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REVIEW

The feeding value of chicory (*Cichorium intybus*) for ruminant livestock

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INTRODUCTION

Chicory (*Cichorium intybus*) is perhaps best known for the extract of its roots used as an ingredient in 'coffee substitute' beverages. It is less well known as a grazed forage for ruminants. Thomas *et al.* (1952) reported the high content of some major and minor trace minerals in chicory grown in the UK, and commented on its use in pasture mixtures as a source of these minerals. Chicory was first mentioned in New Zealand (NZ) literature as an animal forage by Cockayne (1915), but a long period then elapsed before Lancashire (1978) reported its excellent value for forage production under rotational grazing in dry summer conditions. Plant selection then followed and the cultivar 'Grasslands Puna' was approved for commercial release as a grazed forage plant in 1985 (Rumball 1986). The use of Puna chicory has now spread throughout NZ and the variety is also being used commercially in Australia, North America and South America and is being evaluated in parts of Europe and Asia (W. Green, personal communication). Chicory is a herb, whereas other temperate forages used for ruminant production are either grasses or legumes. This paper reviews work on the chemical composition, nutritive value and feeding value of chicory relative to perennial ryegrass (*Lolium perenne*) and to red clover (*Trifolium pratense*), a legume that, like chicory, is used as a forage for dry summer conditions. Throughout this paper, feeding value is defined as the animal production response to grazing a forage under unrestricted conditions (Ulyatt 1973), with its components being voluntary feed intake (VFI), the digestive process and the efficiency of utilization of digested nutrients; the latter two comprise nutritive value/dry matter (DM) eaten.

CHEMICAL COMPOSITION

Puna chicory contains higher concentrations of ash and minerals and lower concentrations of total nitrogen (N) than either perennial ryegrass or red clover (Table 1), but contains very low concentrations of silicon (Crush & Evans 1990). On some soil types the potassium concentration in chicory can be very high (46–92 g/kg DM). Crush & Evans (1990) reported that, relative to perennial ryegrass and white clover, chicory contained similar concentrations of phosphorus, magnesium and copper but higher concentrations of potassium, sodium, calcium, sulphur, boron, manganese and zinc. Both chicory and red clover contain higher concentrations of soluble sugars and pectin (readily fermentable carbohydrates) and lower concentrations of cellulose and hemicellulose (structural carbohydrates) than perennial ryegrass (Table 1). The ratio of readily fermentable

Table 1. *The chemical composition (g/kg DM) of vegetative chicory, compared with that of vegetative perennial ryegrass and red clover*

	Perennial ryegrass	Red clover	Chicory
Ash	105	104	149
Calcium	6·6		14·9
Phosphorus	3·6		3·4
Sodium	0·8		2·1
Potassium	25·5		36·4
Magnesium	1·8		2·8
Total N	45·2	46·9	19·7
Soluble sugar (a)	74	95	111
Pectin (a)	10	39	98
Cellulose (b)	184	115	104
Hemicellulose (b)	212	54	44
Ratio (a:b)	0·21	0·79	1·41
Lignin	10	12	20
Metabolizable energy (MJ/kg OM)	12·3	13·4	13·7
Secondary phenolic compounds:			
Condensed tannin	0·9	1·7	1·7
Sesquiterpene lactones			3·6
Cichoriin			0·5
Chicoric acid			5·8

From Jackson *et al.* (1996), Rees & Harborne (1985), Scales *et al.* (1995).

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carbohydrate:structural carbohydrate is particularly low for perennial ryegrass and higher for the other two forages, with chicory being higher than red clover. Metabolizable energy (ME) concentration is particularly high for vegetative chicory forage.

All three forages contained traces of condensed tannins (CT), but these low concentrations are unlikely to slow the *in vitro* rumen degradation of Fraction I leaf protein (Min *et al.* 1998). Chicory also contains low concentrations of sesquiterpene lactones (lactucin, lactupicrin and 8-deoxylactucin), chicoriin (a coumarin) and chicoric acid (a caffeic acid derivative). These are part of the defensive chemistry of the chicory plant, with sesquiterpene lactones and chicoriin deterring consumption by insects (Rees & Harborne 1985). Sesquiterpene lactones and chicoric acid are also present in root tissue at similar concentrations, and may also function by countering potential infection of the plant by soil-borne micro-organisms.

DIGESTIVE PROCESSES

Digestibility of organic matter (OM) is higher for chicory than for perennial ryegrass, whilst the converse is true for neutral detergent fibre (NDF) digestibility (Table 2). The latter may be due to the much lower rumen pH of chicory-fed animals restricting the activity of rumen micro-organisms degrading cellulose and hemicellulose. Particle breakdown to < 1 mm during eating was similar for deer fed the two forages, but particle breakdown during rumination was much faster for chicory than for perennial ryegrass (Kusmartono *et al.* 1996*a*). The deer which ate chicory required much less time for rumination, with half of these deer showing no rumination at all. This suggests that after chicory has been chewed and swallowed, it then disintegrates extremely rapidly in the rumen, probably due to its high ratio of readily fermentable carbohydrate:structural carbohydrate and low content of silicon. With chicory, less structural support is provided by fibre and more support is provided by pectin as an 'intracellular cement'; the latter seems to degrade very rapidly in the rumen, leading to very fast particle breakdown (Kusmartono *et al.* 1997).

Rumen fractional outflow rate (FOR; %/h) was much faster (and hence mean retention time was much less) for chicory than for perennial ryegrass, for both liquid and particulate matter (Kusmartono *et al.* 1997; Table 2). The faster liquid outflow rate on chicory diets may be a response to the increased osmotic load caused by the high ash concentration in chicory. Thus, chicory was both broken down and cleared from the rumen much more rapidly than perennial ryegrass.

In grazing studies, both the OM and digestible organic matter (DOM) intakes were similar for lambs grazing chicory and those grazing the grass cocksfoot (*Dactylis glomerata*, cv. Grasslands Wana) with 70% of the DOMI digested in the rumen for both forages (Table 3; Komolong 1994). Both N intake and rumen ammonia concentration were lower for lambs grazing chicory, as a consequence of the generally lower N concentration in chicory. However, despite the lower N intake, duodenal flow of non-ammonia nitrogen (NAN) was similar for lambs grazing the two forages, with loss of N across the rumen being lower for lambs grazing chicory (23%) than for lambs grazing cocksfoot (39%). These losses of N across the rumen, due to ammonia absorption, are of the same magnitude as those reported by MacRae & Ulyatt (1974) for the digestion of fresh ryegrasses and white clover by sheep. Duodenal NAN flow/DOMI, a measure of the protein:energy ratio of nutrients leaving the rumen, was similar for lambs grazing chicory or cocksfoot, with the values obtained being similar to those found by Beever *et al.* (1986) and Cruickshank *et al.* (1992) for cattle and sheep grazing grasses but lower than for cattle and sheep grazing legumes. One of the reasons for the reduced rumen N loss with chicory could be increased microbial protein production, as the increased rumen liquid FOR in animals

Table 2. *Kinetics of feed breakdown and outflow from the rumen in red deer fed chicory and perennial ryegrass under indoor conditions*

	Perennial ryegrass	Chicory	S.E.
Composition			
Dry matter (g/kg)	247	161	
Total N (g/kg DM)	30·4	26·9	
Ash (g/kg DM)	102	180	
Apparent digestibility			
Organic matter	0·744	0·820	0·0311
NDF	0·755	0·679	0·0231
Rumen pH	6·44	5·63	
Particle breakdown efficiency			
Eating	0·37	0·27	0·038
Ruminating	0·47	0·65	0·038
Chewing time (min):			
Eating	221	209	49·2
Ruminating	257	30	54·6
Rumen fractional outflow rate (%/h)			
Liquid	13·6	18·9	2·18
Particulate (lignin)	2·78	4·08	0·551
Particulate (ADF)	2·02	4·30	0·506
Rumen mean retention time (h)			
Liquid	8·9	6·4	0·01
Particulate (lignin)	49·0	37·7	9·61
Particulate (ADF)	52·5	27·9	4·66

From Dryden *et al.* (1995), Kusmartono *et al.* (1996*a*, 1997).

Table 3. *Sites of organic matter (OM) and nitrogen (N) digestion in lambs grazing chicory or cocksfoot*

	Cocksfoot grass	Chicory
Liveweight gain (g/d)	205	273
Organic matter (OM intake (g/kg LW daily)	41	36
Digestible OM intake (g/kg LW/d)	34	29
DOM apparently digested in rumen	0·70	0·70
Nitrogen intake (g/kg LW/d)	1·80	1·23
Rumen ammonia (mg N/l)	313	156
Duodenal NAN flow		
g/kg LW/d	1·10	0·95
g/g NI	0·61	0·77
g/kg DOMI	32	33

From Komolong (1994).
NAN, non-ammonia nitrogen.

fed chicory could be expected to increase rumen outflow of microbial protein (Harrison *et al.* 1975). The high ratio of readily fermentable:structural carbohydrate in chicory would also provide increased energy for microbial growth.

There are also seasonal differences in nutritive value between grasses and chicory, and this is best illustrated by *in vitro* OMD in the data of Kusmartono *et al.* (1996*b*); OMD of vegetative chicory remained relatively constant at *c.* 85% throughout the growing season, whereas OMD of perennial ryegrass/white clover pasture peaked at 85% in spring, declined to 70% in summer and then increased to 78% in autumn. Nutritional advantages of chicory over perennial ryegrass/white clover pasture are therefore likely to be greatest over the summer/autumn period.

FEEDING VALUE AND VOLUNTARY FEED INTAKE

Body growth

Chicory has a very strong tendency to move into the reproductive state during summer, and earlier studies in which calves (90 kg) grazed mid-reproductive chicory and mature pasture in summer recorded growth rates of 0·60 kg/day on both forages (Clark *et al.* 1990). Subsequent studies (Table 4) were conducted with chicory maintained in the vegetative state. Relative to perennial ryegrass, the growth of young sheep and deer over the late summer/autumn period was much greater when grazing chicory, with the differences averaging +70% for lambs and +41% for deer. Growth on chicory was faster than growth on the legumes red clover and lucerne, but not as fast as for animals grazing white clover. It can thus be concluded that the feeding value of chicory over summer/autumn is vastly superior to perennial ryegrass, and is between that of white clover and the taller and more stemmy legumes, red clover and lucerne.

The same deer experiments referred to in Table 4 were also continued in spring, when the nutritive value of perennial ryegrass-based pasture was higher and the increases in liveweight gain (LWG) to feeding red clover (+14%) and chicory (+10%) were much smaller. In all these experiments, VFI was generally higher for animals grazing chicory than perennial ryegrass-based pasture, with the differences being larger in summer/autumn than in spring. In the experiments of Kusmartono *et al.* (1996*b*), VFI of deer grazing chicory was higher than that of deer grazing perennial ryegrass-based pasture by 56% during summer, 26% during autumn and 15% during spring. Ulyatt (1973) concluded that approximately half of the higher LWG of young sheep grazing legumes compared to grasses could be explained by the higher VFI, with the remainder being due to the higher nutritive value of legumes. From the evidence available to date, it seems that the higher feeding value of chicory can be explained by higher VFI and higher apparent digestibility, with protein:energy ratio in absorbed nutrients not being a factor (Table 3). However, future studies involving calorimetry are needed, to study the efficiency with which absorbed energy is retained in animals fed chicory compared with those fed grasses and legumes.

Wool growth

Wool growth is well known to be dependent upon the absorption of essential amino acids (EAA) from the small intestine, and particularly the sulphur-containing amino acids. Thus, averaged over 3 years, relative wool growth of sheep fed chicory was higher (130) than on perennial ryegrass (100) but was not as high as on *Lotus corniculatus* (152) or on white clover (144), with increased EAA absorption from the action of condensed tannins probably being a major factor with lotus (Fraser & Rowarth 1996).

Lactation

Early studies with dairy cows fed diets of chicory alone identified a bitter taint in the milk, and for this reason chicory feeding to dairy cows is limited to 2 h/day, generally following the morning milking, to restrict chicory intake to *c.* 25% of the total daily DM intake. Degradation products of the sesquiterpene lactones, namely dihydrolactucin, tetrahydrolactucin and hydroxyphenylacetic acid (HPAA) have been identified as the taint compounds in the milk of chicory-fed cows (Visser 1992). Tetrahydrolactucin

Table 4. *Growth (g/day) of sheep and deer grazing chicory, relative to perennial ryegrass and to the legumes white clover, red clover and lucerne. Data in parentheses are relative to perennial ryegrass as 100, and can be regarded as an index of relative feeding value*

Author	Perennial ryegrass	Chicory	White clover	Red clover	Lucerne
		Lambs (summer/early autumn)			
Scales *et al.* (1995)	182	311 (171)			222 (122)
	134	250 (187)			250 (187)
	(100)	(179)			(155)
Fraser & Rowarth (1996)	128	182 (142)	219 (171)		
	98	181 (185)	225 (230)		
	136	214 (157)	233 (171)		
	(100)	(161)	(191)		
		Deer (autumn)			
Semiadi *et al.* (1993)	192*			263 (137)	
Soetrisno *et al.* (1994)	207*			237 (114)	
Kusmartono *et al.* (1996*b*)	191*	282 (148)			
Min *et al.* (1997)	172*	230 (134)			
	(100)	(141)		(126)	

* Perennial ryegrass/white clover pasture.

and dihydrolactucin are probably formed by hydrogenation in the rumen, whilst HPAA is a degradation product of lactupicrin. A selection programme has now been carried out to produce low sesquiterpene lactone chicory, with a view to feeding this to dairy cows as a greater proportion of the diet. Seed will be available for research purposes in 1999. However, whilst this may solve the milk taint problem, extra care will be needed with management of this plant, as the reduced concentration of sesquiterpene lactones may have lowered its chemical defence against fungal diseases.

MANAGEMENT OF FORAGE CHICORY

Chicory is normally sown at *c.* 4 kg seed/ha. It establishes quickly, using either full cultivation or direct drilling, with best results if sown at a shallow depth (1 cm). Chicory (cv. Grasslands Puna) is winter-dormant, but grows rapidly at other times; with its deep taproot it grows particularly well over summer/autumn, especially under dry conditions. One of the main initial management problems with chicory was loss of plant density with time, with the plant dying out of swards after 2 years. This has now been improved using rotational grazing instead of set-stocking and by not grazing during winter and other periods of prolonged wet weather. A second problem was reduced feed quality due to reproductive growth during summer; this is now reduced by mechanical topping (generally twice) in late summer, to keep chicory in the vegetative state. For good livestock production, research at the Massey University Deer Unit has shown that pre- and post-grazing herbage mass should be *c.* 3500 and > 2100 kg DM/ha for chicory, higher than the values recommended for perennial ryegrass/white clover pasture (*c.* 2500 and > 1750 kg DM/ha). These correspond to initial forage surface heights of *c.* 25–30 cm for chicory and *c.* 10 cm for pasture. Similar conditions are suggested for grazing by other livestock species.

Changes in plant density with time for chicory grazed under these conditions are shown in Fig. 1 (Li *et al.* 1997). Plant numbers still declined with time, but at a much slower rate, and this was accompanied by an increase in the number of shoots per plant, giving a 'rosette' of six shoots per plant after 4 years. This progressively led to a smaller number of larger chicory plants, with bare ground appearing between plants which can be colonized by weed species or (in the case of NZ) white clover growing from buried seed. Li *et al.* (1997) considered that a chicory stand had expired when the density fell below 25 plants/m^2; in Fig. 1 this occurred after 4 years but in drier soils it can be up to 6 years.

Pure swards of chicory were grown to generate the forage mentioned earlier (Tables 2–4), and these required inputs of N fertilizer. Normal inputs at Massey University were 45 kg N/ha when growth commenced in spring, and a similar dressing at 2-monthly intervals throughout the 8-month growing season of chicory in NZ. This could be reduced by sowing with a persistent large leaved variety of white clover (2 kg seed/ha), which will spread to fill the gaps in the chicory stand in addition to fixing N. Optimum growth is attained in high fertility situations, but chicory will tolerate a soil pH range from 4·8 to 6·5 (W. Green, personal communication).

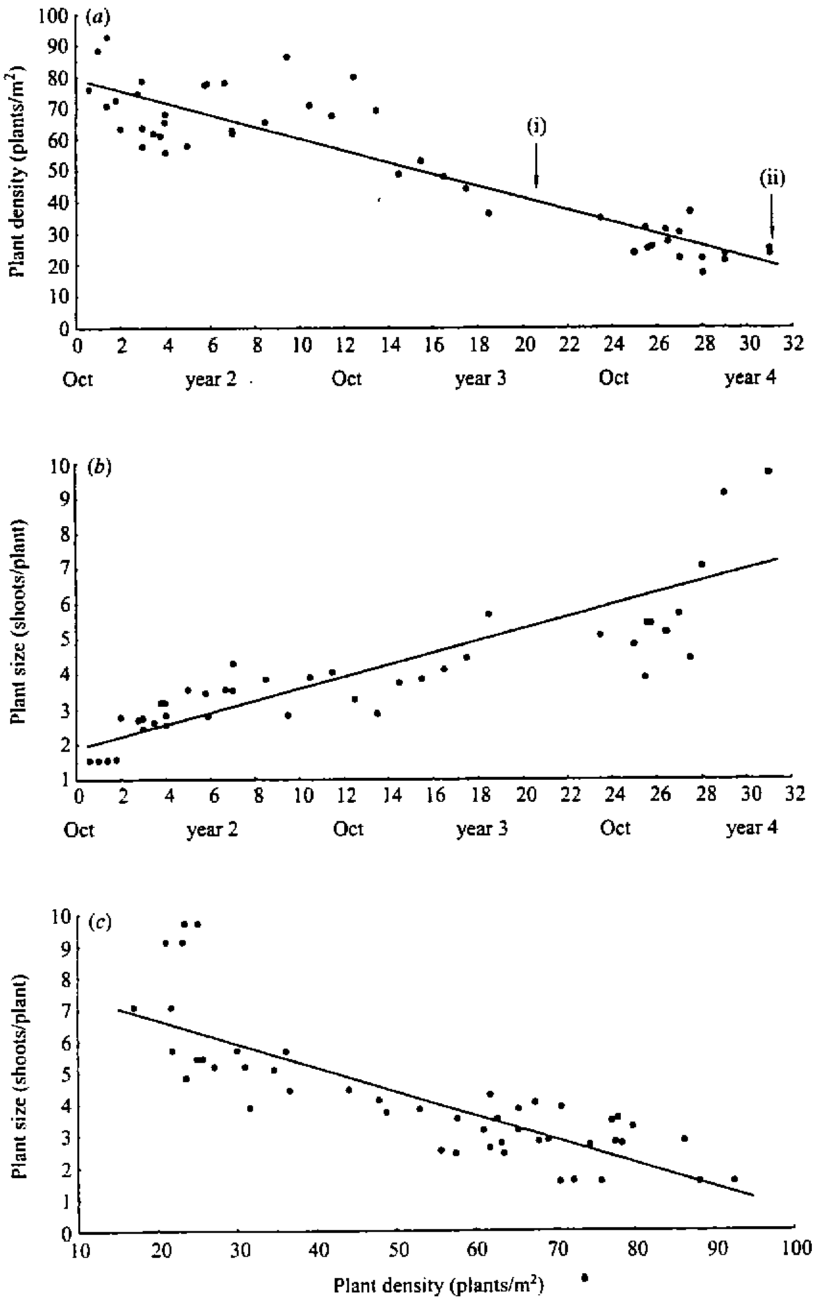

Fig. 1. Plant density and plant size dynamics for chicory over 3 years.
(*a*) plant density versus plant age (month unit), arrows show predicted month for (i) 50 and (ii) 75% losses; $y = 79{\cdot}18 - 1{\cdot}90\,x$, $R^2 = 0{\cdot}82$, $P < 0{\cdot}01$;
(*b*) plant size versus plant age (month unit); $y = 1{\cdot}88 + 0{\cdot}17\,x$, $R^2 = 0{\cdot}74$, $P < 0{\cdot}01$;
and (*c*) plant size versus plant density; $y = 8{\cdot}15 - 0{\cdot}075\,x$, $R^2 = 0{\cdot}66$, $P < 0{\cdot}01$. From Li *et al.* (1997).

ANIMAL HEALTH

Chicory has been associated with a number of advantages in the health of grazing animals, relative to grasses or legumes. Firstly, chicory does not cause bloat when fed to cattle. Bloat is caused by a high solubility of forage proteins leading to the development of a stable foam in the rumen (Mangan 1959), and is especially prevalent on legumes during spring. Possible reasons why chicory is non-bloating include the high rumen liquid FOR, which will reduce the residence time of soluble protein in the rumen, and the low rumen pH, which may reduce foam stability. Compared to sheep grazing grasses, grazing chicory has also been associated with reduced effects of internal parasites in depressing growth (Scales *et al.* 1995). Compared with animals receiving regular anthelmintic treatment, parasitized lambs showed reduced growth on grasses but not when grazing chicory. Fewer infective larvae/kg forage DM were present on chicory than on the grasses, and this was associated with lower faecal nematode egg counts in lambs grazing chicory. Similar results were reported for weaner deer during autumn, where the withdrawal of regular anthelmintic treatment dramatically reduced LWG of deer grazing perennial ryegrass-based pastures but had no effect on the LWG of deer grazing chicory (Hoskin 1998). Moss & Vlassoff (1993) seeded different herbage species with strongylate nematode eggs from sheep and recovered fewer nematode larvae from chicory than from grass and the other herbage species. One of the reasons for reduced parasite problems with chicory is probably its taller growth habit relative to grasses, with fewer infective larvae reaching the stratum that is consumed by grazing animals. Another possible reason is that some of the secondary phenolic compounds in chicory may inhibit the growth of infective larvae and this is an area for future research.

OTHER FORAGE HERBS

Plantain (*Plantago lanceolata*) and sheeps burnet (*Sanguisorba minor*) are herbs that have also been evaluated as forages in NZ. Plantain leaves have both a high ratio of readily fermentable:structural carbohydrate (1·28) and OMD (0·85), similar to chicory, and contain 14 g condensed tannins/kg DM (Jackson *et al.* 1996). However, both LWG and wool growth from grazing lambs are much lower than found for chicory and are similar to those found for lambs grazing perennial ryegrass (Frazer & Rowarth 1996). These authors considered plantain to have a low palatability, perhaps due to its content of aucubin or other secondary compounds. Both plantain and sheeps burnet are low yielding relative to chicory and neither have made an impact upon pastoral ruminant animal production.

CONCLUSIONS

For successful use, forage chicory requires a different management from conventional perennial ryegrass-based pasture. Management procedures have been defined and, with their use, a chicory stand will persist for a minimum of 4 years. When utilized under these conditions, chicory is of high feeding value and will promote a faster rate of animal growth over the late summer/autumn period than that from grass-based pastures and slightly faster than from grazing the legumes red clover or lucerne. The reasons for its high feeding value are discussed. The animal health advantages of chicory are that it is non-bloating to cattle and problems with internal parasites are substantially reduced, compared with grass-based pastures. Chicory is currently recommended for feeding to dairy cattle at *c.* 25% of the total diet, due to sole diets of chicory causing tainting of the milk. The compounds causing the taint have been identified and plant selection to lower the concentrations of these compounds has been completed. Chicory (cv. Grasslands Puna) is winter-dormant, but is of particular value as an alternative forage for promoting rapid animal growth over the summer/autumn period, particularly under dry conditions. It can be sown as a pure crop, with N supplied by fertilizer, or as a mixture with white clover to reduce fertilizer N requirements.

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