SOME FACTORS GOVERNING THE NUTRITIVE VALUE OF BRASSICA CROPS

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ABSTRACT

Liveweight gains of young sheep consuming brassica crops in New Zealand (95-147 g day^{-1}) are considered to be low, in view of the high apparent DM digestibilities (81-89%) and total N content (1.8-2.0% DM or greater). Factors that could be limiting the nutritive value of these crops are discussed, and it is suggested that toxic substances released by the action of chewing or rumen fermentation upon sulphur-compounds present in the NPN fraction could well be limiting animal production. It is further suggested that the quantitative effects upon liveweight gain of the anaemia produced from SMCO fermentation in animals fed kale should be established. Methods available for reducing SMCO content in brassica plants are discussed.

INTRODUCTION

In traditional systems of livestock production in New Zealand the two main uses of brassica crops have been either as a winter feed for breeding sheep or as a fattening feed for lambs during summer and autumn. Kale has been shown to be superior to other brassica crops in terms of DM yield (Scott and Barry, 1972, Drew *et al.*, 1974), and as attention is therefore likely to be focused on this crop for integration into future livestock production systems particular attention will be paid to kale in this review. Where data from kale-fed animals is not available, reference will be made to swede feeding to illustrate the general principles involved. This review will be confined to evaluating brassica crops with young sheep, because most New Zealand data have been collected in this way. However, the general principles developed will also apply to cattle. Because brassica crops have to be integrated into pasture-based farming, comparisons with pasture will be made at intervals.

CHEMICAL COMPOSITION

Total N content in swedes and kale is generally about 2% DM or slightly greater (Table 1), which is lower than found in autumn pasture. Conversly total S content is generally higher than found in pasture, with the consequence that total N: total S ratios are very low in brassicas, especially in kale. Protein forms a lower proportion of total N in brassicas than in pasture. The high content of NPN is of special significance in the nutrition of ruminant animals fed on brassicas, especially in relation to sulphur compounds present in the NPN.

Brassica foliage contains very high calcium: phosphorous ratios (Table 1) in relation to ratios stated to be desirable for ruminant feeds (1:1 - 2:1, ARC 1965). Kale also contains low concentrations of copper.

APPARENT DIGESTIBILITY AND LIVEWEIGHT GAIN

A summary of all published New Zealand literature since 1940 for the apparent digestibility and liveweight gain of young sheep grazing brassica crops is shown in Table 2. Apparent DM digestibility was high for all four crops. Within crops there was little variation in liveweight gain, as indicated by the relatively low and uniform standard errors. Also there were only small differences between the amount of liveweight gain promoted from feeding different crops. The comparisons shown in Table 2 are confounded by the fact that some crops such as swedes were always grazed during winter, whereas other crops such as rape were always grazed during

TABLE 1: Chemical composition of brassica crops compared with pasture.

	Swedes		Kale		Autumn Pasture
	leaves	bulbs	leaves	top stem	
Total nitrogen (% DM)	2.62	2.77	2.84	1.82	3.43
Protein (% total N)	78	58	76	59	90
Total sulphur (% DM)	0.65	0.46	0.90	0.59	0.41
Total N: total S	4.0	6.0	3.2	3.1	8.4
Calcium (% DM)	2.94	0.13	3.35	1.29	0.88
Phosphorus (% DM)	0.27	0.24	0.30	0.26	0.43
Ca : P	10.9	0.5	11.2	5.0	2.0
Copper (ppm)	-	-	3.2	2.9	6-7

Data from Cornforth *et al* (1978).

TABLE 2: Apparent digestibility and liveweight gain recorded with young sheep consuming brassica crops in New Zealand.

	Dry matter digestibility		Liveweight gain (g day^{-1}) †	
	Number of trials	(%)	Number of trials	(mean ± SE)
Swedes	5	89.1	5	95.2 ± 19.8
Turnips	2	89.3	7	127.3 ± 15.2
Kale	2	81.2	10	121.8 ± 18.6
Rape	2	85.1	13	147.3 ± 14.2

† Initial liveweight 25-30 kg

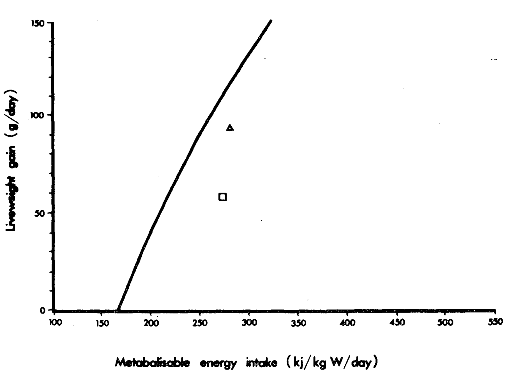
Data from Nicol and Barry (1979)

summer. Where kale was grazed during summer (5 trials) liveweight gains were approximately 60 g day^{-1} greater than when it was grazed during winter (5 trials). Considering the generally satisfactory levels of total N (1.8-2.0% DM or greater) and the very high apparent digestibilities, the liveweight gains shown in Table 2 are considered to be low.

REASONS FOR LOW LIVEWEIGHT GAINS OF YOUNG SHEEP CONSUMING BRASSICAS

In Figure 1, data obtained from feeding chipped swede bulbs *ad libitum* for 12 weeks to young sheep kept indoors have been plotted against the energy requirements of the ARC (1965). At a given ME intake liveweight gains were less than would be expected, indicating that the efficiency of utilisation of the ME in the diet was limiting liveweight gain. However, if the efficiencies had been similar to those used in the ARC data, the voluntary intakes achieved would only have supported liveweights gains of 100-120 g day^{-1}. Thus these data indicate that at least for swede diets, liveweight gain is limited by both low intake and reduced efficiency of food utilisation.

Figure 1: Liveweight gains and metabolisable energy intakes of young sheep fed chipped swedes *ad libitum* indoors during winter. □ Drew (1968); △ Drew 1972 unpublished; ———— energy requirements for growth of young sheep as proposed by A.R.C. (1965).



The joint effect of environmental exposure and having to harvest the food through grazing caused a marked increase in the energy intake of young sheep fed swedes during winter, coupled with a small reduction in liveweight gain (Table 3). It is to be expected that this effect of environment on animals grazing brassicas would be much less during other seasons of the year. Hay supplementation consistently increased liveweight gain in these trials, but the magnitude of the increase was very small.

TABLE 3: Effect of environment and hay supplementation on the intake and liveweight gain of young sheep fed swedes during winter.

Diet	Environment	Metabolisable energy intake (kj kgW^{-1} day^{-1})	Liveweight gain (g day^{-1})
Swedes	(Indoors †	233	76
	(Grazing	384	61
Swedes & hay	(Indoors †	275	99
	(Grazing	369	88

Means of 3 years data from Drew (1967, 1968) and 1972 unpublished.
† Swede bulbs chipped and fed *ad libitum.*

FACTORS GOVERNING INTAKE IN ANIMALS FED BRASSICA CROPS

One of the most consistent features of New Zealand data on brassica crops is that animals take at least 5 weeks to obtain stable intakes following the transfer from grazing pasture. This is illustrated in Table 4 for young sheep grazing rape during summer and for young sheep fed chipped swedes indoors during winter; these two examples have been selected because in both instances effects of time would not be affected by changes in environment. This initial period of depressed intake and liveweight gain has also been observed with cattle in New Zealand after introduction to grazing kale (Scales, unpublished) and in United Kingdom work with cattle fed on sliced swedes (Kay, 1974).

TABLE 4: Voluntary intake and liveweight gain of young sheep as influenced by time after introduction to brassica crops.

	Period of feeding on crop			
	1	2	3	4
RAPE				
Days of experiment	1-8	9-16	17-24	25-32
Intake (kj ME kg W^{-1} day^{-1})	-	308	351	371
Liveweight gain (g day^{-1})	41		125	
SWEDES				
Days of experiment	8-21	22-35	36-49	50-77
Intake (kj ME kg W^{-1} day^{-1})	180	212	286	274
Liveweight gain (g day^{-1})	29		89	

Data for rape from Greenall (1959) and for swedes from Drew (1968).

A field management factor which could in turn govern the amount of crop eaten is the daily quantity of DM that is on offer to animals. This is shown in Table 5 for young sheep grazing kale, where it can be seen that a low allowance (or forcing the animals to utilise a high proportion of the crop) reduced both liveweight gain and the quantity of DM utilised $animal^{-1}$ day^{-1}. However, allowing the animals a very high daily DM allowance (or reducing the proportion of the crop utilised to very low levels) produced no extra increase in either liveweight gain or DM utilised $animal^{-1}$ day^{-1} compared with a medium level of DM allowance. In this trial DM utilised $animal^{-1}$ day^{-1} was calculated from measurements of crop DM cut to soil level before and after grazing; it is considered that intake is the principal component of this figure, but that it will also include any bias or random error associated with any of the two DM measurements. Thus changes in DM utilised $animal^{-1}$ day^{-1} should represent changes in intake, but DM utilised $animal^{-1}$ day^{-1} is not considered to be an absolute measure of daily DM intake.

Time of exposure to kale feeding had a considerable effect on liveweight gain, with the gains during weeks 7-12 being approximately 50 g day^{-1} greater than recorded during weeks 1-6. DM utilised $animal^{-1}$ day^{-1} was also greater in the second period.

TABLE 5: Effect of dry matter allowance on the performance of young sheep grazing kale.

		DM allowance		
		low	medium	high
DM on offer (kg $head^{-1}$ day^{-1})		1.3	2.6	3.9
Crop utilised (%)		79	53	37
Liveweight gain	(1-42 days)	60	105	112
(g day^{-1})	(43-84 days)	110	157	153
DM "utilised"	(1-42 days)	0.93	1.27	1.32
$head^{-1}$ day^{-1} (kg)	(43-84 days)	1.17	1.47	1.53

Data from Barry (1978, unpublished).

In New Zealand work with young sheep grazing swedes the effect of offering supplementary hay has been to decrease swede intake by 0.8 kj ME for each additional 1.0 kj ME consumed as hay, thus effecting little change in total intake (Nicol and Barry, 1979). With young sheep grazing kale or turnips, Jagusch *et al.*, (1976) found that substituting approximately 1/3rd of the DM intake with pasture had no effect on either total DM intake or liveweight gain. However, whilst adding hay/pasture supplements to brassica diets has not yielded beneficial results in New Zealand work, where the opposite extreme has been tried in United Kingdom trials and small quantities of sliced swedes added to rolled barley diets some quite beneficial results have been obtained. Thus in intensive production trials with beef cattle Kay (1974) found that the initial period of depressed intake and liveweight gain could be eliminated if swedes comprised 33% or less of the total DM intake.

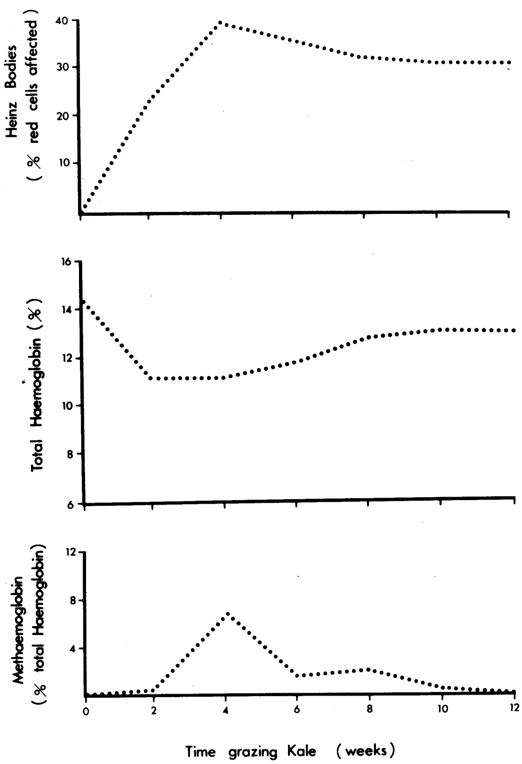
METABOLISM OF BRASSICA NPN IN RELATION TO NUTRITIVE VALUE

Compounds present in the NPN fraction of brassica plants that affect nutritive value are shown in Table 6; the glucosinolates and SMCO are sulphur-containing compounds.

S-methyl cysteine sulphoxide (SMCO) is neither a metabolite or an anti-metabolite in non-ruminant tissues. However, in ruminants the rumen microflora ferment part of it to volatile sulphur compounds, of which the principal compound is believed to be dimethyl disulphide (Smith, 1974). When absorbed from the digestive system dimethyl disulphide destroys the reducing capacity of red blood cells, causing the formation of Heinz bodies on the red cells and a fall in total blood haemoglobin concentration. This is particularly severe in animals fed kale. After approximately 6 weeks the haemoglobin concentration returns to near-normal values, but Heinze body counts still remain elevated. This is shown for New Zealand work in Figure 2; these data were collected from the low and medium allowance groups referred to in Table 5. It can be seen that the initial period of depressed animal production corresponds with the time when the Heinz body anaemia was most severe. S-methyl cysteine sulphoxide is present in the leaves, stems and roots of all brassica plants used in agriculture (Whittle *et al.*, 1976). However, its conversion to volatile toxic compounds in the rumen may differ between brassica species as animals consuming swedes do not suffer so severe an anaemia as animals consuming kale, despite the fact that at similar ages the two species contain similar levels of SMCO.

When the brassica plant contains high levels of soluble carbohydrate, such as swede and turnip bulbs, any nitrate present is normally reduced in the rumen to ammonia. However, when brassica leaves are fed an intermediate compound, nitrite, can be formed in the rumen. When absorbed, nitrite converts some haemoglobin to methaemoglobin. This is also shown in Figure 2 for the kale-fed sheep referred to above; the levels of methaemoglobin found are not regarded

Figure 2: The development of anaemia in young sheep grazing kale. Yield was approx. 6 t DM ha^{-1} and grazing commenced on 22 March 1978. Liveweight gains in the same trial are given in Table 5.



as clinically significant except for those recorded for some sheep in the earlier stages of the trial. In general, conditions favouring high levels of nitrate formation in brassica plants are days of high minimum temperatures with heavy cloud cover, such as can be encountered in autumn.

Glucosinolates that give rise to thiocyanate only occur in high concentration in brassica leaves, especially in kale (Greenhalgh, 1971). The goitrogenic properties of thousand head kale have been well documented under New Zealand conditions (Sinclair and Andrews, 1958, 1959, 1961), but as this can readily be reversed by oral or subcutaneous iodine administration it is not considered a practical problem. The thiouracil-type goitrogens do not cause a swelling of the thyroid gland, rather they block the conversion of T4 thyroid hormone which is circulating in the blood plasma to T3 hormone. The latter is the active form of the thyroid hormone, and is involved in the animals' regulation of protein synthesis and energy metabolism. Thiouracil-type goitrogens occur in only low concentrations ($< 0.06\%$ DM) in the leaves of swedes, turnips and kale stems and are stated to be absent in kale leaves; however, in swede and turnip bulbs they comprise 0.36 and 0.17% DM respectively (Greenhalgh, 1971). Feeding thiouracil-type goitrogens to rats in medical research has depressed T3 concentration in all studies and in some studies has depressed liveweight gain; effects of these compounds on the growth of sheep and cattle have never been assessed.

In summary it seems that the NPN components that are most likely to affect productivity are fermentation products from SMCO, especially in animal fed kale, and perhaps thiouracil-type goitrogens in animals fed swede bulbs. Nitrate poisoning is likely to be an intermittent problem, depending on weather conditions and upon the quantity of nitrogenous fertiliser used.

RESEARCH PRIORITIES ON BRASSICA DIETS

The first priority is to identify the factors responsible for both the initial and the subsequent depressed performance. In view of the very high digestibility of brassica crops and the high ratios of soluble: structural carbohydrate (kale approximately 4-9, swedes approximately 4-5), it is unlikely that rate of particle size breakdown in the rumen, which is a limiting factor in diets of grasses and clovers (Ulyatt *et al.*, 1977; Ulyatt, 1978), will limit nutritive value of brassica diets to the same extent. Also whilst protein absorption from the intestines appears to be a second factor limiting the nutritive value of grasses and clovers (Ulyatt *et al.*, 1977; Ulyatt, 1978), liveweight gain responses to post-ruminal amino acid supplements in young sheep fed brassica diets have

TABLE 6: Metabolism of non-protein nitrogen in brassica plants by ruminants.

Present in brassica plants	Non-protein nitrogen				
	Glucosinolates		SMCO		Nitrate
Produced by chewing or rumen metabolism	goitrogens				
	thiocyanate	thiouracil	non-toxic metabolites	dimethyl disulphide	nitrite
Effect in animal body	goitre	reduces protein synthesis		Heinz body anaemia	methaemo--globin formation
				Reduced oxygen transport capacity	Reduced oxygen transport capacity

Areas inside blocks represent principal metabolic problems in ruminants fed kale.

either been small (Barry and Drew; 1978) or zero (T. N. Barry, unpublished). This suggests that either amino acid absorption is not limiting on brassica diets, or else some other factor is more limiting in restricting the animal response. Thus the area of most fruitful research with brassica crops is likely to be into toxic properties, of which SMCO metabolism is considered to be most important. There is an urgent need to add synthetic SMCO to a feed of high nutritive value that does not normally contain this compound, to quantify how much intake and liveweight gain are depressed as SMCO intake increases. Should the detrimental effects of SMCO prove to be large, then an urgent agronomic priority will be the development of brassicas, particularly kales, of low SMCO content. Brassica foliage increases in SMCO content with age (Table 7); thus as yield increases with time it is important to note that toxicity also increases. Of the kales currently available variety Maris Kestrel appears to be the lowest in SMCO content, and at least in some instances (i.e. rape) selection for low thiocyanate has also produced low levels of SMCO. Intensive plant selection programmes are underway in the United Kingdom aimed at reducing SMCO content by genetic means (Gosden, personal communication). Also, as SMCO functions as a reservoir in brassicas for excess sulphur to that required for plant protein synthesis, it may be possible to reduce its level through adjustments in fertiliser practice.

The second priority, using the cultivars that are available at this time, is to get animals established on brassica diets without the initial period of depressed performance. The United Kingdom data (Kay, 1974) suggests that this can best be achieved by initially using a system where the brassica is only a minor part of the diet; under New Zealand conditions the remainder of the diet would of course be grazed pasture. As the animals adjust to the brassica it may be possible to gradually increase the proportion of this in the diet until after 6-7 weeks an all-brassica diet is achieved. Under this system the diet changeover will obviously have to take place at a time when the pasture is capable of supporting very high

TABLE 7: Factors affecting the S-methyl cysteine sulphoxide content of brassica crops grown in the United Kingdom

Variety	Approximate age (months)			
	3	5	7	9
KALE				
Maris Kestrel	0.46	0.54	0.83	1.44
Thousand) high thiocyanate	0.63	0.79	0.91	-
Head) low thiocyanate	0.66	0.96	0.92	-
RAPE				
High thiocyanate	0.59	0.55	0.69	0.82
Low thiocyanate	0.30	0.35	0.41	0.63

Data from Whittle *et al* (1976).

animal growth rates, which could mean at an earlier time during summer than is currently practiced.

In summary there are certain aspects of plant chemical composition, in addition to DM yield, that are likely to influence the amount of animal production that can be expected from brassica diets. Agronomists should give consideration to these aspects in a wider approach to problems associated with the integration of crops into livestock production systems in New Zealand.

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