in stems and leaf sheaths than in leaf blades (Table 2). All these walls appeared too thick to be fully digested during the time the particles are likely to be in the rumen. In addition, these cells were typically in tightly-packed blocks, as noted by Wilson and Mertens (1995), which would delay, and to some extent prevent, access by microbes.

Thin-walled cells occupied a large proportion of cross-sectional area in all the plant parts examined, particularly in *Z. mays* stems, *M. sativa* leaflets and *Z. mays* and *F. arundinacea* leaf sheaths (Table 1). In general the walls of the thin-walled cells appeared thin enough and accessible enough to be fully digested during the time the particles are likely to be in the rumen. This also applied to the inner walls of the epidermal cells of the *F. arundinacea* leaf blades and *M. sativa* leaflets.

Quantitative data of the type presented should contribute to a fuller understanding of forage digestion and provide guidance to plant breeders and agronomists who are seeking to increase digestibility.

REFERENCES

- Monson, W.G., Powell, J.B. and Burton, G.W. 1972. Digestion of fresh forage in rumen fluid. *Agronomy Journal* **64**:231-233.
- Wilman, D., Mtengeti, E.J. and Moseley, G. 1996. Physical structure of twelve forage species in relation to rate of intake by sheep. *Journal of Agricultural Science, Cambridge* **126**: 277-285.
- Wilson, J.R. and Mertens, D.R. 1995. Cell wall accessibility and cell structure limitations to microbial digestion of forage. *Crop Science* **35**: 251-259.

Table 1				
Proportion of different cell types in the cross-sectional area of plant parts (%)				
	<i>Medicago sativa</i>	<i>Festuca arundinacea</i>	<i>Zea mays</i>	SEM
		Leaf blades ^z		(15 DF)
Thick-walled	4.6	22.5	26.4	1.26
Thin-walled	78.0	56.5	41.2	1.05
Epidermal	17.4	21.0	32.4	1.06
		Leaf sheaths		(9 DF)
Thick-walled	—	17.0	15.4	0.60
Thin-walled	—	71.9	76.4	1.35
Epidermal	—	11.1	8.2	1.10
		Stems		(11 DF)
Thick-walled	36.6	—	18.3	3.28
Thin-walled	59.9	—	80.7	3.43
Epidermal	3.5	—	1.0	0.30

^z Excluding midribs of *Z mays*.

Table 2				
Wall thickness (mm) in different cell types of plant parts				
	<i>Medicago sativa</i>	<i>Festuca arundinacea</i>	<i>Zea mays</i>	SEM
		Leaf blades ^z		(15 DF)
Thick-walled	1.46	1.21	1.44	0.043
Thin-walled	0.23	0.27	0.34	0.016
Epidermal				
Inner wall	0.29	0.27	0.98	0.021
Outer wall	1.70	4.02	5.03	0.119
		Leaf sheaths		(9 DF)
Thick-walled	—	1.45	2.33	0.078
Thin-walled	—	0.30	0.60	0.031
Epidermal				
Inner wall	—	0.66	2.15	0.105
Outer wall	—	5.10	6.92	0.392
		Stems		(11 DF)
Thick-walled	1.84	—	2.03	0.117
Thin-walled	0.35	—	0.58	0.024
Epidermal :				
Inner wall	1.05	—	1.72	0.104
Outer wall	4.43	—	5.11	0.318

^z Excluding midribs of *Z mays*.