
THE PROCEEDINGS OF THE
NEW ZEALAND SOCIETY
OF
ANIMAL PRODUCTION
VOLUME 62 2002

Some measurements of ruminated forage particles

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ABSTRACT

Regurgitated and reswallowed rumination boli from 6 diets were collected from oesophageal fistulated sheep. After wet sieving, large particles retained on the 4mm sieve were treated with propan-2-ol and examined under a binocular microscope for types of structural damage.

Particle types were identified as leaf, stalf, endodermis and cuticle. Bolus particle composition was different for each diet and for regurgitated and reswallowed material. The overall effect of rumination chewing on bolus composition was to increase the number of stalk particles retained on the 4mm sieve.

Surface area (length x width) of particles was determined. Individual red clover leaf particles were markedly larger than all other particle types. Significant differences in individual particle surface area occurred in 2 ways after rumination chewing. For immature and mature ryegrass diets, surface area in stalk and leaf particles increased respectively but red clover, meadow hay and lucerne chaff showed decreased surface area of stalk particles.

Keywords Sheep; rumination; bolus composition; particle size; chewing damage.

INTRODUCTION

Digestion in ruminants is closely related to feed particle size reduction during ingestion and rumination chewing. Reduction in size is necessary to allow undigested residues to pass out of the rumen (Waghorn *et al.*, 1986) and to facilitate anaerobic fermentation. The effort required to achieve this breakdown varies with diet. For example, John *et al.* (1988) have shown that twice the number of rumination chews are required for the same amount of reduction of fresh regurgitated ryegrass as for meadow hay.

Little is known of the interaction between chewing and the structure of forage. The aim of this paper is to investigate the effect of chewing on large particles regurgitated during rumination. Only particles retained on a 4mm sieve were chosen to study the effect of rumination chewing as this fraction comprises feed particles that require physical breakdown and has the advantages of no input of new particles from other sources.

MATERIALS AND METHODS

Sample boli of regurgitated and reswallowed rumination material were collected from 8 oesophageal fistulated Romney wether sheep (John *et al.*, 1988). The sheep were kept indoors in metabolism crates, fed hourly and sampled twice. daily over 4d. Six diets were fed; 2 fresh ryegrass diets (immature and mature), 2 fresh legume diets (red clover and lucerne) and 2 dried chaffed diets, meadow hay and lucerne hay. It was not possible to collect both regurgitated and reswallowed boli in a single rumination cycle, but all samples were assumed to be derived from the same rumen pool and thus comparable. Boli were bulked across animals and days for each diet and separated into particle sizes by wet sieving (sieve sizes 4, 2, 1, 0.5 and 0.25mm). Particles were treated with propan-2-ol to clarify the tissue.

The effect of rumination chewing was studied by detailed microscopic examination. The propan-2-ol treatment revealed the internal vascular and sclerenchyma bundles as opaque lines within the intact particles. Detailed observations and identification of the origin of the particle within the plant, measurement of the maximum length and width of each particle, and type(s) of internal damage within the particle were made on 100 particles per diet from the 4mm sieve. Representative particle types and damage were also photographed.

RESULTS AND DISCUSSION

Identification of Particle Origin in the Plant

Four categories of particle type were identified: leaf, stalk, endodermis and cuticle. Two distinct types of leaf particles occurred. Both leaf types occurred as flat flexible sheets, but the ryegrasses have parallel venation (Plate 1), in contrast to the net venation of legumes (Plate 2). Stalk particles were rigid blocks of tissue (Plate 3). Endodermis (a cylinder of tissue occuring in dicotyledon stalk) occurred as particles which were flexible, flat ribbons of fine interwoven cells (Plate 4).

Each diet was characterised according to the bolus particle composition (Fig. 1). Leaf and stalk particles comprised over 90% of the ryegrass boli. Both legumes had a small percentage of leaf particles

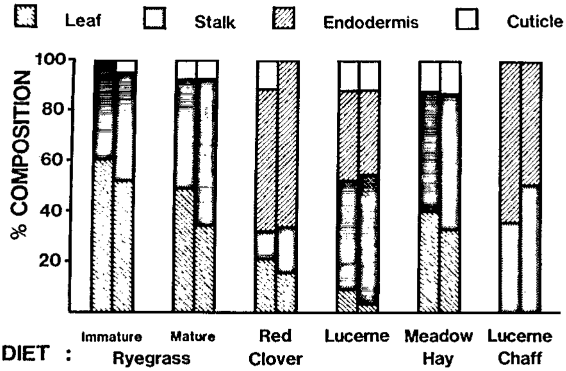

FIG. 1 Composition of ruminated boli of leaf, stalk, endodermis, and cuticle particles. Regurgitated bolus composition, followed by the reswallowed bolus for each diet.

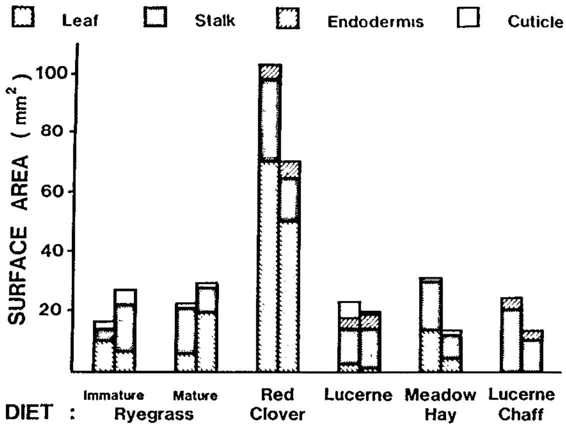

FIG. 2 Average surface area (length x width) of individual leaf, stalk, endodermis and cuticle particles. Regurgitated bolus followed by reswallowed bolus for each diet.

but red clover comprised over 50% endodermal particles in contrast to lucerne with 50% stalk and 30% endodermal particles. The dried diets had reduced leaf particles compared to the corresponding fresh diets.

Rumination chewing decreased the number of leaf particles and increased stalk particle numbers in all diets. Endodermal particle numbers increased in red clover in contrast to the lucerne diets.

Measurements of Lengths and Widths

A binocular microscope fitted with an eyepiece graticule was used at predetermined magnifications (x3, x9.5, x38) to accurately measure the maximum length and width of each particle.

There were differences in length and width of particles between the diets. Surface area, defined by length x width, was used to describe these differences (Fig. 2). Red clover leaf and stalk particles were significantly larger ($P<0.001$) than the other diets. Endodermal particle surface area was small, 4 to 5mm^2, for all legume diets. Lucerne chaff stalk particles were larger than in fresh lucerne or chaffed meadow hay. In contrast meadow hay stalk particle surface area did not differ from that of fresh ryegrass.

When the surface area of each particle type was combined with the composition of ruminated boli, the relative importance of the particles altered. Endodermal particles, which made up a large proportion of the bolus, provided only a small amount of the total surface area available for chewing. Cuticle was negligible. Stalk particles provided the majority of the total surface area in all diets, except regurgitated immature ryegrass and red clover, where leaf particles dominated.

Although there is a large quantitative drop in the total weight of particles retained on the 4mm sieve after rumination (Ulyatt *et al.*, 1986), the effect of chewing on surface area was not always to reduce the size of individual reswallowed particles. Immature and mature ryegrass showed a significant ($P<0.001$) increase in surface area of stalk and leaf particles respectively. Length did not change, but the width was doubled in both particle types in the reswallowed material (Table 1). The apparent increase resulted from the manner in which the ryegrass particles broke apart when chewed and how the particles passed through the sieve. Narrower particles were

TABLE 1 Significant changes ($P<0.001$) in length(mm) and/or width(mm) of individual particles before and after rumination chewing.

Diet	Particle type	Measurement	Regurgitated	Reswallowed	SEM
Immature ryegrass	Stalk	Width	0.52	1.08	0.10
Mature ryegrass	Leaf	Width	0.51	1.08	0.21
Red clover	Stalk	Width	1.78	0.95	0.19
		Length	17.83	12.42	1.48
Meadow hay	Stalk	Width	1.40	0.96	0.12
Lucerne chaff	Stalk	Length	13.23	7.44	1.08

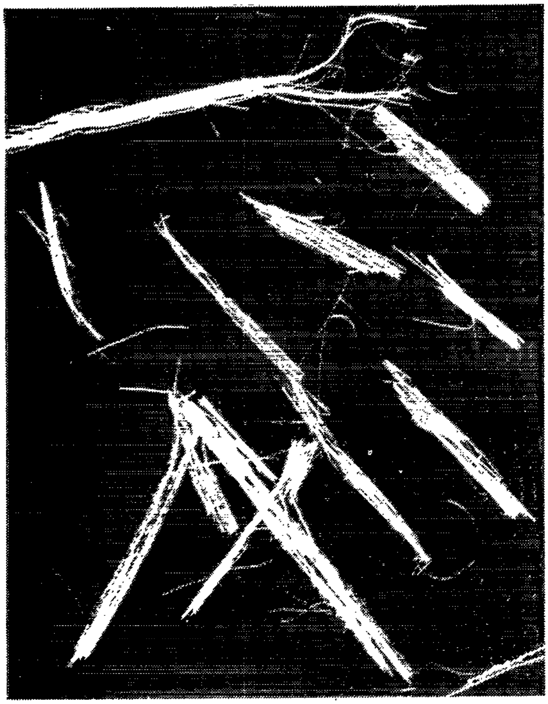

PLATE 1. Fresh ryegrass leaf particles with ripping along the length between vascular bundles (x3).

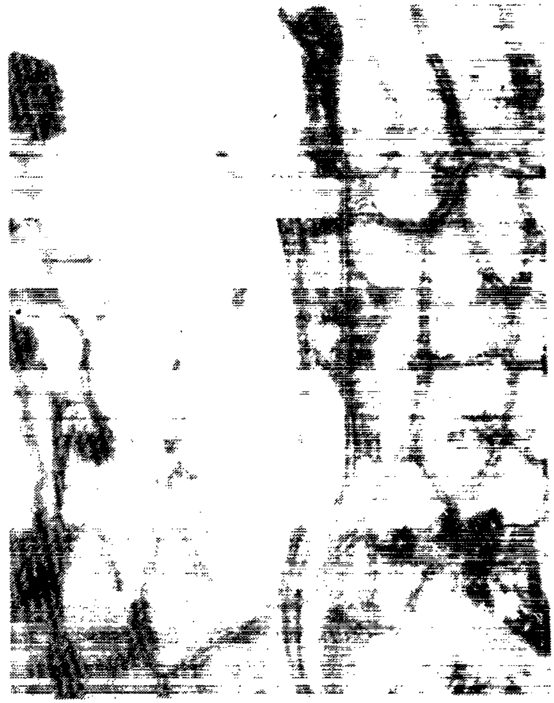

PLATE 2. Fresh red clover leaf particle with leaf blade and vascular tissue removed (x38).

PLATE 3. Fresh lucerne stalk particle ripped cleanly across the vascular bundles (x9.5).

PLATE 4. Dried lucerne chaff endodermal particle with ripping along the length between cells (x 38).

not retained, leaving behind on the 4mm sieve a residue of unchewed and partially chewed particles.

In the other diets, significant ($P<0.001$) decreases in surface area were localised in stalk particles length and/or width (Table 1). The surface area of all other particle types did not change.

The overall composition of the reswallowed bolus in terms of the proportional particle surface area was not altered by rumination chewing in the dried diets or fresh lucerne. Red clover and immature ryegrass had significantly increased proportions of stalk as a result of increased stalk particle size and numbers. Mature ryegrass had a proportional decrease in stalk particle surface area despite increased numbers in the bolus composition.

Observations on Types of Internal Damage

Particles regurgitated for rumination are already damaged by chewing and by microbial action. The large particles remaining after rumination chewing are a mixture of particles that escaped chewing, or even though chewed, remained too large to pass through the 4mm sieve.

Particle damage was defined as either external, as seen at the edges, or internal, within the intact outline of the particle. External damage was similar for all diets with over 70% of all particles having clean cut edges. The incidence of particles with irregular or frayed edges increased after rumination chewing but clean cut edges continued to predominate. Internal damage was clearly visible because of selective penetration of vascular and sclerenchyma bundles by the propan-2-ol into damaged areas. This produced leaf and stalk particles with clarified areas of damage (arrowed in Plate 1) and in the case of clear endodermal tissue, bending damage was visible as opaque bands (Plate 4, arrow) across the width of the particle.

Characteristic types of damage were associated with each of the particle types. Ryegrass leaf particles (Plate 1), with parallel venation, showed a pattern of ripping along the length between the vascular and sclerenchyma bundles, as individual rips or areas of frayed damage. Rips did not occur across the particles. Rumination chewing has not effectively cut across the bundles, indicating they are an area of structural resistance in ryegrass leaf particle breakdown. In legume leaf particles (Plate 2) the net vascular venation was easily damaged. Chewing broke and removed the fine vascular structure producing characteristic holes in the leaf blades.

Stalk particles (Plate 3) were similar for all diets with damaged areas flattened and broken open. Rips occurred across the width and across internal vascular structure without fraying. Chewing damage to stalk particles reduced both length and width, along and across particles producing clean cut edges. The internal structure of stalk particles, irrespective of diet, did not resist chewing breakdown.

Endodermal particle damage (Plate 4) occurred as characteristic bands across the particle from bending and areas of fraying, with rips between cells. No breakage across particles occurred at these damaged areas. Endodermal and cuticle particle numbers and size were unaffected by rumination chewing.

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