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Why is clover better than ryegrass?

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ABSTRACT

This review quantitatively compares the nutritive value of ryegrass and clover. It confirms that the animal performance on clover is on average 40% higher than on ryegrass. It establishes that although the digestibility of clover is less affected by stage of vegetative growth than ryegrass, the digestibility and metabolisable content of the two species is little different when compared at a young vegetative stage. Although the crude protein content of clover is often higher than that of grass the ratio of metabolisable protein to metabolisable energy supply is similar from the two forages. Despite a similar metabolisable energy content, the utilisation of metabolosable energy for growth is higher for clover than ryegrass. This may be due to a greater proportion of energy digestion in the small intestine. Most of the elements of ingestive behaviour, bite size, biting rate and intake rate are greater for clover than ryegrass and consequently the total gazing time and thus cost of harvesting clover are lower. The review concludes by estimating the relative contribution of increased efficiency of utilisation, reduced costs of ingestion and increased intake to the higher animal performance from clover.

Keywords: nutritive value; clover; ryegrass.

INTRODUCTION

Perennial ryegrass and white clover are the dominant species in the majority of New Zealand sown pastures. The higher level of animal performance of animals grazing clover dominated pasture than those with high ryegrass content (Waghorn & Clark, 2004) and the strong positive partial dietary preference for clover versus ryegrass by sheep, cattle and goats (Edwards *et al*., 2008) has long been recognised. It is critical for the future development of a more sustainable mix of clover and ryegrass in pastures that the reasons for the stronger dietary preference and higher animal performance on clover be well understood (Parsons *et al*., 1991; Edwards *et al*., 2008).

The objective of this review is to identify the differences between clover and ryegrass and their relative importance so that rational approaches can be taken to resolve these differences.

The review will be in three parts:

a) Differences in the nutritive value of the two plant species.
b) Comparison of the relative costs of ingesting clover and ryegrass.
c) Justification of the difference in voluntary feed intake (VFI) of the two forages.

NUTRITIVE VALUE OF RYEGRASS AND CLOVER

The higher sheep liveweight gain (LWG) from clover than ryegrass, by around 45% (Table 1), is variously attributed in the popular press to a higher digestibility, higher metabolisable energy (ME) value, higher protein content, better protein supply and higher intake

There is evidence that although the ME value of clover may be slightly lower, the efficiency of utilisation of ME from clover for growth is a little higher than from ryegrass. In this regard the nutritive value of clover is better than ryegrass. The most obvious difference between the two diets is the higher proportion of digestion in the small intestine. Evidence for these conclusions is given below.

Digestibility

A difference in nutritive value of ryegrass and clover cannot be attributed to consistent differences in digestibility. Values for the organic matter digestibility of both ryegrass and clover are high (>750 g/kg, see Waghorn & Barry, 1986) and not significantly different when compared at a similar early vegetative stage of growth. However it is well recognised that the digestibility decreases more with plant maturity for ryegrass than for clover (see Waghorn & Barry, 1986).

Metabolisable energy content

The difference in nutritive value between ryegrass and clover cannot be explained by their ME values (MJ ME/kg dry matter (DM)). Where the ME content of clover and ryegrass has been measured (Table 2) rather that estimated from digestibility, values for the two species are similar. Methane production as a proportion of gross energy is similar and the slightly lower mean ME value of clover reflects the slightly higher urinary energy losses with clover (Ulyatt *et al*., 1973).

TABLE 1: Liveweight gain (g/day) of sheep consuming clover or ryegrass.

Herbage species		Difference		Animals	Source
Clover (C)	Ryegrass (R)	(C-R)	(C-R) x 100 / R		
333	226	107	47	Grazing yearlings	Ulyatt (1969)
249	156	93	60	Grazing yearlings	Ulyatt *et al*. (1973)
123	86	37	43	Penned yearlings	Rattray and Joyce (1974)
238	171	67	39	Grazing lambs	Gibb and Treacher (1984)
321	227	94	41	Intact grazing lambs	Cruickshank *et al* (1992)
202	153	49	32	Canulated grazing lambs	Cruickshank *et al* (1992)
226	121	105	86	Grazing lambs	Fraser and Rowarth (1996)
228	182	46	25	Grazing lambs	Speijers *et al*. (2004)
131	81	50	62	Lactating ewes	Venning *et al*. (2004)
309	246	63	26	Suckling lambs	Venning *et al*. (2004)
236	165	71	45	Average	

TABLE 2: Measured metabolisable energy (ME) content (MJ ME/kg dry matter) of clover and ryegrass.

Herbage species		Source
Clover	Ryegrass	
11.8	12.2	Ulyatt *et al*. (1973)
12.3	11.7	Rattray and Joyce (1974)
10.5	11.7	Beever *et al*. (1985)
11.5	11.9	Average

Metabolisable protein supply

In experiments where the flow of non-ammonia nitrogen, a combination of microbial protein and non-degraded dietary protein, from the rumen has been measured in grazing lambs or cattle (see Table 9 in Cruickshank *et al*., 1992) no significant difference was detected in the non-ammonia nitrogen (g) reaching the small intestine per kg digestible organic matter intake.

This lack of a higher nitrogen supply per unit of energy with clover is despite the crude protein or nitrogen content of clover often being significantly higher than ryegrass in the order of 350 versus 250 g/kg DM (see Waghorn & Barry, 1987). When the crude protein content of either ryegrass or clover exceeds around 270 g/kg DM, there is extensive proportional loss of 0.20 to 0.40 of nitrogen from the rumen as ammonia to be excreted as urea (see Cruickshank *et al*., 1992).

Cruickshank *et al*. (1992) identified microbial nitrogen as a proportion of non-ammonia nitrogen facilitating the estimation of metabolisable protein supply per MJ ME (Table 3). Based on this calculation, the metabolisable protein supply per MJ ME from both clover and ryegrass is above the theoretical requirement for growth of lambs or young cattle. The requirement is around 6-8 g metabolisable protein/MJ ME (Brookes & Nicol, 2008). It therefore seems unlikely that the slightly higher supply of metabolisable protein per MJ of ME from clover than ryegrass contributes significantly to its higher nutritive value. A slightly higher proportion of metabolisable protein, of 0.58 for clover and 0.52 for ryegrass, is of dietary rather than microbial origin.

Efficiency of utilization of metabolisable energy and nitrogen

An important indicator of nutritive value is the proportion of the nutrient available for production that is actually retained in the body or as milk. The partial efficiency of utilisation of ME for liveweight gain (k_g) is higher for clover than ryegrass. In serial slaughter experiments Rattray and Joyce (1974) and Thompson *et al.* (1979) measured a higher k_g of 0.51 and 0.41 respectively for clover, whereas the k_g for ryegrass was 0.33 and 0.37 respectively.

Possible explanations for this slightly greater efficiency of utilization of ME for growth from clover are provided below.

Site of digestion

A consistent finding from digestion studies of ryegrass and clover is that there is no significant difference in the proportion of organic matter digestion of ryegrass and clover that occurs in the rumen. Estimates of from 0.52 to 0.65 have been reported (Ulyatt, 1969; Ulyatt *et al*., 1973; Beever *et al*., 1988 Cruickshank *et al*., 1992). In contrast, almost twice as much energy disappears in the small intestine with clover than with ryegrass (Table 4) with a concomitant decrease in the large intestine (Ulyatt & MacRae, 1971). These observations are not intuitive and are discussed further.

TABLE 3: Estimation of the metabolisable protein supply per kg digestible organic matter, from clover and ryegrass. (Based on data from Cruickshank *et al.* (1992)). N = Nitrogen.

Measurement	Herbage species		Calculation
	Clover	Ryegrass	
Non-ammoniaN (g)	45.0	39.2	
Microbial N (g)	21.5	21.0	
Undegraded dietary N (g)	23.5	18.2	(Non-ammonia N - microbial N)
Microbial crude protein (g)	134	131	Assume crude protein = 6.26 x N
Undegraded dietary protein (g)	147	114	
Microbial protein from Microbial crude protein (g)	86	84	Microbial protein = 0.64 x Microbial crude protein
Microbial protein from Undegraded dietary protein (g)	118	91	Microbial protein = 0.8 x Undegraded dietary protein
Proportion microbial protein from undegraded dietary protein	0.58	0.52	
Microbial protein/MJ metabolisable energy	10.6	9.2	19 MJ metabolisable energy/kg digestible organic matter

TABLE 4: Relative proportion of energy digested along the gut in sheep offered clover and ryegrass (Ulyatt and MacRae, 1974).

Digestion site	Herbage species	
	Clover	Ryegrass
Rumen	0.60	0.61
Small intestine	0.35	0.16
Large intestine	0.05	0.23
Total	1.00	1.00

It might be expected that a greater proportion of organic matter be degraded in the rumen with clover than with ryegrass given:

- the higher proportion of readily degradable carbohydrates in clover (Ulyatt, 1969; Burke *et al.*, 2006),
- the faster rate of organic matter degradation in the rumen with clover (0.13 and 0.10, for clover and ryegrass respectively, Barrell *et al.*, 2000) and
- a higher rate of production and rumen concentration of volatile fatty acids (VFAs) with clover, even although the water soluble carbohydrate content of clover is lower than that of ryegrass at typically 80-100 and 150-200 g per kg respectively, (Waghorn *et al.*, 2007).

However, the fast turnover or shorter residence time of digesta in the rumen of six versus ten hours for clover and ryegrass, respectively, (Ulyatt, 1969) means that there is:

- less of the digestible energy degraded to VFAs (25% versus 33%, clover and ryegrass, respectively, Macintosh & Ulyatt, 1970) reflected in a lower rumen degradability of neutral detergent fibre of clover than ryegrass (Cruickshank *et al*., 1992).
- a slightly higher proportion of propionate in the VFAs from clover (24.4%) than ryegrass (21.4 %) (Ulyatt, 1969), although both proportions are sufficiently high to meet requirements for gluconeogenisis (Orskov & Allen, 1966).
- a faster turnover rate in the rumen which should (AFRC, 1993) result in a greater yield of microbial protein per unit of digestible organic matter. It has been suggested that the increased digestion in the small intestine represents digestion of more protein (Rattray & Joyce, 1974). But as was shown by more recent work (see above) the yield of microbial crude protein/kg digestible organic matter is no greater for clover than ryegrass and Ulyatt and MacRae (1971) showed a similar proportion of digestible nitrogen digested in the small intestine for both forage species.

However, if the increased digestion of organic matter in the small intestine represents soluble or even readably degradable carbohydrates that have escaped rumen degradation, but are capable of breakdown in the small intestine and absorption as energy sources, then this could contribute to increased efficiency of ME utilization. There is no quantitative evidence of how this might contribute to the higher k_g for clover than for ryegrass.

Amino acid supply

Although the supply of metabolisable protein per MJ ME from both ryegrass and clover appears to meet the requirements for growth of lambs, responses to supplementary duodenal protein and amino acid mixtures have been demonstrated with sheep offered mixed ryegrass/white clover diets (Barry, 1981; Fraser *et al*., 1990). However, the specific limiting amino acid remains elusive and the possibility that the protein/amino acid supplement acts as an energy supplement is still debated. Any differential response to such supplementation on pure ryegrass and clover diets has not been reported.

The small increase in the proportion of dietary protein retained in yearlings offered clover (0.134 compared with 0.106 for clover and ryegrass, respectively) and the marked increase in their wool growth (24 vs 16 g wool/kg digestible organic matter for clover and ryegrass, respectively, Rattray & Joyce, 1974) would support the concept of a sulphur limiting amino acid but Gibb and Treacher (1984) found the proportion of dietary nitrogen retained was similar for both species.

The biological value of legume protein is slightly lower (57.5) than that of ryegrass (68.0) (Eppendorfer, 1977) so the slightly higher proportion of metabolisable protein from clover originating from the diet is unlikely to be any benefit in terms of amino acid supply.

Liveweight gain and carcass gain

Care must be taken in interpreting differences between ryegrass and clover in terms of liveweight gain which underestimate any advantage to clover because of a higher dressing out percentage (Deaker *et al.,* 1994: Speijers *et* al., 2004) or lower gut fill on clover. For example, gut contents were 0.16 versus 0.23 as a proportion of live weight for clover and ryegrass, respectively (Gibb & Treacher, 1984).

Nutritive value is the *net* benefit of consuming food. That is a benefit in terms of nutrient supply as reviewed above minus the costs of ingestion.

RELATIVE COSTS OF INGESTING RYEGRASS AND CLOVER

Grazing intake expressed as kg DM/head/day, can be defined as:

Grazing intake = Intake rate (g DM/min) x Grazing duration (min/day) (Allden & Whittaker, 1970).

Grazing duration can be further broken down to the product of the duration and frequency of meals, and intake rate itself the product of biting rate and bite mass. The value of these equations is that they can provide some insight into the mechanisms by which ryegrass and clover differ in their apparent nutritive value.

TABLE 5: Ingestive behaviour of lactating ewes grazing perennial ryegrass or white clover swards maintained at a sward surface height of 7 cm (Penning *et al*., 1995).

Measurement	Herbage species	
	Clover	Grass
Live weight (kg)	85	
Bite mass (mg dry matter/ prehension bite)	93	83
Intake rate (g dry matter consumed/minute grazing)	5.9	4.5
Prehension bites/minute	67.1	59.1
Mastication bites/minute	88.9	99.9
Eating time (seconds/g dry matter ingested)	4.1	4.6
Ruminating time (seconds/g dry matter ingested)	5.4	7.9

Intake rate of ryegrass and clover

The first major component of daily intake is intake rate, which is calculated as the product of bite mass and prehension (harvesting) biting rate. Sheep grazing white clover generally have a higher intake rate than sheep grazing perennial ryegrass when pastures are offered at the same sward surface height (Penning *et al.,* 1991; 1995; Edwards *et al*., 1995) (Table 5). In part, this is due to larger bite masses from white clover than ryegrass (Penning *et al*., 1995; Edwards *et al*., 1995). Detailed analyses of the components of bite mass in sheep (Edwards *et al*., 1995) show that the larger bite masses in sheep grazing white clover are in turn due to larger bite areas, as there was little difference in bite depth between ryegrass and white clover when offered at the same pasture height (Edwards *et al*., 1995). Clover also has a greater bulk density in the grazed horizon which contributes to its greater bite mass.

TABLE 6: Comparison of grazing and ruminating behaviour of dry ewes grazing perennial ryegrass or white clover swards maintained at a sward surface height of 7 cm (Penning *et al*., 1991).

Measurement	Herbage species	
	Clover	Ryegrass
Grazing		
Total duration (minutes/24 hours)	355	476
Number of bouts (per 24 hours)	8.8	7.4
Duration of bouts (minutes)	38	68
Inter-bout intervals (minutes)	143	148
Intake per bout (g dry matter)	122	145
Ruminating		
Total duration (min/24hr)	112	261
Number of bouts (per 24 hr)	6.2	10.0
Duration of bouts (min)	16	26

However, the effect on intake rate of larger bite mass may be smaller than expected due to an associated decline in prehension rate as bite mass increases (Penning, 1986; 1991). There is a relatively fixed time cost associated with severing (prehending) each bite that is determined by the time required to open and close the mouth. This is relatively unaffected by bite mass. However, each bite has a variable time cost associated with masticating the bite which increases with bite mass (Parsons *et al*., 1994b; Newman *et al*., 1994).

A lower mastication cost for clover than for ryegrass has more impact on intake rate of white clover than bite mass (Newman *et al*., 1994; Parsons *et al*., 1994; Penning *et al*., 1995). Although sheep spend a similar time per kg DM prehending herbage (approximately 3,500 seconds/kg DM ingested), they spend less time masticating white clover (7,500 seconds/kg DM ingested) than ryegrass (9,600 seconds/kg DM ingested). This can explain why sheep are able to maintain higher intake rates from white clover, using larger bite masses, without substantially reducing prehension rate (Penning *et al*., 1991).

Grazing time on ryegrass and clover

The second major component of daily intake that may differ between perennial ryegrass and white clover is grazing time. Grazing time is an important compensatory mechanism that may counter variation in bite mass and intake rate. However, despite being easy to measure (Penning & Rutter, 2004), less progress has been made in understanding factors controlling the total duration of grazing compared with factors controlling components of intake such as bite mass, bite rate.

Studies with dry sheep (Penning *et al*., 1991) show that although sheep eat clover faster than they can eat grass, they graze in shorter bouts (Table 6). However, the inter-bout interval is similar between white clover and ryegrass, suggesting that a satiety mechanism rather than hunger mechanism regulates bout length. This may reflect the more rapid digestion of clover compared to grass, leading to a faster rise in metabolite load and earlier triggering of a satiety response. Despite, the lower consumption per bout in this example for clover than ryegrass, sheep grazing on clover had more grazing bouts during the day and

TABLE 7: An estimate of the contribution of the lower energy costs of ingesting clover compared to ingesting ryegrass relative to the greater liveweight gain on clover. ME = Metabolisable energy; k_g = Efficiency of utilisation of ME for liveweight gain; k_m = Efficiency of utilization of ME for maintenance.

Measurement	Herbage species		Explanation
	Clover	Ryegrass	
Live weight (kg)	40	40	Finishing lamb/hogget
DM intake (kg/day)	1.28	1.28	Mean from Ulyatt (1969)
Grazing time (minutes/day)	477	695	From Penning *et al*. (1991; 1995)
Energy cost (MJ/day)	0.73	1.07	From Osuji (1987)
Ruminating time (minutes/day)	140	253	From Penning (1991; 1995)
Energy cost (MJ/day)	0.01	0.02	From Osuji (1987)
Total costs (MJ/day)	0.74	1.10	By addition, from Osuji (1987)
Cost saving (MJ/day)	0.36		By subtraction
ME savings (MJ ME/day)	0.52		Assumes k_m = 0.68
Additional energy retention (MJ/day)	0.24		Assuming k_g = 0.46
Additional liveweight gain (g/day)	20		Assuming 12 MJ/kg liveweight gain

TABLE 8: Daily voluntary feed intake of sheep consuming clover or ryegrass.

Herbage species		Difference $\frac{(C-R) \times 100}{R}$	Units of intake measurement	Source
Clover (C)	Ryegrass (R)			
1.15	0.95	21	kg organic matter	Ulyatt (1969)
774	711	9	g dry matter	Rattray and Joyce (1974)
30.0	25.8	16	g/kg live weight	Gibb and Treacher (1984)
33.4	28.8	16	g/kg live weight	Cruickshank *et al*. (1992)
1.77	1.03	71	kg dry matter	Fraser and Rowarth (1996)
1.66	0.98	69	kg dry matter	Speijers *et al*. (2004)
		33	Average	

total intake was the same (13.2 g/kg live weight/day) for both forages.

The interesting point in this example is that sheep do not benefit, in terms of daily DM intake, from being able to satisfy their daily energy requirements in less time grazing clover. However, when faced with more challenging grazing conditions, such as the high energy demand associated with growth and lactation in combination with restricted availability of feeds, the differences between ryegrass and clover may assume greater importance. Animals grazing clover have a greater capacity to extend the duration of grazing to meet energy requirements than do animal grazing ryegrass which may be operating near their maximum. Penning *et al*. (1991) showed that dry sheep eating ryegrass spent more than 12 hours in each day grazing and ruminating while sheep grazing clover spent less than eight hours in these activities. Furthermore, when lactating sheep of high energy intake demand grazed restricted swards at surface height of 3 cm, sheep benefitted from the fact that it takes less time to graze clover than ryegrass, and daily intakes were greater on clover than ryegrass (Penning *et al*., 1995).

Energy costs of eating

The energy costs of time spent grazing and ruminating have been established (see Osuji, 1987). These contribute to the ME requirements of animals. Any reduction in the costs of ingestion means more energy is available for production at any given ME intake. When the costs of grazing and ruminating are applied to the differences in grazing and ruminating times (Penning *et al*., 1991), the reduction in costs of eating clover rather than ryegrass, can be estimated for a particular intake (Table 7). Because the costs associated with eating are a function of live weight, any change in the costs of grazing time has less absolute impact on the energy requirements of small animals than heavier animals. For example, in a 40 kg lamb/yearling (Table 7) the saving in costs when grazing on clover compared with ryegrass is equivalent to the ME required for an additional 20 g liveweight gain per day. We believe that this is the first time that the contribution of the lower cost of ingestion of clover has been credited to a proportion of its superiority in promoting liveweight gain.

VOLUNTARY FEED INTAKE OF RYEGRASS AND CLOVER

The voluntary food intake of growing lambs offered clover is significantly higher by 30% on average, to that of those offered ryegrass (Table 8). The control of, and factors affecting voluntary food intake are still actively debated (Forbes, 1995; Ketelaars & Tolkamp, 1996). Some of the suggested factors do not apply to the ryegrass-clover comparison. For example, higher intake is associated with feeds of higher ME value, and better metabolisable protein:metabolisable energy ratio, neither of which apply to a ryegrass-clover comparison. It has been hypothesised that the higher intake on clover is in response to the faster degradation rate and rumen clearance (Ulyatt, 1969), however, rumen fill does not appear to be a factor which controls intake on highly digestible substrates such as vegetative ryegrass or clover (Thomson *et al*., 1985). There are two potential control mechanisms which do deserve discussion here in regard to the difference between ryegrass and clover.

The concept of “optimal foraging” (Stephens & Krebs, 1986) maintains that organisms will stop eating when the marginal benefits cease to exceed the marginal increase in costs. Blaxter and Boyne (1978) illustrate that the increase in gross efficiency (energy retained/gross energy, ER/GE or ER/ME) is curvilinear and the marginal change (ΔER/ΔME) can be calculated for feeds of known k_g. Making this calculation using the mean k_g values for ryegrass (0.35) and clover (0.46) from Rattray and Joyce (1974) and Thomson *et al*. (1979) shows that the intake of clover would be higher by 0.10 MJ metabolisable energy/live weight$^{0.75}$/day to yield the same marginal increase in ER/ME as ryegrass. For a 40 kg lamb, this increase would promote an additional 60 g liveweight gain/day (based on a k_g of 0.46 and 12 MJ/kg liveweight gain).

The sum of the additional liveweight gain as a result of reduced costs of ingestion and higher intake equate to 80 g/day which is slightly higher than the mean advantage to clover over ryegrass in Table 1.

When voluntary food intake is not limited by the rate of disappearance of digesta, the maximum heat that an animal can dissipate has been suggested to be a limitation to voluntary food intake (Poppi *et al*., 1994). Using k_g values of 0.46 and 0.35 for clover and ryegrass respectively, equivalent heat production associated with liveweight gain would be produced at liveweight gains 58% greater on clover than ryegrass; for example 237 and 150 g/day for clover and ryegrass respectively. This difference is similar to, but slightly greater than the mean difference between the species in Table 1.

CONCLUSIONS

This review concludes that the higher animal performance from consuming clover than from consuming ryegrass is *not* due to a better ME or nitrogen supply per kg eaten. Rather it is the result of a greater efficiency of utilisation of ME for growth. This may reflect the greater proportion of digestion in the small intestine with clover. A significant proportion (close to 30%) of the higher liveweight gain on clover can be attributed to the lower costs of ingestion.

The higher voluntary food intake of clover over ryegrass is unlikely to be due to limitations of digesta disappearance but can be justified on grounds of equal marginal increases in gross efficiency and/or an equal level of heat production of animals consuming the two species.

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