SUPPLEMENTARY FEEDS AND FORAGE INTERACTIONS AND THEIR EFFECTS UPON DAIRY COW PERFORMANCE

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SUMMARY

The total organic matter intake of grazing dairy cattle has been shown to be influenced by many factors, of which liveweight, milk yield, stage of lactation, herbage allowance and amount of supplement fed appear to be the most important. Mathematical models are being developed which offer some explanation of the effects of stage of lactation and body condition upon intake and upon substution rate of grass and supplement.

Measurements of the herbage allowance by before and after cutting with the conventional cutter bar mower may seriously underestimate the amount accessible to the grazing animal on some types of swards, so that judgements that the cow's intake was below the maximum may have been in error and the scale of response to any supplement affected.

The short term nature of many trials, and the use of Latin square changeover experimental designs, often underestimates the longer term effects of supplements upon the energy balance of the cow, because of the cow's facility to store excess feed energy as fat, or to mobilise body fat to meet energy deficits.

In the light of current knowledge about the rate of degradation in the rumen of the various fractions of feed, and their effects upon rumen microbial synthesis and rates of passage of digestion, a new approach is needed to the selection of supplements, their amount and timing, when-offered to the grazing dairy cow.

INTRODUCTION

The adequacy of pasture in meeting the nutritional demands of the lactating cow continues to be difficult to assess, largely because of the numerous plant and animal factors which govern herbage intake in a particular situation. These include live weight, milk yield and stage of lactation of the cow; sward structure and density, herbage mass, grazing severity and the availability and nature of supplementary feeds.

Until recently, there was a sharp conflict between the conclusions of research workers and the commercial practice of skilled dairy herd managers as regards the use of supplements for grazing cattle. Leaver et al (1968) in their review of this subject showed that for a range of supplements, the response in terms of milk ranged from 0.16 to 1.0 kg milk/kg supplement, In short term trials, the response was about 0.3 kg milk/kg feed and in longer term trials, 0.5 kg/kg. The range of supplements used was limited ie. oats, flaked

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maize, barley, sugar beet pulp and balanced concentrates. These levels of response have always been uneconomic under UK conditions. The authors did note however that "In nearly all of the experiments quoted up to 1965, ample pasture of good quality was provided for the dairy cows when concentrates were given".

Bines (1976) in his review of this subject, states that "any effect of physiological state on abdominal capacity will affect intake e.g young, fat or pregnant animals will have a reduced capacity compared to older, thin or non pregnant animals". Forbes (1977) developed a mathematical model of the cow which took into account changes in abdominal fat upon rumen capacity in predicting changes in voluntary food intake of the cow. This agrees with the finding that age, liveweight , stage of lactation and milk yield are significant parameters in the prediction of the organic matter intake (OMI) of grazing cows by Curran and Holmes (1970).

The significance of liveweight change as a measure of the overall energy balance of the cow, and the pattern of energy balance during lactation was not appreciated in many experiments executed before 1970, so that no records were taken of liveweight nor any account taken of the carry over effects which changes in energy balance might have had upon subsequent performance. There is good reason therefore to have a fresh look at this subject taking into account developments in our understanding of the composition of feeds, the biochemistry of rumen fermentation and the changing nutrient requirements of the lactating cow. It is not proposed to deal exhaustively with all the factors which can affect the total nutrient intake of grazing dairy cattle, but to comment on those where recent research gives reason to doubt the usefulness of much previously published research work in this field.

FACTORS OF ANIMAL ORIGIN

Stage of lactation, milk yield and liveweight change

The effects of stage of lactation upon milk yield, energy balance and resultant liveweight gain or loss are now much more clearly understood, and the basic pattern of hormonal secretion which controls them is being elucidated, Bines and Hart (1982). In early lactation, the demands of lactation normally exceed food intake, the cow is in negative energy balance and body tisue, mainly fat, is mobilised to meet this need. Unless the energy deficit is excessive, milk yields are rising to the maximum achievable by the amounts of udder tissue carried by the cow. Extra energy intake, if achieved, therefore normally goes towards closing the energy deficit, rather than the production of extra milk.

Liveweight change in the dairy cow, if measured at weekly intervals, can be a useful measure of this energy deficit or surplus and has been quantified by Alderman et al (1982) using the results of a series of continuous whole lactation feeding trials. The use of Latin Square changeover designs is quite common when attempting to measure effects upon food intake and milk yield, but because of the short periods normally used and the effects of gut fill changes, liveweight change data, if recorded is of little vlaue.

In mid and late lactation, when the cow is pregnant, milk yield is steadily declining, and the cow is usually in positive energy balance, i.e partitioning more of the energy intake to the foetus and body reserves and less to milk. In this case also, additional energy. intake will be used for extra liveweight gain rather than milk. The long term consequences of liveweight changes upon the current lactation and upon the next lactation's performance are difficult to model in economic terms but it is increasingly realised that there are carryover effects which must be taken into account. Fat storage and utilisation is a remarkably efficient mechanism for the transfer of feed energy from times of surplus to times of deficit.

Cow potential

The range of milk yields achieved within a herd of cows of superficially similar genetic merit is a major cause of variation in dairy cow experiments, and too often the cause of non significant results. An individual cow's peak yield in a particular lactation is poorly correlated with past lactation performance, but is strongly correlated to the total milk yield achieved within the first 10 days of lactation. A covariance analysis on yield over days 2-10 (with all cows fed the same) is currently used by many research stations in the UK, as a way of reducing animal variation in the final analysis of the results.

It follows that if a cow is able to eat sufficient pasture to achieve her potential milk yield, then looking for responses to supplements on milk yield alone is likely to be fruitless. The question of the potential milk yield of cows used in grazing experiments is therefore very relevant to the results observed. With the general rise in the milk yields of the better herds in the UK, it is now quite common for a herd to be turned out on to pasture with an average milk yield in excess of 25kg/d, beyond what can be supported by pasture alone.

In a recent experiment by Jennings and Holmes (1983) using spring calving cows, the mean milk yield at the start was 29 kg/d. A supplement of 4kg/d of two types of concentrate were fed for 14 weeks. The cows on the control treatment averaged 23.6 nd 24.0 kg/d in two experiments, whilst the supplemented cows averaged 27.1 and 26.4 kg/d. Effects on liveweight change were in the direction expected but were not significant. The effects on organic matter intakes were large and of the same order as the supplement feed, i.e no depression of pasture intake and this was confirmed by no change in grazing time per day recorded.

FACTORS OF SWARD ORIGIN

Whilst the interaction of stocking density on animal production per hectare is understood in principal, it also led to the pursuit-of efficiency of grazing as a desirable objective, accompanied by subjective judgements as to when cows had grazed a pasture down sufficiently to justify their transfer to another paddock. There was also confusion between herbage allowance per cow and the area over -which it was dispersed. Stobbs and his coworkers, Stobbs (1973a, 1973b), showed the importance of number of bites per day and the average size of bite on the achieved dry matter intake of cattle. Be also showed that the number of bites per day rarely exceeded 40,000 when bite size became small due lower herbage allowances. Herbage factors which influence bite size and ease of biting therefore directly influence total pasture intake.

Herbage allowance and herbage mass

Until recently most experiments on the relationship between the herbage intake of dairy cows and herbage allowance, have defined the latter as the weight of herbage per cow per day above the sampling height, which has been about 4 cm i.e that achieved by the use of a standard cutter bar *mower*. Using such a technique, intake has been shown, Greenhalgh et al (1966) and (1967), *to* decline at a progressively faster rate when daily allowance was reduced below 20 kg dry matter per cow. Combellas and Hodgson (1979) suggested that the relationship may differ on different swards since the proportion of total herbage situated close to the ground and therefore difficult to prehend, will be greater on short light canopies than on tall heavy ones. They therefore imposed simultaneous variations in herbage mass per hectare and allowance per cow. They also measured herbage allowance by cutting to ground level with hand shears, rather than the customary 4cm of the cutter bar mower.

Subsequent experiments using spring calving Friesian cows, Le Du et al (1979), led to the conclusions that both DM intake and milk yield were depressed once the cows were forced to consume more than 50% of the herbage on offer or to graze the sward down to a mean height of less than 8-10 cm. Highest levels of milk production per hectare were observed when production per cow was depressed by 20-25%. Liveweight gains were significantly greater on the higher levels of herbage a llowance.

Varations in herbage mass are often confounded with stage of maturity, thus leading to a negative relationship between intake and herbage mass. Combellas and Hodgson (1979) found no significant relationships between herbage mass and recorded intakes, but they do comment that herbage mass levels were relatively high on all treatments.

As a general comment, grazing practice in the intensively stocked dairy herds in the UK would result in herbage allowances below those suggested by Le Du et al (1979) and in stock remaining on the pasture until the sward was grazed down below 8-10 cm height. It may be concluded therefore that herbage intakes will be below the maximum of about 16 kg DM/head/d, capable of supporting milk production levels of about 25kg/d. This would explain both the accelerated decline of milk yield observed in grazing cows, and also suggests the probability that supplementary feeding in commercial practice would be additive rather substituting for grazing, as the experiments of Jennings and Holmes (1983) quoted earlier showed.

Herbage digestibility

Although a linear relationship between digestibility and intake has been observed with fresh herbage fed to sheep up to organic matter digestibilities of 0.80, Minson et al (1864), Osbourn et at (1966), workers with grazing dairy cows have usually found the effects to be small or non significant, partly because the range of digestibilities achievable under normal grazing management of temperate grasses is so small as in the work of Curran and Holmes (1970) referred to earlier. Stehr and Kirchgessner (1976) were able to achieve a range of organic matter digestibilities from 0.64 to 0.80, and showed a highly significant relationship between intake and digestibility.

Lower levels of herbage digestibility are found with some tropical crops used for grazing cattle and they are also more difficult to prehend and masticate, so this effect is confounded with fill effects in the rumen and rate of passage of digesta. The ability of cattle to select leaf preferentially also introduces difficulty in assessing in the digestibility of the feed actually consumed. The use of oesophagal fistulae has proved of value in this respect.

CHEMICAL, COMPOSITION AND STRUCTURE OF FEEDS

The partitioning of the structure of feeds into cell walls and cell contents by van Soest (1964) is helpful in understanding the different effects that feeds have and their different reactions to processing. The cell contents, proteins, sugars, starches, oils, fats and most minerals are regarded as highly digestible, once they are liberated from their containing cell walls. They are rapidly degradable once liberated into the rumen liquid phase. An obvious exception are proteins have been treated with heat or formaldehyde or if tannins are present.

The cell walls, consisting of cellulose, hemicelluloses, lignin and silica, can vary considerably in digestibility, and rate of degradation in the rumen. Because of the negative effect of lignin upon cell wall digestibility, the correlation between cell wall content (CWC or NDF) and digestibility is not good, but its correlation with voluntary intake is quite marked, van Soest (1965).

Chemical composition of the sward

Typical pasture grown under a high fertiliser regime in the UK would be characterised by a dry matter content in the range 150 to 250 g/kg, a crude protein content in excess of 200 g/kg, a cell wall content of 500-700 g/kg and a water soluble carbohydrate of 100-300 g/kg depending on variety and amounts of sunshine at the time. Lignin levels are low and overall OMD levels in the range 0.7 to 0.8. There is a considerable excess of protein above the requirements of the rumen microbes or the host animal, but it is nearly all rapidly degraded once released from its containing cell walls.

DEGRADABILITY OF FEED COMPONENTS

The concept of the degradability of a feed or its components within the rumen, particularly in respect of protein, has received a great deal of attention in the last decade, particularly following the publication of the ARC (1980) proposals for protein requirements of ruminants based on rumen degradable protein (RDP) and undegradable protein (UDP). Whilst easy to define in theory, the measurement of degradability in practice has not been easy, nor the calculation of a value to be used that is realistic. Nevertheless, the dacron bag technique of Mehrez and Orskov (1977) has been widely used to measure dry matter and nitrogen disappearance rates of a wide range of feeds. The derivation of *effective degradability' by taking into account rate of passage of feed particles out of the rumen, Orskov and

McDonald (1979) and MacDonald (1981), should have focussed attention on the consequences of rate of degradation of protein in the rumen. Unfortunately, most of the emphasis has been upon the undegraded fraction, since the ARC (1980) system of calculation predicted a need for additional, undegraded protein to meet the needs of the high yielding cow for amino acids.

It follows that feed components which are rapidly degraded in the rumen, unless some recycling phenomena exists, are only likely to have short term effects upon rumen microbial synthesis. Obvious examples are sugars and starches and non protein nitrogen compounds, especially those in grass silage. Intact protein of vegetable origin if unprocessed is also rapidly degraded once released from its cell walls . Cell walls are more slowly and steadily degraded, depending on the degree of lignification of the cell walls.

Purely in terms of the provision of a balance of substrates to the microbes, which must surely be a requisite of any attempt to maximise '(or optimise?) microbial protein synthesis, then the timing and nature of feed supplements is crucial. The success of frequent small feeds of ground pelletted compound feeds under UK conditions is a practical example of the application of this principle.

Protein degradability can be influenced by heat treatment or by treatment with formaldehyde. Fish meal is probably the best known example of the former whilst formaldehyde treated rape/soya mixtures have been available in France, Germany and UK for sometime. The responses observed, whilst attributed to the supply of extra UDP, have in cases where intakes have been recorded, been accompanied by increased intakes of forage sufficient to account for the yield response observed. If intakes are controlled, and the diets made isonitrogenous, no significant effects are observed.

Kirby (1981) working with heavy weight steers, grass silage and supplements of barley and fishmeal, has shown responses to liveweight gain which are significant, but certainly not predicted by any calculation of a need for UDP. One of the several explanations offered, is that the slow release of amino acids into the rumen from the fishmeal has increased microbial protein synthesis, digestibility, amino acid supply and N retention. Detailed measurements of microbial synthesis and amino acid flow will be needed to understand these results.

There have been suggestions that because of the rapid degradation of grass protein in the rumen, that microbial protein synthesis might be inadequate for milk production. Stobbs et al (1977). Cammell et al (1983) have reported measurements of microbial protein synthesis in fresh grass using ^{15}N, and found an average value of 53g microbial N per kg of OM apparently digested in the rumen, compared to the mean value'suggested by ARC (1980) of 30 g/kg. The use of this value in calculations of amino acid supply to the tissues of high yielding cows would eliminate the need for any supply of undegraded protein in the diet. The degradability of the grass N was estimated to be 0.94.

In the case of the grazing cow, which is taking frequent small feeds of grass or forage, the rapid degradation of protein will not affect the future supply of N for the degradation of the cell walls over a longer time scale, since further intake of N will meet this need. In the case of a supplement however, if it is to have any long term effect upon events in the rumen, rather than just total energy intake per day, it must either be fed frequently in small amounts, or else degrade slowly once in the rumen. Only recently have experiments looked at the latter alternative as will be discussed below. Most supplements have been characterised by rapid degradation, and yet have been fed once or twice a day to the grazing cow.

The effects of various supplements fed to dairy cows must therefore be interpreted against this background of the existing balance of nutrients and their rates of degradation in the rumen.

EFFECTS OF SUPPLEMENTS TO GRAZING COWS

Forbes (1983) has suggested several models for predicting the effect of concentrate input upon voluntary intake of cows. Two models deal with physical control of intake due to rumen capacity and rate of disappearance of digesta and one with metabolic limitation. In the latter case, he expected that concentrates would displace roughage in proportion to their metabolisable energy (ME) content. This leads however to calculated substitution rates of greater than 1 for most typical forages, which are never seen, even with low yielding cows. Thomas (1978) found a mean substitution rate of 0.5 in a summary of 16 trials.

When physical control is operating, which is nearly always the case for grazing cows, Forbes suggests that concentrates would displace forage in proportion to the space occupied by the two feeds and suggests that the best readily available measure *is* cell wall constituents (CWC), neutral detergent fibre. Using typical values of 250 and 650 g/kg DM for concentrates and forage respectively, this gives a substitution rate of 0.38 kg/kg forage.

Alternatively, he suggests that the indigestibility of feeds could be used to express their effects upon rumen fill. For digestibilities of 800 and 550 g/kg DM for concentrates and forage, this gives a substitution rate of 0.44 kg/kg forage. These models also predict that improved forage quality i.e decreased CWC or indigestibility, would result in an increase in the substitution rate as has been observed by Blaxter and Wilson (1963). The data of Leaver (1973) on the substitution rates observed with heifers, are a good fit, over a roughage digestibility range of 0.45 to 0.65, to Forbe's indigestibility model.

Forbes also points out that the water content of a forage adds to its bulk in the rumen, and that wetter forages have a higher substitution rate than dry ones of a comparable digestibility. True water content (as distinct from superficial water) can only be released by rupture of the cell walls by mastication, or bacterial attack on the cell walls.

Concentrates

Most of the supplements used in grazing experiments, with the exception of sugar beet pulp, have been offered in the ground and pelletted form which is conventional usage in the UK. Not only therefore are they characterised by a low cell wall content, being essentially oil cake/cereal mixtures, but the processing has ensured that the cell contents are easily and rapidly available for microbial digestion. Thus the feeding of 4kg of supplement as two feeds 10 hours apart, can be expected to result in a rapid release of soluble sugar, an increase in propionic (and lactic) acid formation, a depression in rumen pH and a degree of inhibition of cellulose digestion for some hours after feeding of the supplement. In the UK, where heavy feeding of pelleted concentrates in the milking parlour was practised, numerous cases of acidosis have resulted which have been corrected by opting for more frequent, smaller feeds and the use of $NaHCO_3$ to maintain rumen pH.

Most of the experiments in the literature where concentrates have been used, give little information as to the feeds in the concentrate, referring perhaps to crude protein content or using the phrase 'balanced' concentrates. Jennings and Holmes (1983) however, used two concentrates, differing in crude protein and oil content to give estimated ME values of 12.0 and 13.6 MJ/kg DM. The higher energy concentrate contained 5% white fish meal, 1% meat and bone meal, and 1.7% blended fat. The results have been discussed earlier, but no significant differences were observed between the two concentrates in the milk yield and liveweight responses.

Sugar beet pulp

Dried sugar beet pulp on the other hand, is not ground but screw pressed, dried and pelletted and has a much coarser structure because of its higher cell wall content, 300-500 g/kg DM depending on whether molasses has been added or not, which is external to the cell wall structures. Sugar beet pulp is highly digestible, due to low lignin levels and Forbes* two models would predict substitution rates of about 0.46 to 0.77 for CWC and 0.45 for indigestibility. The higher value predicted by the CWC model might explain the poor responses to this feed observed by Corbett and Boyne (1958).

Cereals

Barley, oats and flaked maize have been tested as supplements to grazed grass, Castle et al (1960) and (1968) Corbett (1958), using amounts of the order of 3-4 kg/head/d, usually in two separate feeds. The responses have been of the order of 0.25-0.33 kg milk per/kg supplement. Castle et al (1968) varied the stocking rate as well as using a supplement of rolled barley and observed differences in liveweight gain between the high stocking rate group without supplement and the group with supplement or on a lower stocking density. Significant differences in milk yield were also observed. The cows receiving the rolled barley supplement spent one hour less per day grazing and spent more time lying down.

Protein Supplements

If direct adherence is made to conventional digestible crude protein standards for dairy cows, the use of protein supplements for cows at grass or on grass, silage diets with crude protein contents in the range 160-200 g/kg DM is not indicated. The ARC (1980) system of calculating protein requirements would not suggest a need for additional protein (in the form of UDP) until milk yields of the order of 30 kg/d are reached.

Nevertheless, responses to supplements of groundnut meal and *soya* bean meal have been observed with grass silage, Castle et al (1977), Gordon et al (1981) and using formaldehyde treated casein fed to cows grazing Chloris gayana, Stobbs et al (1977) and ryegrass Minson (1981). Oldham (1983) in a review of experiments where crude protein dietary levels were varied showed that additional crude protein above conventional requirement levels, resulted in increases in digestibility of the diet and increased dry matter intake, sufficient to account for the milk yield responses observed.

In the experiments of Stobbs et al (1977), Jersey cows with an average milk yield of 18 kg/d were used, and the feeding of 1 kg of formaldehyde treated casein once a day, produced a 20% increase in milk yield, an increase in liveweight, and a greater degree of rumen fill over control or cows receiving untreated csein. It was concluded that the cows had a higher pasture intake, although the mechanism causing this effect was not clear. Minson (1981) working with ryegrass with a high crude protein content, 288 g/kg DM, found only a 5.3% increase in milk yield, (0.8 kg/d) in response to 1 kg/d of formaldehyde treated casein, but concluded that the response was an energy intake effect, since grazing time was not reduced in the treatment group.

These effects upon intake and digestibility suggest that one possibility is an increase in microbial protein synthesis, however caused. Nor should it be overlooked, that proteins with low degradability characteristics, still release some amino acids into the rumen. Since mean retention times in the rumen would appear to be of the order of 10-12 hours, then such supplements fed once a day will have some ef fect upon the rumen fermentation for a longer period than rapidly degraded supplements such as cereals or concentrates.

Foraees

The feeding of small quantities, 1-3 kg/d of hay or cereal straw to grazing cows in the spring, is common practice in the UK, to maintain butterfat levels, which are often depressed at turnout. There would appear to be little reduction of pasture intake and a small increase in milk yield and/or liveweight gain. This may well be because of the low dry matter content of spring grass, and that hay and straw are air dry, 850 g/kg DM, resulting in a reduced substitution effect, as Forbes (1983) has suggested.

Since grass silage is the major forage for the larger UK dairy herds, and a sequence of favourable grass growing seasons have resulted in carryover stocks of silage in the spring, attention has turned to the use of grass silage as a supplement (or buffer feed) to pasture. Phillips and Leaver (1983) have reported two experiments in early and late season. In the spring, offering silage in amounts which varied from 2-4 kg/head/d, they observed no significant efforts on total DM intake, ie. pasture DM intake was depressed on a 1-1 basis as Forbes (1983) cell wall model would predict. Milk yields were slightly depressed, 20 to 19 kg/d, and liveweight gain increased. Grazing time was decreased and ruminating time increased.

In the autumn, lower pasture DM intakes were recorded for the control group, and the group offered ad lib access to silage, ate 10.4 kg DM of the latter and only 2.6 kg pasture DM. The result was a small increase in milk yield, an increase in liveweight gain, but a decrease in milk protein content. Again, grazing time decreased, but rumination time increased as silage intakes increased.

CONCLUSIONS

With the exception of protein supplements, most supplements offered to the grazing dairy cow result in a reduction in herbage intake, ie a substitution rate of 0.5 or more, although stocking rate and high milk yields can influence this at the extremes. The additional energy intake is partitioned between milk yield and liveweight gain (or a reduction in losses). The short term economic benefits are thus often only a fraction of that required to justify supplementary feeding of the grazing cow.

The realisation that supplementation with intact protein supplements with low degradability characteristics does not depress pasture intake, but may enhance it, is surprising, since the effect is not easily explained by current theories of N supply to the rumen microbes and to the host animal. Nevertheless, it represents an important development in this difficult field of research.

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