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The effect of wilting chicory on its voluntary feed intake and digestion by red deer

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SUMMARY

Two experiments were conducted at Palmerston North, New Zealand during 1997, to investigate the effects of wilting chicory to reduce its bulkiness upon voluntary intake of fresh feed and dry matter (DM), apparent digestibility and voluntary water intake. In Expt 1 fresh chicory was cut and wilted for 48 h to determine the drying rate; wilting for 24 h increased DM content from 87 to 173 g/kg, reduced *in vitro* organic matter digestibility (OMD) by 0·016 ($P < 0·05$) and was selected for use in Expt 2. In Expt 2, chicory was fed either fresh (113 g/kg DM) or wilted (250 g/kg DM) to castrated male red deer kept indoors over two time periods, late autumn and early spring. Chemical analyses showed that wilting slightly lowered the concentration of water-soluble carbohydrate from 185 to 158 g/kg DM, but did not change any other aspect of composition. There were no significant differences between fresh and wilted chicory in apparent digestibility of DM, organic matter (OM), hemicellulose and cellulose. Wilting significantly lowered voluntary intake of fresh feed ($P < 0·01$), but significantly increased voluntary DM intake from 49 to 57 g DM/kg $W^{0·75}$/day ($P < 0·05$). Wilting chicory lowered feed water intake ($P < 0·01$) but increased drinking water consumed ($P < 0·001$), with total water intake still being slightly lower ($P < 0·05$) for deer fed wilted chicory.

It was concluded that wilting chicory increased DM intake by reducing its bulkiness, without seriously affecting digestibility, and it is suggested that the feasibility of breeding forage chicory for higher leaf DM content should be investigated. A comparison with literature values showed that DM contents of fresh forages < *c*. 150 g/kg are likely to restrict the voluntary DM intake of ruminants.

INTRODUCTION

Deer hinds in most parts of New Zealand (NZ) calve after the spring flush of growth of conventional ryegrass/white clover pastures at a time when these pastures are decreasing in nutritive value due to moisture stress (Korte *et al.* 1987). During the late spring/summer period, hinds are in peak lactation. In autumn, when calves are weaned, the calves need a high nutritive value forage to maintain high growth rates, if 92 kg liveweight or 50 kg carcass weight targets are to be met by one year of age (Barry *et al.* 1998). During the summer/autumn period, Puna Chicory (*Cichorium intybus* L.) can be used as specialized forage for deer production (Barry *et al.* 1998), increasing the growth of calves by 16% during summer and 47% during autumn.

Chicory grows at rates up to 200 kg dry matter (DM) ha/day during the summer months and has a relatively constant DM content throughout the year at 90–110 g/kg (Hare & Rolston 1987), which is low compared to ryegrass/white clover pastures (*c.* 200 g/kg). Lloyd-Davies (1962), Vérité & Journet (1970) and John & Ulyatt (1987) have shown a positive relationship between DM content of forage and voluntary DM intake of sheep and cattle, in the range 80–160 g/kg DM, 110–220 g/kg DM and 120–240 g/kg DM, respectively.

Animals may eat forage of very low DM content to a constant wet matter intake, implying that bulkiness (weight or volume per unit weight DM) may restrict DM intake, thus explaining how DM intake of these forages decreases with decreasing DM content (John & Ulyatt 1987). However, correlation is not necessarily causation, and the objective of the work reported here was to investigate whether raising the DM content of chicory through wilting, thus reducing bulkiness, would increase its voluntary DM intake by farmed deer.

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MATERIALS AND METHODS

Experimental design

Two experiments were conducted with chicory (*Cichorium intybus* L., cv, Puna). In Expt 1, chicory was wilted for 48 h to determine the effect of drying time on DM content and upon changes in *in vitro* digestibility. Expt 2 was an indoor trial conducted with artificially reared red deer fed chicory either in the wilted or fresh state, to determine effects on voluntary food intake (VFI), apparent digestibility and water intakes. The first experiment was carried out during March and April 1997, and the second experiment was conducted over the two time periods, April/May 1997 (autumn) and October/November 1997 (spring).

Experiment 1

Chicory was spread on drying racks at a density of 7 kg fresh weight/m^2 in a preheated controlled climate room at 29 °C at the Animal Physiology Unit, Massey University. Duplicate samples of chicory were taken after 0, 3, 7, 11, 24, 27, 31 and 48 h, and were analysed for DM content (100 °C; 24 h) and for *in vitro* organic matter digestibility (OMD).

Experiment 2

Diet

Approximately 360 kg of fresh chicory was harvested daily at 13.00 h; half was wilted and the other half was fed fresh. Chicory was wilted for 24 h as described in Expt 1, but with the density reduced to 3·6 kg fresh weight/m^2 to increase the rate of drying.

Animals and housing

Nine mature artificially reared castrated male red deer were used. Mean liveweight (±S.D.) at the start of period 1 (autumn) was 152 (±31·3) kg, and at the start of period 2 (spring) was 139 (±24·2) kg. Deer were housed in specially designed metabolism crates, similar to those described by Milne *et al.* (1978).

Prior to both trial periods the animals were fed on a conventional perennial ryegrass/white clover pasture. Animals were randomly assigned to treatment groups prior to the acclimatization period. The treatment groups were 'fresh treatment' and 'wilted treatment' groups, with the deer changed between treatment groups for the second period. Acclimatization periods of 10–15 days, respectively, for periods 1 and 2, were used to accustom animals to being housed indoors, to being handled, and to adapt to the test diets. Intake and digestibility measurements were then made over 12 days.

During the acclimatization and data collection periods, the animals were fed *ad libitum* at 08.00 and 17.00 h, with feed offered being 15% greater than consumed on the previous day. Feed residues and faeces were collected daily between 13.00 and 17.00 h, with faeces collection for a particular day being done during the 24 h period after that feeding day concluded. Water intake was measured daily for each animal by weighing buckets and corrected for evaporative losses (by recording weight loss of a bucket of water not offered to the animals).

Sampling

During each period, a daily sample of feed offered was taken and pooled for each treatment at −20 °C. Triplicate samples were also taken for daily DM determination of the feed offered (100 °C; 24 h).

Feed refusals from each animal were weighed daily, a refusal sample being taken from each animal pooled and stored at −20 °C. From the remaining refusals, duplicate samples were taken for daily DM determination (100 °C; 24 h).

All faeces were collected daily, weighed, pooled and stored at −20 °C for each animal from day 2 to day 12 of the data collection period. At the end of the data collection period, faeces were thawed, homogenized and triplicate samples were taken for DM determination (100 °C, 48 h) and a 200 g subsample was taken and stored at −20 °C.

Laboratory analysis

All prepared samples of feed, feed residues and faeces were stored at −20 °C, freeze dried and ground to pass a 1 mm sieve (Wiley mill, USA). Organic matter was measured by ashing in a furnace at 500 °C for 16 h.

Hot water-soluble carbohydrate (HWSC) and pectin were extracted using boiling water and ammonium oxalate respectively, and determined using the method described by Bailey & Ulyatt (1970) Neutral detergent fibre (NDF), acid detergent fibre (ADF) and lignin were determined by the detergent system of Van Soest (1994); hemicellulose was calculated as NDF minus ADF and cellulose was calculated as ADF minus lignin. *In vitro* organic matter digestibility (OMD) was determined by the enzymic method developed by Roughan & Holland (1977).

Statistical analysis

Data were analysed using the General Linear Model (GLM) procedure of the Statistical Analysis System (SAS) computer package (1996). Experiment 2 was analysed as a changeover design, using data for both periods. Least squares mean (LSM) and standard errors (S.E.) for each of the treatments were obtained after first removing between-animal and between-feeding sequence variation.

RESULTS

Experiment 1

The DM content increased from 87·5 to 174 g/kg after 24 h drying, when the chicory was spread at a density of 7 kg fresh weight/m^2 (Fig. 1*a*), and then increased to 549 g/kg after 48 h of drying.

Organic matter digestibility (OMD; Fig. 1*b*) decreased over time (t; h) as shown in Eqn 1.

$$\left.\begin{array}{ll} \text{OMD} = 84{\cdot}6 - 0{\cdot}06\text{t} & r^2 = 0{\cdot}560 \\ \text{S.E.} \pm 0{\cdot}53 \pm 0{\cdot}021 & P < 0{\cdot}05 \quad n = 8 \end{array}\right\} \quad (1)$$

Experiment 2

Wilting increased chicory DM content from *c.* 110 to 250 g/kg, slightly reduced the content of water-soluble carbohydrate, but had no effect on the other components measured (Table 1). Deer fed on wilted chicory (Table 2) had lower voluntary intake of wet feed ($P < 0{\cdot}01$), but had significantly higher ($P < 0{\cdot}05$) voluntary DM intake (56·7 g/$kg^{0{\cdot}75}$/day) than those animals fed on fresh chicory (48·5 g/$kg^{0{\cdot}75}$/day).

Feed water intakes (Table 2) were lower for the deer fed on wilted chicory compared to those of the deer fed on fresh chicory ($P < 0{\cdot}001$), whilst drinking water intakes were higher for deer fed wilted chicory than those fed fresh chicory ($P < 0{\cdot}001$). Deer fed the wilted chicory had a slightly lower total water intake (−19%) than deer fed fresh chicory ($P < 0{\cdot}05$).

Generally the observed *in vivo* digestibilities for the wilted chicory were slightly lower than that for the fresh chicory but, with the exception of lignin ($P < 0{\cdot}05$), none of these were statistically significant.

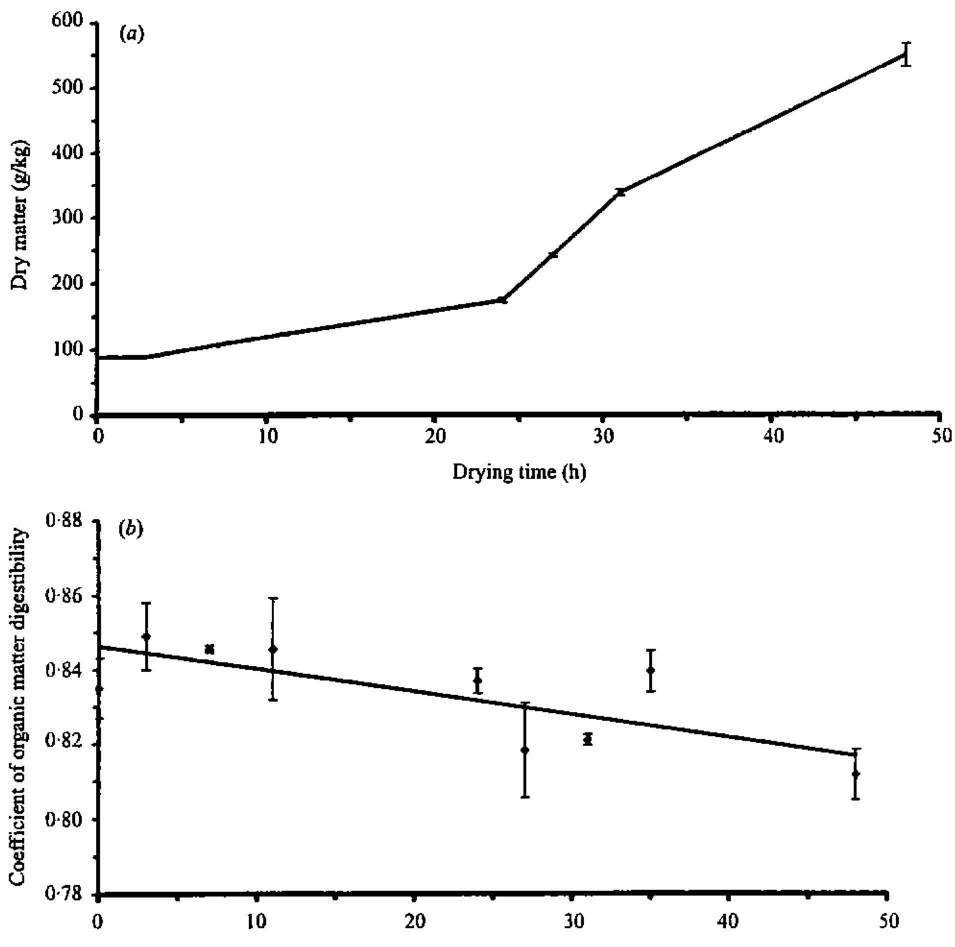

Fig. 1. Experiment 1. Effect of drying time at 29 °C on (*a*) dry matter content and (*b*) organic matter digestibility of vegetative chicory spread on the racks at an initial density of 7 kg fresh weight/m^2. Vertical bars represent the range of duplicate values.

Table 1. *Experiment 2. Dry matter, organic matter, carbohydrate and lignin contents (g/kg) of fresh and wilted chicory fed to deer during period 1 (autumn) and period 2 (spring)*

	Period 1		Period 2	
	Fresh	Wilted	Fresh	Wilted
Dry matter	115·9	268·7	109·4	232·0
Organic matter	868·6	861·9	890·0	884·6
Water soluble carbohydrate	170·3	144·0	200·6	172·9
Pectin	51·9	60·2	77·0	76·5
Neutral detergent fibre	271·8	273·9	222·3	249·1
Acid detergent fibre	190·8	189·7	170·6	189·7
Cellulose	151·5	153·7	127·0	140·5
Hemicellulose	80·9	84·2	51·7	59·5
Lignin	39·3	36·0	43·6	49·1

Table 2. *Experiment 2. Effect of wilting on the voluntary intake and apparent digestibility of chicory by deer*

	Fresh ($n = 9$)	Wilted ($n = 9$)	S.E. (D.F. = 7)
Voluntary intake (g/kg$^{0.75}$/day)			
Wet feed	427·7	263·9	21·14
Dry matter	48·5	56·7	2·16
Drinking water	11·6	104·3	12·00
Feed water	374·3	208·4	20·67
Total water	385·9	312·8	19·85
Coefficient of apparent digestibility			
Dry matter	0·759	0·724	0·0142
Organic matter	0.789	0·755	0·0122
Neutral detergent fibre	0·678	0·646	0·0251
Acid detergent fibre	0·655	0·588	0·0337
Hemicellulose	0·732	0·742	0·0196
Cellulose	0·781	0·741	0·0229
Lignin	0·259	−0·016	0·0722

DISCUSSION

This study shows that low DM content in chicory (113 g/kg) limits voluntary DM intake of this forage by farmed deer. The results of the present study are compared with those from similar studies in Table 3. The low DM content in annual ryegrass (124–130 g/kg) clearly limited voluntary DM intake, by sheep and dairy cows but the higher DM content in annual and perennial ryegrasses (> 150 g/kg) did not limit DM intake. It seems clear that DM content in fresh forages < 150 g/kg restricts voluntary DM intake, with this being true for sheep, dairy cows and deer. However, in the case of deer fed chicory, further experimentation is needed to define the precise DM concentration above which no further increase in VFI occurs.

John & Ulyatt (1987) proposed that animals have a capacity to eat low DM content grasses up to a certain level of wet matter intake. In the present study it was shown that by reducing the bulkiness of the forage through removing some water, there was a higher DMI but a decrease in wet matter intake. Even though the animals on the wilted diet had a significantly lower ($P < 0·001$) feed water intake, this was 56% compensated by drinking more water. Lloyd-Davies (1962) concluded when infusing water directly into the rumen that water *per se* is not the causal factor on limiting VFI when added to a feed. Therefore it is the effect of a high water content withi· the plant cells causing high bulkiness of the feed th. is restricting voluntary DM intake.

Rate of DM clearance from the rumen is normally recognized as being the major limitation to voluntary DMI in ruminants fed forage diets. Particle reduction, rumen digestion rate and rumen outflow rate are all rapid for fresh chicory and are considerably higher than for fresh perennial ryegrass (Kusmartono *et al.* 1996*b*, 1997). This explains why voluntary DM intake is higher for deer grazing chicory than for those grazing perennial ryegrass-based pastures (Kusmartono *et al.* 1996*a*), but it seems that chicory DMI is limited by its bulkiness (and low DM content) rather than its kinetics of rumen degradation, at least for the late and early season material used here.

There was a very small but significant decrease ($P < 0·05$) in OMD in the drying trial (0·016 units at 24 h) but this was not found to be significant in the *in vivo* digestibility trial. Ekern *et al.* (1965) suggested that a decrease in OMD is due to the plant still carrying out the respiration process during wilting, and this is supported by the reduction in soluble sugar content in wilted chicory. The lower apparent lign digestibility in wilted chicory may represent an effec on lignin solubility rather than true lignin degradation. It seems that wilting chicory can be used to increase voluntary DMI, without any significant depression in digestibility.

In a review of all the published information, Barry (1998) showed that livestock production from grazing chicory was considerably higher than from grazing grass-based pastures. However, the present results suggest that it may be possible to further increase animal production from chicory in some circumstances through the use of controlled wilting. Applications of wilting low DM forages especially for deer are that it may be able to be used in a strip grazing management system for lactating hinds in November and December (spring) and for weaners in April and early May (autumn), to meet the high nutritional requirements of these animals. Other potential areas

Table 3. *Summary of published literature on the effect of wilting/dehydration low dry matter content forages upon voluntary intake by dairy cattle, sheep and deer*

Animal species	Forage	DM (g/kg) Fresh	DM (g/kg) Wilted	Coefficient of DM Digestibility	Voluntary Feed Intake ($g\ DM/kg^{0.75}/day$) Fresh	Wilted	Response (%)	Reference
Dairy cows	Annual and perennial grasses	130	D	0·710	—	Δ1·7 kg[1]	13	Vérité & Journet (1970)
		150	D	0·710	—	Δ1·0 kg	8	
		170	D	0·710	—	Δ0·4 kg	3	
		190	D	0·710	—	Δ−0·3 kg	−2	
Sheep	Annual ryegrass							
	August	125	202	0·863	74·2	85·5	15	Wilson (1978)
	October	145	197	0·804	82·5	81·5	−1	
	November	237	300	0·695	77·1	73·3	−5	
Deer	Chicory	113	250	0·742	48·5	56·7	17	Current trial

D, dehydrated at 150–200 °C.
1, Δ, Increase in DM intake of dehydrated over fed fresh in kg/day, calculated from the equation of Vérité & Journet (1970).

where the wilting of chicory could be evaluated are in silage making and as a feed for grazing dairy cows in early lactation, during early spring.

If the low DM content of chicory was shown to restrict livestock production, a possible solution would be to examine whether chicory leaf DM content is a heritable characteristic and, if so, to select for higher plant DM content.

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