Nutritional evaluation of five species of forage brassica

C.T. WESTWOOD, H. MULCOCK
Kimihia Research Centre, PGG Wrightson Seeds Ltd, P.O. Box 175 Lincoln 7640
cwestwood@pggwrightsonseeds.co.nz

Abstract

Despite a growing interest in ruminant nutrition and the ongoing, widespread use of forage brassicas, there is an absence of data that adequately describe the nutritional value of modern brassica cultivars in New Zealand. Five forage brassica species represented by 30 cultivars were evaluated in single-site, single-year trials in the South Island. Replicated plots of leafy turnips, bulb turnips, rape, swede and kale were harvested at 53, 91, 98, 181 and 186 days after sowing, respectively. Whole plants were dissected to leaf, stem and bulb and/or petiole and components assessed for nutritive value. Quality differed significantly among and within brassica species. Within species, percent dry matter (DM) was consistent for rape, bulb turnip and leaf turnip, but differed significantly among cultivars in kale and swede. Mean metabolisable energy (MJ ME) content at harvest was highest for swede (13.8 MJ ME/kg DM) and lowest for kale (11.2 MJ ME/kg DM). For all brassica species, fibre content as estimated by neutral detergent fibre (NDF) content was below optimum for ruminal function, highlighting the importance of high NDF supplementary feeds for brassica-fed stock. For some but not all brassica species, nutritive value may be modified by cultivar selection however factors not investigated in this study including sowing rate and time from sowing to harvest remain important potential moderators of forage brassica quality.

Keywords: Forage brassica, leafy turnip, bulb turnip, forage rape, swede, kale, nutritive value, feed testing

Introduction

Forage brassicas are an essential component of the feedbase for many New Zealand farms. Important species include kale (*Brassica oleracea* ssp. *acephala*), turnip (*Brassica campestris* ssp. *rapifera*), forage rape (*Brassica napus* ssp. *biennis*) and swede (*Brassica napus* ssp. *napobrassica*). Despite widespread use of these crops, performance by brassica-fed animals can be inconsistent. Insufficient allocation of dry matter (DM) (Judson & Edwards 2008), amino acid deficiencies (Barry & Manley 1985) and sub-clinical effects of S-methyl cysteine sulphoxide (SMCO) and/or glucosinolates (Nichol 2007) are implicated in the under performance of brassica-fed stock. The potential for nutritional attributes of forage brassicas to influence animal performance requires further elucidation. Ulyatt *et al.* (1980) defined the nutrient composition of brassica species, however observations were limited to megajoules of metabolisable energy (MJ ME) and crude protein (CP). A more extensive nutritional description of whole plant brassica was provided by de Ruiter *et al*. (2007), however data specific to leaf, stem, petiole and bulb components of commercial New Zealand brassica cultivars are unavailable. The objective of this research was to measure the nutritive value in field-grown commercially available cultivars within and among five forage brassica species.

Materials and Methods

Five randomised complete block experiments with three or four replicates were established at South Island sites and managed under conditions designed to simulate industry standard practice. Seven rape (cv. 'Goliath', 'Greenland', 'HT-R24', 'Interval', 'Spitfire', 'Titan' and 'Winfred'), six bulb turnip (cv. 'Barkant', 'Green Globe', 'HT-BT35', 'New York', 'Rival' and 'York Globe'), and three leafy turnip cultivars (cv. 'HT-LT46', 'Hunter' and 'Pasja') were established under irrigation on a Templeton silt loam at Kimihia Research Centre, Lincoln, Canterbury. Two trials were sown in October 2010 (bulb and leafy turnips) and one in October 2011 (rape) following incorporation of 250 kg/ha di-ammonium phosphate (DAP). Urea was applied at 108 kg/ha prior to canopy closure. Plot sizes were 1.2 × 6 m (rape and bulb turnip) or 1.2 × 8 m (leafy turnip) with three (bulb turnip, rape) or four (leafy turnip) replicates for each cultivar. The leafy turnip, bulb turnip and rape trials were harvested at 53, 91 and 98 days after sowing (DAS), respectively with cut dates defined by optimum crop maturity for each species. Whole plots (rape, leafy turnip) or quadrats measuring 2 m^2 (bulb turnip) were harvested and plants were dissected in the field into leaf and petiole (leafy turnip), leaf and bulb (turnip) and leaf and stem (rape) components. Sub-samples representative of each replicate were submitted for laboratory analysis of percentage DM and forage quality. The leafy turnips were allowed to recover, with regrowth harvested 45 days after the first cut and submitted for the same analysis as the first cut.

In a separate trial, six swede cultivars (cv. 'Aparima Gold', 'Domain', 'HT-S57', 'Invitation', 'Keystone' and 'Major Plus') were established on a non-irrigated site at Gore, Southland. This trial was sown into a Waikoikoi silt loam in early December 2010 following the incorporation of 150 kg/ha of superphosphate followed by 70 kg/ha of urea in late January 2011. Plots measured 2.4 × 8 m with each cultivar represented by three replicates. Cultivars were harvested 181 DAS, and samples taken from one 3.7 m^2 quadrat cut per plot were dissected to tops and bulbs and a random grab sample of each component from each replicate submitted for laboratory analysis of percentage DM and quality.

In a separate trial, eight kale cultivars (cv. 'Caledonian', 'Fuel', 'Gruner', 'Kestrel', 'KRC7867', 'Regal', 'Sovereign' and 'Voltage') with three replicates per cultivar were established under irrigation at Chertsey, Mid-Canterbury into a Lismore shallow silt loam. The trial was sown in November 2010 following the incorporation of potassic superphosphate 15%, DAP and boron at rates of 300 kg/ha, 100 kg/ha and 10 kg/ha, respectively. A single application of urea was applied to each 1.5 × 6 m replicate at 80 kg/ha two months after establishment. One 1.5 m^2 quadrat from each replicate was harvested 186 DAS and dissected into stem and leaf, with samples from each replicate submitted for laboratory analysis of DM and quality.

For laboratory analysis, samples were dried by heating at 65°C for 24 hours. Following grinding, samples were submitted to a commercial feed testing laboratory (Analytical Research Laboratories, Napier). Crude protein, digestibility (DOMD), acid detergent fibre (ADF), neutral detergent fibre (NDF), water soluble carbohydrates (WSC), lipid and ash were determined by near infrared spectroscopy (NIRS) for leaf and petiole, with wet chemistry analytical techniques used for stem and bulb samples.

Statistical Analysis

Treatment effects on leaf, bulb, petiole, stem and whole plant quality results were analysed using the one way analysis of variance (ANOVA) implemented in Genstat version 14. In cases of significant ANOVA results, means were separated using the unprotected least significant difference (LSD) test. Significance was declared at $P<0.05$.

Results

Leafy turnip

Table 1. Leaf turnip whole plant nutritive value and proportion of leaf and petiole for three cultivars at two consecutive cuts. All values are expressed as percentage of DM. DM% = dry matter percentage; MJ ME = megajoules of metabolisable energy; DOMD = digestibility; CP = crude protein; ADF = acid detergent fibre; NDF = neutral detergent fibre; WSC = water soluble carbohydrate.

First cut											
Cultivar	DM %	MJ ME	DOMD	CP	ADF	NDF	WSC	Lipid	Ash	Leaf %	Petiole %
HT-LT46	14.1	12.8	85.3	21.7	13.4	16.1	18.9	4.8	11.5	72.7	27.3
Hunter	13.4	13.1	87.8	23.0	13.9	15.9	19.8	4.7	10.8	68.3	31.8
Pasja	13.6	13.0	87.1	22.9	13.3	14.9	18.9	4.9	11.0	76.1	24.0
P-Value	0.434	0.286	0.033	0.115	0.431	0.082	0.849	0.393	0.288	0.212	0.212
Mean	13.7	13.0	86.7	22.6	13.5	15.6	19.2	4.8	11.1	72.0	28.0
S.E.D	0.48	0.18	0.74	0.57	0.52	0.43	1.79	0.13	0.40	3.90	3.90
$LSD_{0.05}$	1.24	0.44	1.82	1.40	1.27	1.09	4.38	0.31	0.98	9.5	9.5
Second cut											
Cultivar	DM %	MJ ME	DOMD	CP	ADF	NDF	WSC	Lipid	Ash	Leaf %	Petiole %
HT-LT46	15.6	13.2	86.0	15.5	13.5	14.9	22.0	3.8	8.7	57.3	42.7
Hunter	17.5	13.8	90.3	14.0	12.9	12.4	25.8	3.4	7.5	56.5	43.5
Pasja	17.0	13.4	88.0	16.4	13.1	13.3	22.1	3.9	8.5	60.7	39.3
P-Value	0.526	0.051	0.042	0.520	0.903	0.523	0.153	0.088	0.163	0.651	0.651
Mean	16.7	13.4	88.1	15.3	13.2	13.5	23.3	3.7	8.2	58.0	42.0
S.E.D	1.59	0.20	1.29	2.02	1.30	2.09	1.92	0.19	0.59	4.70	4.70
$LSD_{0.05}$	3.88	0.50	3.15	4.93	3.17	5.38	4.69	0.48	1.43	11.4	11.4

Leaf contributed up to 76% of total DM at the first cut, but less than 61% at cut two (Table 1). Compared with plants harvested at the first cut, second-cut leafy turnips were on average more digestible, contained more energy and WSC, and less CP and NDF.

Crude protein concentration of leaf was 25.8% and 20.2%, for cut one and two, respectively (individual leaf and petiole nutritive data not presented). Mean CP concentration of the petiole was 14.5% and 9.6% for first and second cuts, respectively. Neutral detergent fibre concentration of whole plant leafy turnip was 15.6% and 13.5% at cut one and two, respectively. NDF content was similar for petiole and leaf material at both cuts.

Petiole WSC content was double that of leaf (leaf 14.3% and 14.7%, petiole 31.2% and 36.8% for cut one and two, respectively). Leafy turnip cultivars 'Pasja' and 'Hunter' did not differ significantly (P>0.08) in any aspect of nutritive value at either the first or second cut. In contrast, the DOMD of whole plant 'HT-LT46' was significantly (P<0.05) lower than either 'Pasja' or 'Hunter' at the first but not the second cut.

Table 2. Bulb Turnip whole plant nutritive value and proportion of leaf and bulb for six cultivars. All values are expressed as percentage of DM. DM% = dry matter percentage; MJ ME = megajoules of metabolisable energy; DOMD = digestibility; CP = crude protein; ADF = acid detergent fibre; NDF = neutral detergent fibre; WSC = water soluble carbohydrate.

Cultivar	DM %	MJ ME	DOMD	CP	ADF	NDF	WSC	Lipid	Ash	Leaf %	Bulb %
Barkant	9.8	11.9	89.0	14.0	19.2	22.0	28.6	NA[1]	10.4	55.5	44.5
Green Globe	10.4	11.4	87.8	14.3	18.9	23.2	26.3	NA[1]	10.9	56.8	43.2
HT-BT35	10.1	11.3	89.1	16.0	19.2	23.5	21.1	NA[1]	10.6	56.4	43.6
New York	10.0	11.6	89.4	13.8	18.8	22.2	29.0	NA[1]	10.9	53.4	46.6
Rival	10.1	12.2	88.4	13.6	18.0	21.0	29.2	NA[1]	9.0	60.1	39.9
York Globe	10.3	11.5	90.2	13.6	19.6	23.4	27.6	NA[1]	10.6	49.9	50.1
P-Value	0.935	0.023	0.22	0.085	0.059	0.043	0.004	NA[1]	0.112	0.233	0.233
Mean	10.1	11.7	89.0	14.2	18.9	22.5	27.0	NA[1]	10.4	55.4	44.6
S.E.D.	0.64	0.23	0.92	0.79	0.44	0.74	1.59	NA[1]	0.65	3.79	3.79
$LSD_{0.05}$	1.43	0.50	2.04	1.75	0.97	1.66	3.54	NA[1]	1.46	8.5	8.5

[1] Lipid content was not determined for turnip bulbs

Table 3. Rape whole plant nutritive value and proportion of leaf and stem for seven cultivars. All values are expressed as percentage of DM. DM% = dry matter percentage; MJ ME = megajoules of metabolisable energy; DOMD = digestibility; CP = crude protein; ADF = acid detergent fibre; NDF = neutral detergent fibre; WSC = water soluble carbohydrate.

Cultivar	DM%	MJ ME	DOMD	CP	ADF	NDF	WSC	Lipid	Ash	Leaf %	Stem %
Goliath	14.2	12.9	88.0	10.2	21.9	24.6	27.1	2.6	8.9	65.2	34.8
Greenland	14.9	12.8	87.6	9.1	22.7	24.9	26.6	2.5	9.1	64.9	35.1
HT-R24	14.3	12.6	86.2	10.1	20.1	23.4	28.3	3.0	9.0	71.0	29.0
Interval	13.8	11.5	78.6	11.1	26.0	30.5	25.1	2.7	8.8	58.9	41.1
Spitfire	14.1	13.4	91.4	9.9	16.7	18.9	29.8	3.2	8.5	69.9	30.2
Titan	14.2	13.4	92.0	12.2	17.6	20.1	29.1	2.8	8.9	72.0	28.0
Winfred	14.9	13.5	92.8	13.2	17.4	19.9	25.2	3.2	10.3	68.7	31.3
P-Value	0.952	<.001	<.001	0.041	0.003	<.001	0.108	0.062	0.512	0.004	0.004
Mean	14.3	12.9	88.1	10.8	20.3	23.2	27.3	2.9	9.1	67.2	32.8
S.E.D	1.13	0.206	1.38	1.13	1.85	1.95	1.74	0.25	0.85	2.65	2.65
$LSD_{0.05}$	2.46	0.45	3.00	2.45	4.03	4.25	3.78	0.55	1.86	5.77	5.77

Bulb turnip

Mean percentage DM of whole plant bulb turnip was 10.1% (Table 2) with percentage DM of bulb and leaf at 7.5% and 12.2%, respectively (component data not presented). Ratio of leaf to bulb was consistent between cultivars with mean values of 55% leaf and 45% bulb, and the ratio did not differ significantly (P>0.2) between cultivars. Bulbs were more digestible than leaf (mean values of 96.4% and 83.0% for bulb and leaf, respectively). Whole plant CP content was 14.2% (mean of 12.2% and 15.7% for bulb and leaf, respectively. 'HT-BT35' turnip tended (P=0.085) to contain more CP than other cultivars. Mean whole plant NDF content across cultivars was 22.5%. Bulb content of WSC was variable with 'HT-BT35' characterised by significantly (P<0.001) lower concentration of WSC than other cultivars. Across all cultivars, mean content of WSC was 46.6% (bulb) and 10.7% (leaf).

Rape

On a whole-plant basis, average rape percentage DM was 14.3% (Table 3). Ratio of leaf to stem was significantly (P=0.004) lower for 'Interval' rape compared to other cultivars. Whole plant quality was influenced by ratio of leaf to stem and quality of stem because leaf digestibility did not differ significantly between cultivars (P >0.4). On a whole-plant basis, 'Spitfire', 'Titan' and 'Winfred' were significantly (P<0.001) more digestible and contained more energy than other rape cultivars.

Crude protein content of rape stem was half that of leaf (6.3% and 13.1% CP, respectively) with whole plant CP averaging 10.8%. On a whole plant basis, 'Titan', 'Spitfire' and 'Winfred' contained significantly less NDF (P<0.001) than other rapes. Mean leaf NDF content was half that of stem (16.5% and 36.5%, respectively).

Water soluble carbohydrate contents of rape stem and leaf were similar, with mean levels of 28.5% and 26.8%, respectively; whole-plant WSC averaged 27.3% and did not differ significantly among cultivars.

Swede

Mean whole-plant percentage DM of swedes was 10.3% (Table 4), with bulbs averaging 9.7% and leaf 12.0% DM. Swede bulb was the major contributor to whole plant DM yield, with all but one cultivar yielding more than 75% bulb on a DM basis. The exception was 'Invitation', that yielded significantly (P<0.001) less bulb and more leaf at 66% bulb and 34% leaf on a DM basis. Digestibility and energy content of whole plant swede averaged 93.5% and 13.8 MJ ME/kg DM respectively, but did not differ significantly between cultivars (P>0.05). Mean digestibility for bulb and leaf was 96.7% and 83.9%, respectively. Crude protein content of leaf ranged from 26.5% to 31.6% in contrast to relatively lower bulb CP contents of between 9.7 and 14.7%. Whole plant CP concentration did not differ significantly (P=0.33) between cultivars.

'Aparima Gold' and 'Major Plus' swedes contained significantly (P=0.008) more NDF than some other cultivars. On a whole plant basis, WSC concentration ranged from 47.3% to 53.3% for 'Aparima Gold' and 'Major Plus' cultivars, respectively. For all cultivars, bulbs contributed the majority of whole plant WSC, with a mean content of 58.9% and 22.6% for bulb and leaf, respectively.

Kale

For whole-plant kale, digestibility was 77.0% (Table

Table 4. Swede whole plant nutritive value and proportion of leaf and bulb for six swede cultivars. All values are expressed as percentage of DM. DM% = dry matter percentage; MJ ME = megajoules of metabolisable energy; DOMD = digestibility; CP = crude protein; ADF = acid detergent fibre; NDF = neutral detergent fibre; WSC = water soluble carbohydrate.

Cultivar	DM%	MJ ME	DOMD	CP	ADF	NDF	WSC	Lipid	Ash	Leaf %	Bulb %
Aparima Gold	10.3	13.7	93.1	14.5	15.0	16.0	47.3	1.9	6.1	23.0	77.0
Domain	9.5	13.8	94.3	12.9	13.8	14.7	51.1	1.6	6.1	19.4	80.6
HT-S57	10.5	13.8	94.0	13.8	13.2	14.4	51.4	1.9	6.0	24.4	75.6
Invitation	11.5	13.7	92.4	14.3	14.0	14.7	48.2	2.1	6.4	34.0	66.0
Keystone	10.1	13.8	93.8	13.5	14.3	15.0	47.6	1.7	6.4	22.5	77.5
Major Plus	9.8	13.8	93.4	12.9	13.2	16.6	53.3	1.8	5.8	24.9	75.1
P-Value	0.023	0.283	0.066	0.326	0.274	0.008	0.008	0.16	0.566	<.001	<.001
Mean	10.3	13.8	93.5	13.7	13.9	15.2	49.8	1.8	6.1	25.0	75.0
S.E.D	0.46	0.084	0.56	0.84	0.79	0.49	1.43	0.11	0.36	1.80	1.80
$LSD_{0.05}$	1.03	0.18	1.26	1.87	1.80	1.08	3.18	0.25	0.79	4.0	4.0

5), and 73.7% and 82.2% digestibility for stem and leaf respectively, mean metabolisable energy was 11.2 MJ ME/kg DM (10.8 MJ ME/kg DM and 12.0 MJ ME/kg DM, stem and leaf, respectively) and mean NDF was 28% (32.4% and 17.4% for stem and leaf, respectively). Ratio of leaf to stem was significantly (P<0.001) greater for the leafy kales 'Kestrel',' Regal' and 'Sovereign' compared with other kale cultivars, however whole plant digestibility, NDF and CP content did not differ significantly (P>0.139) between cultivars.

Discussion

This work reports the nutritive value of replicated cultivars of five species of forage brassicas sown at single sites on the South Island of New Zealand. These data support previous studies (de Ruiter *et al.* 2007; Kaur *et al.* 2011) showing that forage brassicas in general yield forage of superior quality compared to perennial ryegrass dominant pastures. Whilst total crop DM yield and crop utilisation remain the key drivers of animal productivity (Judson & Edwards 2008) and yield data are not reported here, the other potential modifier of animal performance, nutritive value, varied significantly within each species of brassica.

Swedes apparently yielded the greatest concentration of energy, averaging 13.8 MJ ME/kg DM compared with kale at 11.2 MJ ME/kg DM however between-species comparisons should be made with caution because species were grown at different sites. Further, interpretation of calculated MJ ME results may be limited because field observations suggest that high MJ ME values reported for brassicas and other winter crops including fodderbeet (*Beta vulgaris*) do not always translate to expected levels of animal performance. Error associated with estimates of crop utilisation (Judson & Edwards 2008) and brassica-associated anti-nutritional compounds (Nichol 2003) may alter the feed conversion efficiency of brassica-fed animals. Further work is required to elucidate this apparent inconsistency between calculated MJ ME of brassicas and animal productivity.

Within species, MJ ME content of cultivars differed significantly for bulb turnips and rape, but not for leafy turnip, kale or swedes. Ratio of kale leaf to stem differed significantly between cultivars, yet kale whole-plant MJ ME was similar for all cultivars, possibly reflecting the relatively early DAS harvest date for kale. While this study did not investigate the potential influence of time from sowing to harvest (DAS) on brassica quality, previous work with forage rape has shown DAS as an important modifier of whole plant quality. Rape leaf as a percentage of total DM was inversely correlated with DAS (Nichol 2003); rape stem hardness increased from day 82 to day 123 DAS (Nichol 2003) and the DM, NDF and ADF contents of 'Goliath' rape increased while CP content decreased with increasing DAS from week 7 to week 13 of maturity (Kaur *et al.* 2011). Decisions with regard to cultivar selection and timing of crop harvest relative to sowing date will potentially alter whole-plant quality for rape (Nichol 2003; Kaur *et al.* 2011) and possibly kale.

Within bulb brassica species, ratio of leaf to bulb differed significantly between cultivars of swede but not turnips, suggesting that for swede but not turnip, between cultivar variation may be one way to modify whole plant nutritive value. Turnip sowing rate

Table 5. Kale whole plant nutritive value and proportion of leaf and stem for eight cultivars. All values are expressed as percentage of DM. DM% = dry matter percentage; MJ ME = megajoules of metabolisable energy; DOMD = digestibility; CP = crude protein; ADF = acid detergent fibre; NDF = neutral detergent fibre; WSC = water soluble carbohydrate.

Cultivar	DM%	MJ ME	DOMD	CP	ADF	NDF	WSC	Lipid	Ash	Leaf %	Stem %
Caledonian	17.3	11.4	78.0	6.3	22.8	27.0	38.7	1.9	6.2	20.7	79.3
Fuel	17.2	11.9	81.4	11.1	21.7	25.0	37.5	2.1	7.0	25.1	74.9
Gruner	18.0	11.1	76.1	7.2	26.9	32.0	33.6	1.5	6.0	23.7	76.3
Kestrel	14.7	11.7	80.4	13.8	21.3	24.6	28.0	2.2	8.5	38.5	61.5
KRC7867	20.0	10.7	73.1	7.6	24.1	29.7	33.9	2.0	6.3	28.3	71.7
Regal	14.9	11.4	78.0	11.0	22.7	27.0	31.4	1.9	7.9	34.7	65.3
Sovereign	15.5	10.7	73.6	11.1	25.0	30.2	32.3	2.5	7.1	33.8	66.2
Voltage	20.6	11.0	75.0	9.3	23.8	28.8	32.1	2.7	7.1	24.6	75.4
P-Value	0.013	0.432	0.421	0.139	0.398	0.208	0.060	0.050	0.008	0.001	0.001
Mean	17.3	11.2	77.0	9.7	23.5	28.0	33.4	2.1	7.0	28.7	71.3
S.E.D	1.54	0.60	4.12	2.57	2.45	2.88	2.94	0.30	0.58	3.43	3.43
$LSD_{0.05}$	3.32	1.29	8.89	5.52	5.26	6.17	6.36	0.65	1.24	7.35	7.35

(Jung & Shaffer 1993) and leaf resilience to disease, insect pressure and/or environmental factors are other important moderators of whole plant quality.

Forage brassica species were characterised by a wide range of percentage DM from 7.5% DM for turnip bulbs to 22.6% for the stem of one kale cultivar, reflecting not only between-cultivar and between-species differences but also the probable effects of site and seasonal variance in this single-site, single-year study. The wide range of DM% highlights the importance of submitting whole plants for DM analysis to provide more accurate DM yield predictions.

Mean whole-plant kale CP levels were unexpectedly low at only 9.7%, most likely reflecting minimal rates of nitrogen applied between sowing and harvest. Crude protein content of whole-plant kale is typically higher, with levels in some cases exceeding 16% (de Ruiter *et al.* 2007; Keogh *et al.* 2009). Similarly, rape whole-plant CP was only 10.8%, again most likely reflecting insufficient plant available N because rape is typically characterised by higher CP content (Nichol 2003, Kaur *et al*., 2011). Rape whole-plant CP content did not appear to be associated with percentage leaf, despite Nichol (2003) reporting that whole plant CP was influenced more by percentage leaf than by CP content of stem and leaf.

Low concentrations of CP may constrain the performance of brassica-fed animals due to reduced yield of metabolisable protein, particularly for cattle fed kale as a single daily meal (Judson *et al.* 2010). Where a high crop CP concentration is desirable for high performance stock classes, opportunities exist to manage for more leaf relative to stem (or bulb) through the selection of alternate rape, swede or kale but not leafy turnip or bulb turnip cultivars, by altered sowing rate (Jung & Shaffer 1993), changing DAS (Nichol 2003; Kaur *et al*, 2011), managing for improved leaf persistence and/or by more strategic use of nitrogen fertiliser.

Whole plant NDF content of brassicas did not always meet minimum concentrations of 35% and 27–30% considered appropriate for cattle and sheep, respectively (Kolver 2002; Jolly & Wallace 2007). The content of WSC in whole plant brassica was variable, ranging from 19.2% for first cut leafy turnip to 49.8% for swede. Cattle that consume low NDF, high WSC feeds may under some circumstances be at risk of clinical or sub-acute ruminal acidosis (SARA). The ruminal pH of dairy cattle fed only kale did not fall below 6.0 (Keogh *et al.* 2009) however cattle were hand-fed whole plant kale with no opportunity for cattle to select leaf in preference to stem (Keogh *et al.* 2009). Individual cattle allocated high rates of brassicas and that preferentially consume leaf, but not stem (rape, kale), or that ingest bulb but not leaf (turnip, swede) may be at greater risk of SARA, particularly during the first 3 weeks of exposure to brassicas and/or if plant material is frozen.

Conclusions and practical implications

Based on single site data, within each species of forage brassica there was significant variance in some but not all aspects of nutritive value.

Brassica cultivar selection may under some circumstances modify whole plant nutritive value, however other factors not evaluated in this study, including timing of harvest, sowing rate and leaf retention as a crop matures, are potentially important moderators of whole plant nutritive value.

Crude protein concentration of N-deficient whole plant rape and kale may under some circumstances be too low for some classes of stock.

Neutral detergent fibre content of all species of forage brassica were lower than those recommended to support optimal ruminal function (in cattle, particularly) if brassica was to be fed as the sole diet.

Significant within-species variation in whole plant DM% provided evidence to support the standard industry recommendation that brassica plant material should be tested for DM% as part of crop DM yield calculations.

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