Optimising the intake of feed by pasture-fed sheep and cattle

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Abstract: *Intake of pasture dry matter (DM) by ruminant species is a critical driver of production and profit for any Australian pasture-based business. Pasture allowance (kg of DM/head/day) is positively associated with intake of pasture DM however excessive allowances may reduce utilisation and quality of pasture grown.*

Pasture DM intake (DMI) is a function of time spent grazing x bite size x bite rate. Bite size is a key driver of intake, as influenced by depth of bite into a sward and by density of pasture. Grazing time reflects management factors that influence time spent at pasture and whilst is of lesser importance for more extensively managed sheep and beef enterprises, is becoming increasingly important for some large dairy herds. Debilitating animal health conditions and/or management practices that suppress appetite will further reduce grazing time.

The presentation of appropriate quantities of high quality pasture to animals and the freedom of pastures from anti-nutritional compounds or contaminants that cause a behavioural aversion to the intake of pasture will improve both intake of pasture DM and utilisation of pasture. The supplementation of pasture-fed sheep and cattle with grains or forages will reduce pasture DMI through substitution, as will restriction of intake of drinking water for some classes of grazing ruminants.

Developing a strategy for improved intake of pasture DM requires an understanding of the entire farm system, including the animals and pastures that they graze, stock water access and the concurrent use of supplementary feeds.

Key words*:* intake, pasture, stocking rate, dry matter, sheep, cattle

Introduction

The use of grazing sheep and cattle to harvest pasture *in situ* remains the cornerstone of the relatively simple, low-cost grazing systems of New South Wales (NSW). The diversity of pasture type reflects multiple ecosystems characterised by wide ranging climatic, geographic and topographical parameters. Areas of native and naturalised pastures constrain animal performance (except during drought) as a result of sub-optimal dry matter (DM) yield and quality of pasture. Use of introduced temperate and/or tropical grasses and legumes will potentially enhance animal performance, however efficiencies of use are dictated by rainfall, temperature, elevation, soil types, pests/diseases present and stock classes.

The following key performance indices (KPI) drive the success of pasture-based livestock enterprises:

- Maximum tonnage of pasture grown (kg DM/ha/year) as influenced by pasture species, soil fertility, pH and drainage, topography, rainfall/irrigation and climate.
- Optimum pasture consumed by livestock grazed *in situ* and/or taken as silage or hay (kg DM/ ha/year), expressed as a percentage of pasture grown. Utilisation is influenced primarily by stocking rate (DSE or dry sheep equivalent) per ha.
- Effective conversion of pasture consumed to animal products (liveweight, wool or milk).

Our aim is to balance the effective utilisation of pasture grown with the appropriate delivery of nutrients to an increasingly discerning high performance animal. Exceptional pasture utilisation is achieved by matching livestock demand for pasture with available pasture grown – a challenge given between and within season variability in pasture growth rates and pasture quality.

The inverse association between animal productivity and pasture utilisation can challenge the best pasture manager to strike an appropriate balance between the two KPIs for a business. Inevitably a compromise is reached, with the nutritional demands of pasture-fed, high genetic merit stock not always fully addressed in order to support optimal utilisation of pasture.

Whilst stocking rate remains a key driver of dry matter intake (DMI), further moderators of pasture intake include the health and well being of the animal, grazing management decisions and characteristics of different pasture species.

This paper reviews concepts and ideals for pasture-fed animals with a specific focus on key drivers of DMI. Practical suggestions and ideas for improving the pasture intake of sheep and cattle are discussed.

Drivers of pasture dry matter intake: the animal-pasture interface

The successful conversion of pasture to meat, wool or milk begins with presenting to animals high quality, easy to harvest pasture. High quality pasture does not however always guarantee exceptional levels of animal performance. Multiple interrelating animal-centric factors interact with pasture attributes to collectively determine pasture DMI (Figure 1).

No single pasture, animal or management attribute should be considered in isolation as a potential driver of DMI. Rather each component of the grazing system should be collectively considered, given the multiple interactions between each of these variables.

Dry matter intake (kg DM/head/day) is typically expressed as a function of:

DMI = $R \times S \times T$

Where R = bites/unit time, typically minutes; S = average bite size, typically g DM/bite; T = time available for grazing (minutes/day)

Bites per unit time

The number of bites taken per minute is influenced by both animal and pasture associated factors. Sheep and cattle differ in their time efficiency of pasture harvest. Cattle are more efficient harvesters of pasture because they chew feed less thoroughly before swallowing. Sheep spend more than double the amount of time chewing prehended feed before swallowing –

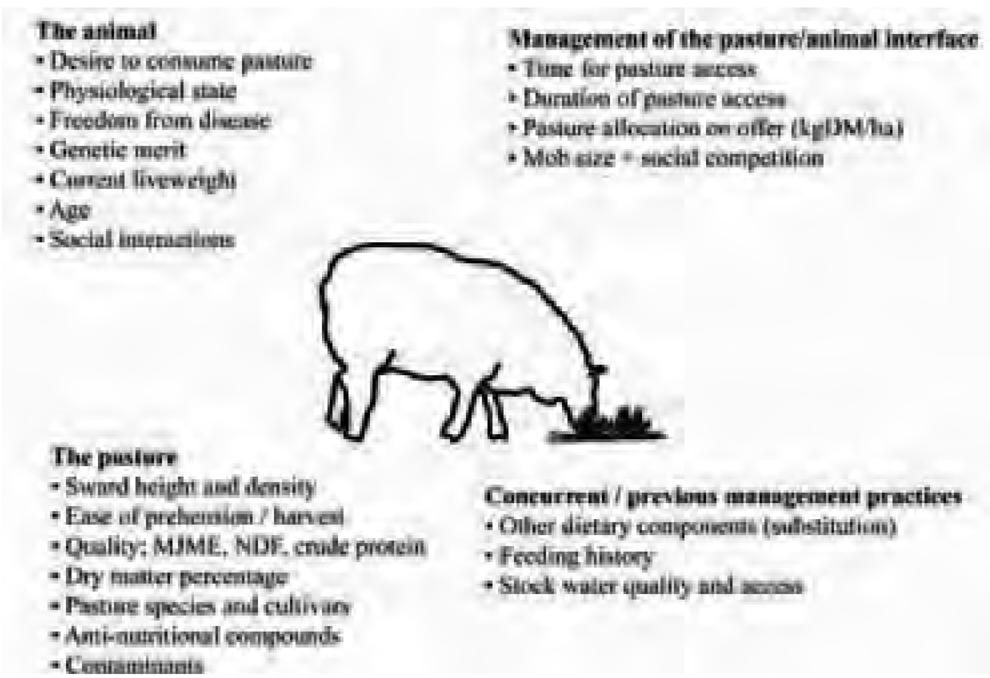

Figure 1. Factors that influence the intake of pasture dry matter by sheep and cattle.

contributing to a relatively slower, less efficient rate of feed consumption. Cattle swallow feed quickly and move on for another bite of pasture, whilst sheep continue to chew and swallow before moving onto their next bite.

An animal's ability to take multiple bites per minute is influenced by the time taken to open the mouth, to tear or bite pasture and to close the mouth. Slower bite rates can occur with higher pasture masses because a greater mass of feed requires more chewing, potentially slowing the rate of bites per unit time. Conversely, sheep (but not cattle) grazing shorter pasture swards can increase daily bite rates as a compensatory means for smaller bite sizes. More bites per day often does not compensate for a smaller bite mass, therefore daily DMI typically falls on short pasture swards.

Dairy cows of high genetic merit have faster biting rates and longer grazing times compared with cows of low genetic merit (Bargo *et al.* 2003) implying potential milk yield and/or body condition benefits for dairy cattle. Potential DMI advantages do not necessarily translate to improved body condition score if greater DMI fails to adequately compensate for the greater genetic drive to produce milk and/or pasture is not offered to cattle in an easy to harvest state.

Leafy, upright, dense, highly digestible pasture can be quickly and effectively harvested within a fixed number of bites per day. High quality pasture is unlikely to directly restrict intake of pasture DM unless pasture allowances are inappropriately low.

Conversely, as pasture grasses mature, flower and reproduce, or lose quality for other reasons including severe frosting and/or leaf loss through senescence, tensile strength and shear time increase, slowing the rate of harvest and decreasing the number of bites per unit time. For intensively managed pasture systems, pre-grazing topping/slashing, a shorter rotation length, strategic nitrogen (N) fertiliser use or removal of poorer quality pasture as silage or hay are all advocated as ways to aid overall pasture DM intake by stock.

Sheep will slow their consumption of pasture when the sward contains predominantly dead material with only a small pick of green leaf, due to the time consuming process of active selection (Forbes 2007*a*).

Surface moisture on external leaf surfaces can change the coefficient of friction, slowing the bite rate by cattle because of slippage of pasture between the incisors and dental pad, contributing to slower swallowing times. This has implications for high performance stock classes such as dairy cattle grazing in wet weather, or following a heavy dew.

Increasing the legume and/or herb component of a mixed pasture sward is a common strategy used to minimise the impact of poor quality grasses on reduced bite rate (and bite size). Grasses with different heading dates, with reduced aftermath heading and tetraploid ryegrasses used in place of diploid cultivars are options to consider when selecting grasses for more intensively managed systems.

Average bite size

Bite size is a function of both animal and pasture characteristics. Cattle will consume more DM per bite than sheep when offered pasture of similar pregrazing mass and height, due to cattle consuming a larger mass of feed per bite. Bite size (200–1100 mg DM/bite for cattle and 83–93 mg DM/bite for sheep) is a key driver of pasture DMI. Animal liveweight does not influence bite rate, but can influence bite size because heavier, larger dairy cattle consumed larger bites than smaller, lighter cattle (Laborde *et al.* 1998).

Physiological state influences bite size because lactating ewes consumed more feed per bite than dry sheep and fasted sheep ate more per bite than non-fasted sheep (Cosgrove and Edwards 2007).

Pasture length (height) and pasture density are important moderators of pasture DM consumed per bite (Figure 2). For temperate pastures, pasture height is the major limiter of bite size, as influenced by bite depth in the sward rather than bite area (Cosgrove and Edwards 2007). Around one third of the height of pasture is removed by a grazing dairy cow (Bargo *et al.* 2003) and between 30 and 50% by beef cattle and sheep, irrespective of pasture height. Reduction of pasture height to inappropriately low levels is an important constraint to DMI by all classes of ruminants, particularly cattle.

The relationship between pasture height and bite size varies with pasture type (temperate *vs* tropical, vegetative *vs* reproductive grass states) and between set stocking and rotationally grazed swards. Care is required when recommending sward heights that optimise DMI. For example, for tropical pasture species, the proportion of green leaf mass: stem present is a more appropriate predictor of probable bite mass than pasture height alone.

Pasture plant and leaf density will influence final bite size as well as bite rate. Bulk density of pasture within the bite catchment is a more important determinant of bite size than plant erectness *per se* (Elliot and Hughes 1991). If density of pasture is low, stock will take more steps between bites and each bite collected may contain less material, limiting total DM intake.

For temperate, ryegrass dominant pastures, optimum pasture heights that encourage the best amount of DM consumed per bite are:

- Set stocked ewes: >4–6 cm
- Set stocked beef cattle and deer: >8–10 cm
- Dairy cattle: >18 cm height

Tall swards do not guarantee more DM per bite because if bulk density of pasture decreases and

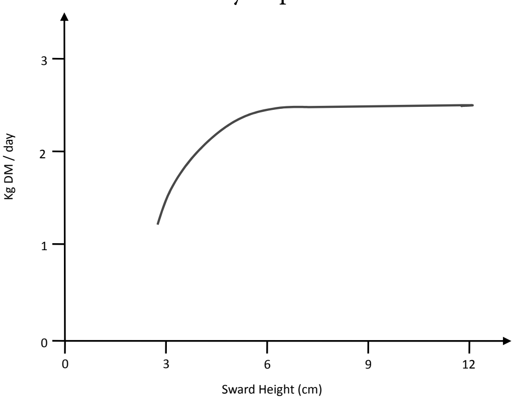

Figure 2. Relationship between sward height and intake of dry matter by sheep grazing temperate pastures (Cosgrove and Edwards 2007).

stalky poor quality pasture is present, stock may consume less feed per bite than a shorter, denser sward. More DM per bite from a taller sward doesn't always translate to a greater intake of DM because as bite mass increases, prehension biting rate can decrease (Cosgrove and Edwards 2007; Figure 3) due to increased chewing time required for a bigger mouthful of feed.

Short pasture may constrain bite size, because there is less feed available per bite. At shorter pasture heights, both grazing time and biting rate can to some degree compensate for a reduced bite mass (g of DM per bite) harvested per bite however it is generally accepted that cattle (unlike sheep), have limited scope to alter bite rate adequately to compensate for reduced bite size.

Pasture species will modify feed consumed per bite because for sheep, bite masses were greater from white clover swards than from perennial ryegrass swards (Cosgrove and Edwards 2007), reflecting a greater bite area and reduced chewing time associated with the consumption of white clovers.

Time available for grazing/motivation of the animal to consume pasture

Time spent grazing is function of:

- Time made available for stock to graze
- The willingness of the animal to effectively utilise available time grazing.

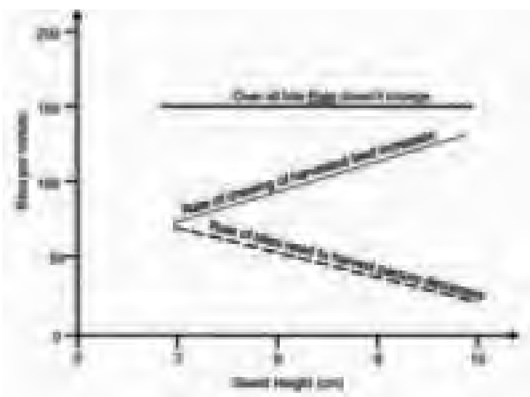

Figure 3. Relationship between sward height and bite rate by sheep grazing temperate pastures (Cosgrove and Edwards, 2007). As sward height increases, fewer bites are needed to prehend feed, but more chews are required per bite to process feed before swallowing.

Time on pasture

For drystock sheep and beef enterprises, time available for grazing is not a common moderator of the *R* x *S* x *T* relationship with stock that are typically continuously at pasture. Inclement weather (heat, rainfall, wind chill) and stock movement towards watering points in extensively managed, larger paddocks will modify grazing time, as will prolonged time off pasture during yarding. Stock can however compensate for time spent away from pasture by increasing grazing time and eating more quickly after returning to pasture (Cosgrove and Edwards 2007).

For dairy cattle, grazing time is considered an important modifier of DMI, particularly for larger dairy cattle herds. With the size of the average Australian herd increasing over recent years, grazing time is becoming a more commonly encountered limiter of pasture DMI. Within larger herds, the effect of daily activities including walking and milking on time available for grazing is greater than for smaller herds. Dairy cattle are unwilling or unable to graze for more than 10–12 hours/day and may have a maximum grazing duration of just over 13 hours/day (Bargo *et al.* 2003). Within a 24-hour day in addition to grazing, cows have a fixed time requirement for ruminating and sleeping. Cattle are unlikely to adequately compensate for restricted grazing time by increasing either bite rate or bite size, therefore net daily pasture DM falls.

Inclement weather

Extremes of temperature outside of the thermoneutral zone (5 to 20°C for cattle; –5 to 35°C, fleece dependent for sheep) will influence the DMI and metabolic activity of pasture-fed sheep and cattle (NRC 2001).

Adverse winter weather events reduce DMI because stock seek shelter in preference to grazing, reducing the daily grazing times, despite increased basal metabolic intensity and an increased drive to consume feed. Wet, muddy conditions reduce pasture utilisation, accentuating the challenge of poor pasture DMI. Selecting free draining paddocks, offering shelter to reduce wind chill, and offering rotationally grazed, break fed animals a larger than normal area of pasture are the standard approaches to managing for very cold, wet conditions.

Conversely, during extreme heat and humidity, stock seek shade in preference to grazing, reducing daily DMI. Acute heat exposure will reduce DMI by pasture-fed stock to a greater extent than chronic exposure to heat because stock are capable of some acclimatisation to heat, however the response to heat is both species and breed dependent. Grazing cattle are on average less tolerant of heat than sheep however heat tolerance is moderated by fleece length, age and physiological state. Under hot grazing conditions, middle eastern sheep breeds including the Awassi will maintain a greater appetite for pasture than Merinos which in turn tolerate heat better than British breeds.

Pasture-fed beef cattle are more tolerant of heat than dairy cattle because heat production by beef cattle is generally less than that of lactating dairy cattle. Under hot conditions, *Bos taurus* breeds cease grazing and seek shelter earlier in the day than *B. indicus* breeds, and crossbreds consumed more total DM than either *B. taurus* or *B. indicus* (Forbes 2007*b*) illustrating the potential benefits of hybrid vigour with regard to heat tolerance at pasture.

For grazing stock, the effects of heat stress are accentuated by concurrent changes in pasture quality. Hot conditions predispose to greater concentrations of cell wall constituents for both temperate (C_3) and tropical (C_4) species. More cellulose, hemicelluloses and lignin increases the heat of fermentation generated during digestion, accentuating the effects of environmental heat stress and reducing voluntary intake of pasture. Strategies that target improved forage quality through management and/or forage selection will potentially reduce the ruminal heat of fermentation.

Ergovaline or ergopeptides produced by perennial ryegrass and tall fescue infected by wild type endophytes, respectively may accentuate the effects of heat stress. Modern cultivars contain endophytes that produce lowered or nil concentrations of ergopeptide alkaloids, offering alternative pastures that reduce risk of heat stress.

During hot weather, offering intensively managed stock relatively greater areas of pasture at night will encourage improved pasture consumption and utilisation. Increased grazing activity can be encouraged by establishing shade areas and salt block locations away from watering points, encouraging stock to graze as they move between shade, salt licks and water during hot weather. Further practical tips regarding the management of pasture-fed dairy cattle through the hotter months are well reported and summarised by www.coolcows.com.au.

Motivation by the animal to graze

Desire to graze is moderated by health and well being, pasture allowance, pasture quality and the freedom of pasture-associated anti-nutritional compounds that restrict the consumption of DM. Factors include:

Physiological state of the animal and the desire to consume pasture. Demand for nutrients is defined by the requirement for energy, protein, macro and trace minerals, as influenced by liveweight (and hence maintenance demands), liveweight gain, pregnancy and/or lactation, and walking during grazing or whilst accessing stock water. Energy and protein demands can be calculated by feed formulation programs, or can be manually calculated in a factorial manner. Sheep and cattle with a greater demand for energy and other nutrients will tend to have a greater 'drive' for DMI to support those needs.

Physical satiety or factors associated with the distension of the alimentary tract. For stock maintained on *high quality*, highly digestible temperate pastures, ruminal distension is an uncommon constraint of DMI. Conversely, for laxly grazed, poor quality pasture e.g. when grasses are heading in late spring, ruminal distension may constrain pasture intakes. Ruminal capacity (or 'stretch') will allow stock to adapt to some degree to high fibre diets, however despite capacity adaptation, high fibre diets remain unsuitable for high performance stock classes including lactating dairy cattle.

Health constraints to DMI. Appetite suppression secondary to illness or injury will limit an animal's ability to effectively graze. Anorexia as a result of hyperthermia (high body temperature) associated with infectious disease, or anorexia secondary to ruminal acidosis, metabolic disease e.g. sleepy sickness pre-lambing or lameness due to e.g. footrot, can reduce the desire to graze.

The sudden transition of stock from poor to high quality pasture may constrain DMI, particularly in cattle. Reduced appetite may reflect sub-clinical or clinical ruminal acidosis. Alternately a learned aversion to high quality pasture may reflect high concentrations of ruminal and blood ammonia that can accompany the abrupt transition from poor to good quality pastures.

Clinical and sub-clinical ruminal bloat will restrict pasture DMI because ruminal distension, frothy or free gas ('feedlot') bloat limits ruminal capacity and the desire to eat.

Temporal grazing patterns and grazing time. Diurnal variation in grazing behaviour modifies both the duration and pattern of grazing activity. Under temperate conditions, most grazing occurs during daylight hours, with the greatest activity during the early morning and late afternoon. During late afternoon grazing, sheep have greater bite masses which combined with greater grazing activity lifts the rate of intake late in the day. For dairy cows, pasture DMI is often greatest in late afternoon/pre-dusk resulting from a combination of increased grazing activity and the greater DM % of pasture at dusk. The nutritional status of stock can be improved by late afternoon grazing because concentrations of water soluble carbohydrates (WSC) in grasses and starches in legumes are typically greatest pre-dusk. Animal species and physiological state moderate grazing patterns because for lactating dairy cows, the greater metabolic 'drive' to eat encourages the active consumption of pasture at night in addition to during the day (Cosgrove *et al.* 2006; Cosgrove and Edwards 2007).

Pasture species further moderate temporal grazing patterns because dairy cows grazing side by side monocultures of ryegrass and clover spent proportionately more time grazing at night than cows grazing either grass only, a grass/clover pasture mix, or grass at night and clover during the day (Cosgrove *et al.* 2006).

Climatic conditions moderate grazing behaviour because hotter conditions are associated with reduced daytime grazing activity, typically compensated for by greater time grazing during the night.

The exact control mechanisms that initiate and terminate a grazed pasture 'meal' remain unknown and most likely reflect multiple factors including concentrations of volatile fatty acids, ammonia and ruminal pH. Taweel (2004) concluded that termination of grazing by dairy cows at dusk was triggered by factors associated with ruminal distension.

Psychogenic effects on grazing time and pasture DMI. The psychogenic regulation of DMI involves the animals behavioural response to inhibitory or stimulatory factors associated with the pasture and/or paddock.

Grazing management techniques can modify behavioural response by stock to pasture and therefore potential DMI. For example, use of electric fencing to break feed pasture may reduce grazing time (and hence intake of pasture) because stock cease grazing despite relatively high post-grazing residuals, in anticipation of being moved onto a new break of pasture.

Palatability of pasture plants also modifies psychogenic regulation of pasture DMI. Stock often express preference for one type of pasture species over another. The rejection or acceptance of less palatable species is a function of soil type, fertiliser use, incidence of plant disease, companion pasture plants present, grazing management and pasture allocation. Less well accepted pasture species are more likely to be consumed when animals are underfed. Table 1 outlines examples of paddock-centric factors that may influence the intake of pasture DM.

Pasture composition and DMI by sheep and cattle

The extremely variable composition of pasture, expressed both as the proportional contribution of various pasture species and cultivars, and as the overall nutritional composition of the sward [DM%, neutral detergent fibre (NDF) and crude protein (CP)] will directly and indirectly influence DMI by grazing ruminants.

The influence of grass, legume and herb species

In sheep, a higher forage DMI is associated with forages characterised by low NDF concentrations with fewer widely spaced and fragile veins (Waghorn and Clark 2004) because less physical damage by chewing is required to reduce particle size of the forage; this relationship will likely be true for beef and dairy cattle also. High quality legumes are desirable components of a pasture sward because legumes contain, on average, greater concentrations of desirable nutrients per kg of DM and have been associated with greater DMI by cattle compared with intakes reported for grass-fed cows. The preferential grazing by cattle of pasture herbs chicory (*Cichorium intybus*) and plantain (*Plantago lanceolata)* established as part of perennial ryegrass/white clover swards is widely reported and is likely associated with a greater total intake of pasture DM.

Digestibility, metabolisable energy content of pasture and DMI

A positive association between pasture digestibility and pasture DMI is generally presumed (Waghorn and Clark 2004). Paradoxically, as pasture DMI increases, the digestibility and megajoules of metabolisable energy content of pasture declines, a function of more rapid rumen outflow rate and reduced extent of digestion of pasture DM. Management practices that encourage higher quality, more digestible pasture swards remain the aim for any high performance pasture system.

Neutral detergent fibre content of pasture and pasture DMI

For Total Mixed Ration (TMR)-fed ruminants, the quadratic correlation between ration NDF content and the potential DMI of animals is well reported. High concentrations of forage NDF can limit DMI, however the rate and extent of NDF degradation will moderate this relationship. Conversely, low NDF concentrations constrain

Table 1. Factors that may contribute to the psychogenic regulation of pasture dry matter intake.

Pasture-centric factors that may adversely influence intake of pasture by grazing cattle
Prostrate pasture species (e.g. grazing brome Bromus stamineus) compared with those with a more upright, erect growth habit (e.g. Italian ryegrass Lolium multiflorum).
Diploid ryegrasses with thinner, less erect tillers consumed less vigorously compared with more upright tetraploid ryegrasses characterised by fleshier tillers and larger leaves.
Perennial ryegrass cultivars that contain the wild type endophyte, producing endophyte alkaloid compounds characterised by reduced consumption of pasture. Newer novel endophyte–ryegrass associations e.g. AR1 or AR37 are generally associated with improved pasture DMI compared with ryegrasses infected with a wild type endophyte.
High pasture contents of sulfur, potassium, and possibly nitrates.
Lower pasture contents of WSC due to recent application of nitrogen fertiliser or cultivar effects (differences in WSC concentrations have been reported between ryegrass cultivars and between tall fescue cultivars).
Presence of disease such as leaf rust or leaf spot on pasture surface or fungi at the base of sward e.g. Fusarium.
Overzealous use of supplementary minerals, e.g. heavy application of fine lime to pasture as a calcium supplement.
Recent application of effluent to pasture or areas of pasture heavily soiled by faeces, cattle appear more adverse to the presence of faeces than sheep to faecal-soiled pasture. Pastures covered with dust or mud may reduce pasture harvesting rates.
Previous grazing in recent days of pasture break with another stock class e.g. calves and associated faecal/urine staining of pasture.
No stock water access in the paddock (importance of this point depends on the DM% and hence water content of the grazed pasture).
Learned response by stock to daily routine of shifting cattle onto a new break of pasture, inhibiting grazing activity on existing break whilst waiting to move onto new break.

energy intake because feedback inhibitors (satiety) limit DMI (Figure 4).

For grazing ruminants, the relationships between forage NDF, rumen fill and pasture DMI are less well understood (Waghorn and Clark 2004), because ruminants can to some extent adapt to the chronic ingestion of high NDF pasture. The rumen contents of pasture-fed New Zealand dairy cows at 70 days after calving was 22% of liveweight compared with 17 and 12% of liveweight for cows in the USA fed pasture or TMR diets, respectively (Waghorn and Clark 2004) suggesting a long-term adaptation by New Zealand cattle to the ingestion of relatively high NDF pastures.

The concentration of dietary NDF is often used as a 'rule of thumb' to predict the potential DMI of cattle and sheep. For TMR fed stock, an upper limit of no more than 1.2% of liveweight as NDF appears to approximately correlate with intake of DMI. This TMR NDF rule-of-thumb is unlikely to apply to stock that consume temperate high quality species because of the relatively greater rate and extent of ruminal degradation of pasture NDF compared with hay and silages (Kolver 1998).

The practical use of NDF as a rule-of-thumb predictor of intake of pasture DM is either inappropriate, or requires the use of alternate coefficient. For dairy cows consuming high quality pasture, an upper limit of 1.5% of bodyweight as NDF may be more appropriate (Kolver and Muller 1998).

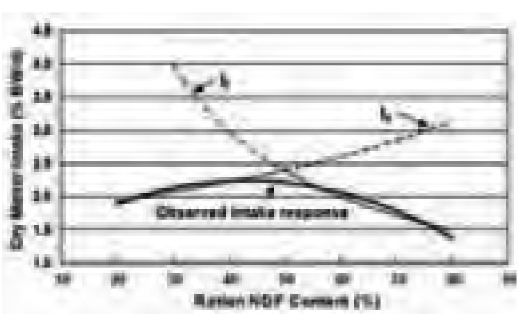

Figure 4. Illustration of intake predicted by simple concepts of energy demand (Ie) and fill limitation (If) when compared with intakes typically observed when ration NDF is varied (Mertens 2009).

Dry matter content of pasture

The DMI of TMR-fed stock is said to be optimised by a target ration DM% of between 40 and 60% DM. With high quality, immature leafy pastures characterised by DM concentrations as low as 11% of wet weight (Stevenson *et al.* 2003) the intake of a high volume of water relative to DM has been proposed as a potential modifier of DMI by stock, particularly when surface water is also present as a result of rainfall, dew or irrigation.

Mechanisms that limit the voluntary consumption of low DM%, wet pastures are unclear but may include a reduced efficiency of harvest of low DM% pasture. For a high performance dairy cow to collect 20 kg DM as wet grass would necessitate a wet volume intake of 200 kg of 10% DM pasture. For a confined cow fed a TMR formulated at 40% DM, wet intake is only 50 kg to provide 20 kg DM, requiring relatively fewer mouthfuls, with less physical exertion and less motivation required. An inefficiency of harvest of low DM% pasture will be less relevant for dry stock that are continuously at pasture.

Ruminal distension caused by excessive intake of water when low DM% pasture is consumed is an unlikely contributor to DMI restriction. The placement of a balloon containing water in the rumen of young growing lambs limited the DMI of dried but not fresh (DM 15–25%) forages (John and Ulyatt 1987). Damage to plant cells during prehension and chewing causes virtually complete release of intracellular water and soluble nutrients, allowing the ready absorption of water.

Fat content of pasture and pasture dry matter intake

An inverse association between the fat concentration of a ration and DMI reflects the effects of both increased energy density of high fat diets impacting on energy satiety and therefore appetite, as well as reduced digestibility of fibre in the presence of higher concentrations of dietary fat. Fat concentrations of high quality leafy pasture may exceed 7% of DM and are characterised by a relatively high proportion of polyunsaturated fatty acids (PUFA), frequently implicated as potent inhibitors of ruminal fibre digestion. Total fat intakes by stock grazing higher quality pastures can exceed the recommended upper concentration of no more than 5% of DM and faeces from these pasture-fed cattle can sometimes appear 'greasy' or 'oily'. The relationship between potentially high PUFA intakes by pasture-fed cattle and pasture DMI requires further elucidation.

Crude protein content of pasture

High concentrations of pasture crude protein are unlikely to moderate DMI of stock unless very high levels of ruminal or blood ammonia contribute to a learned aversion to pastures following an acute change in diet. Low levels of crude protein may contribute to reduced pasture digestibility through inappropriately low concentrations of both total dietary crude protein and rumen degradable protein required to support optimal rumen microbial function. Stock will to some extent adjust to low concentrations of dietary crude protein through improved efficiencies of nitrogen recycling as salivary urea.

Water soluble carbohydrate content of pasture and DMI

The concentration of WSC varies considerably among pasture species and potentially among cultivars of ryegrass and clover (Edwards *et al.* 2007), as well as being influenced by temperature, season and use of nitrogenous fertilisers. The positive correlation between WSC content of pasture and grazing preference is reported anecdotally in the field, yet is not strongly supported by investigations of the association between DMI by cattle and concentration of WSC in pasture species under controlled experimental conditions (Taweel 2004; Edwards *et al.* 2007).

Concentrations of macro minerals

Anecdotal reports suggest that under some conditions, high pasture concentrations of potassium and sulfur may negatively influence the consumption of pasture DM.

Anti-nutritional compounds

Anti-nutritional compounds associated with pasture including mycotoxins and endophyte alkaloid compounds may reduce the consumption of pasture DM by grazing cattle and sheep. Mycotoxins include those associated with fungal growth in dead litter at the base of the sward including *Fusarium* spp. The presence of crown or leaf rust (*Pucinnia coronate*) on the surface of ryegrass plants may reduce the rate and extent of consumption of pastures by grazing cattle. The production of a range of endophyte alkaloids by many 'wild type' perennial ryegrass–endophytic fungal associations are negatively associated with the acceptance of pasture by cattle and sheep. Newer perennial ryegrass–novel endophytic associations produce alternate profiles of endophyte alkaloids that are less likely to negatively impact on pasture DMI of cattle and sheep. Pastures with a high content of nitrate N have been associated anecdotally with a higher incidence of pasture refusal by cattle.

Access to stock water and effects on DMI

Restricted access to stock water and/or reduced water consumption due to undesirable water attributes will influence DMI. Ruminants respond to reduced consumption of water by reducing meal size, possibly as a protective homeostatic mechanism for maintaining the normal osmotic buffer function of the rumen and therefore regulating osmotic balance of body fluids (Burgos *et al.* 2001). The DMI of pasture-fed stock may be less influenced by variable water intake than hay or silage-fed stock because of the relatively greater intake of water consumed from pasture. Very lush pasture that contains water at 85% or more of wet weight may reduce or even remove requirements for supplemental stock water for some stock classes under cool conditions.

The influence of water restriction on pasture DMI is variable, being influenced by pasture DM%, mineral concentrations of both pasture and water (sodium, particularly), ambient temperature, species and breed. Sheep on average consume less water per kg of DM of pasture than cattle.

Water for pasture-fed stock should be of acceptable volume and quality. Undesirable water quality attributes including undesirable taste and odour attributes, dissolved calcium, phosphorus, magnesium and sulfur can affect water intake and therefore, intake of pasture DM. Conversely, excessive intakes of salts, such as sodium chloride, can increase water intake as the animal attempts to eliminate excess sodium with little if any consequence for total daily DMI.

The appropriate location of easily accessible watering points that contain acceptable quality water is an important modifier of potential intake of pasture by stock, particularly under hot environmental conditions.

Conclusions

The successful management of the interface between pasture and the grazing animal is a critical driver of profit for NSW pastoral businesses. Whilst achieving the target 'fine line' balance of achieving optimum pasture DMI by stock and excellent utilisation of pasture is challenging, achieving this balance is an appropriate and attainable target for most pasture-based businesses.

Pasture allowance remains possibly the most important driver of pasture DMI and is one key aspect of pasture management that can be both monitored and controlled by farm managers. For more intensively managed systems including dairying, grazing time is an important moderator of DMI. Grazing time constraints may be relevant for more extensively managed systems, as influenced by extremes of environmental temperature, adverse weather events and proximity of pastures to stock watering points. Bite size as influenced by pasture allowance and bite rate contribute to net daily pasture DMI, *albeit* to a lesser extent than grazing time.

Within the agronomic constraints of an individual paddock or property, pasture should 'ideally' be presented as a high quality, easy to harvest feed and remain free of associated compounds that might otherwise reduce an animal's desire to consume pasture. By allowing stock access to appropriate quantities of high quality temperate pastures for an appropriate length of time, grazed no lower than 4–6 cm (sheep) or 8–10 cm (beef and dry dairy cattle) or 18 cm (lactating dairy cattle) will typically allow stock sufficient bite sizes to support optimal intake of pasture DM, whilst utilising acceptable quantities of pasture grown. Measures of animal productivity including rate of liveweight gain, body condition score and or reproductive indices must be monitored to ensure pasture utilisation is not being achieved at the expense of animal well being and productivity.

Maximising DMI by pasture-fed ruminants requires an understanding of all factors that collectively influence DMI by individual animals, whilst optimising utilisation of pasture grown.

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