Fodder beet: know what you are feeding for a nutritionally balanced diet for dairy cattle

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Abstract
Fodder beet's (FB) high soluble sugar and low crude protein content provide environmental benefits but also nutritional challenges, making it a unique crop in New Zealand dairy systems. Knowledge of dietary nutrient content is important to inform both mineral supplementation and type of supplementary feed to offer. This will help ensure nutritional requirements for dairy cows are met, maximising the likelihood of positive outcomes for animal health and production. A database containing 694 samples of FB leaf and bulb tissue was compiled from monitor farm data, research projects, and cultivar evaluation trials with the objective of determining the variability in nutritional content. Descriptive statistics were used to highlight the range and variability in FB leaf and bulb nutritional composition between regions and cultivars. Our results reinforce that FB bulbs (which usually make up 70-90% of the crop DM) are typically low in crude protein, fibre, phosphorus, calcium, and sulphur, but are high in soluble sugars. The variation in nutrient content between cultivars, and within cultivars both between and within regions shown in this study highlights the importance of paddock-specific feed analyses, and the limitations of textbook values, particularly whole crop values which do not differentiate between bulb and the more nutritionally valuable leaf.

Keywords: *Beta vulgaris* L., crop, crude protein, phosphorus

Introduction
Fodder beet (*Beta vulgaris* L.; FB) has become a widely used forage for feeding dairy cattle through the autumn and winter months in southern New Zealand. Made up of both leaf and bulb, FB is a unique crop because of its high soluble sugar, and low crude protein (CP), fibre and phosphorus contents, driven by the bulb proportion of the plant (Dalley et al. 2017; Dalley et al. 2020a). While this low CP content makes FB an attractive feed to reduce nitrogen excretion (Dalley et al. 2017; Waghorn et al. 2019), at high proportions in the diet it is a challenging forage for providing sufficient nutritional balance to meet dairy cow requirements (Waghorn et al. 2018; 2019). Diets supplying insufficient nutrients can reduce animal production, negatively impact animal health (Grace et al. 2010; Dittmer et al. 2017; Hammond et al. 2021) and increase the risk of metabolic disease (Fleming et al. 2021).

Recommended dietary intakes to meet nutrient requirements for lactating cattle (on a dry matter (DM) basis) include: 14-18% CP depending on stage of lactation, >27-33% neutral detergent fibre (NDF), <38% soluble carbohydrate, 0.3-0.45% phosphorus (P), >1% potassium (K), 0.23% sulphur (S), 0.6-0.8% calcium (Ca), and 0.22-0.28% magnesium (Mg) (Kolver 2000; DairyNZ 2021). Whereas, non-lactating cow recommended dietary intakes of CP are 12% on a DM basis (Kolver 2000).

The nutritional composition of FB leaves and bulbs are very different (Table 1), thus the proportion of FB leaf vs. bulb influences the composition of the whole crop when grazed and whether the crop will meet dairy cattle requirements. Typically, FB crops are 70-90% bulb at the time of grazing (Dalley et al. 2020b; Pacheco et al. 2020) which can make it challenging to meet cow nutritional requirements for diets containing high proportions of FB. Recently Hill Laboratories published a summary of results from FB leaf and bulb analysis from their large dataset (Hill Laboratories 2020; Table 1). While this dataset is a useful addition to industry knowledge, it does not include information about the likely variation between cultivars, regions, or management of the crops, nor does it include the variation observed within the FB leaf and bulb analyses. Knowledge of this variation is important to understand the applicability of using "book values" for determining animal diets.

To minimise nutritional risks when feeding fodder beet, farmers and their advisors need accurate information on the nutritive value of the feeds they are offering, particularly the protein and mineral composition. Nutritive values for FB found in DairyNZ's Facts and Figures booklet (DairyNZ 2021) are reported for FB as a whole crop, rather than having the leaf and the bulb reported separately, with no values for key minerals reported (Table 1). Only a few New Zealand publications report mineral values for FB (e.g.,

Table 1 Feed composition of fodder beet as a whole crop from DairyNZ Facts and Figures (DairyNZ 2021) and analysis of fodder beet leaf and bulb from Hill Laboratories (Hill Laboratories 2020).

Feed component[1]	DairyNZ Facts and Figures	Hill Laboratories mid-point typical values	
	Whole crop	*Leaf*	*Bulb*
Dry matter (DM; % of fresh weight)	14-20	11.7	16.2
Metabolisable energy (ME; MJ ME/kg DM)	12.0-12.5	11.6	14.4[4]
Crude protein (CP; %)	9-14	21.8	9.0
Neutral detergent fibre (NDF; %)	11-16	24.2	11.4
Soluble sugars (SS; %)	na[3]	19.0	64.2
Soluble sugars and starch (SSS; %)	60-65	na	na
Starch (%)	na	<1	<1
Starch (% of SSS)	5	na	na
Ash (%)	na	16.3	5.8
Digestibility of organic matter in dry matter (DOMD; %)	na	72.3	90.2
Nitrogen (N; %)	na	3.4	1.4
Phosphorus (P; %)	na	0.29	0.15
Potassium (K; %)	na	3.6	2.0
Sulphur (S; %)	na	0.39	0.08
Calcium (Ca; %)	na	1.08	0.16
Magnesium (Mg; %)	na	0.75	0.14
Sodium (Na; %)	na	1.81	0.35
Chloride (Cl; %)	na	2.5	0.5
Manganese (Mn; mg/kg)[2]	na	240	57
Zinc (Zn; mg/kg)	na	54	28
Copper (Cu; mg/kg)	na	7	6
Iron (Fe; mg/kg)[2]	na	320	400
Boron (B; mg/kg)	na	44	13
Molybdenum (Mo; mg/kg)	na	0.51	0.11
Cobalt (Co; mg/kg)[2]	na	0.23	0.22
Selenium (Se; mg/kg)	na	0.08	0.02

[1]values are on a dry matter basis, unless otherwise specified; [2]Mn, Fe and Co are highly variable where soil and/or fungicide contamination is present; [3]na = not available in this source; [4]note that ME values for fodder beet bulb here are not comparable to the current study as this report was published prior to Hill Laboratories updating their equation for estimating ME in September 2021.

Waghorn et al. 2018; Waghorn et al. 2019; Dalley et al. 2020a; Dalley et al. 2020b).

In this paper we aimed to quantify the nutritional composition, including minerals, of FB leaf and bulb, and determine the variation between cultivars, and within cultivars both between and within regions, to provide more detailed information for farmers and nutritionists when feeding FB. We also aimed to determine how important paddock-specific nutritional testing is for farmers feeding FB diets.

Materials and Methods

A database containing 694 samples of FB leaf or bulb was compiled over several years from monitor farm data, research projects, and cultivar evaluation trials (Table 2). The data included information about cultivar (24 cultivars in database), region (data from Waikato, Taranaki, Manawatu, Canterbury, Otago and Southland in database), DM content, feed quality parameters (as analysed by near infrared spectroscopy), and mineral analysis where available. The majority of FB samples were analysed through Hill Laboratories (Hamilton, New Zealand). For FB leaves metabolisable energy (ME) was derived from digestibility of organic matter in dry matter (DOMD) using the following equation: ME = 0.16 × DOMD. In September 2021 Hill Laboratories revised their equation for estimating ME in FB bulbs to: ME = 0.14 × DOMD + 0.25 × crude fat; thus the ME content of FB bulbs in this database have been re-calculated using this equation.

Descriptive statistics were calculated for each variable (mean, standard deviation, minimum, median, maximum, coefficient of variation) across the whole database using SAS 9.4 (2016, SAS Institute Inc., Cary, NC, USA; Proc Means). From this, bulb and leaf nutritional composition data were combined based on typically observed bulb proportions of 75%, 80% and 85% to give weighted average estimates of the nutritional composition of the whole FB plant, as well as a scenario where whole FB is fed with pasture silage.

Data were then imported into R software version 4.2.1 (R Core Team 2022) for data visualisation and analyses. Due to the unbalanced nature of the available data (with respect to region, cultivar, sampling month), more balanced subsets were selected to determine the variation between cultivars and between regions within cultivars.

To compare variability between cultivars, a subset of the dataset was created containing only FB leaf and bulb samples collected between May and August

Table 2 Sources of data in the fodder beet database used in the current study.

Project ID (Lead organisation -project name/number)	Date range	Regions	Bulb (N)	Leaf (N)
DairyNZ – *Southern Wintering Systems:* MPI 10-027; DairyNZ SY1001	2011-2013	Southland	18	17
Plant and Food Research – *Forage Footprints for Dairy Wintering in Canterbury:* SFF 11/034; *Fodder beet agronomic solutions:* SFF 404915	2016, 2019	Canterbury, Manawatu, Otago, Southland, Taranaki, Waikato	40	40
DairyNZ – *Forages for reduced nitrate leaching:* DairyNZ RD1422, MBIE DNZ1301	2015-2019	Canterbury, Waikato	89	79
DairyNZ – *Southern Dairy Hub systems:* DairyNZ RDN1805; CB1917	2017-2021	Southland	50	42
Agricom – Cultivar evaluation trial	2019	Canterbury, Manawatu, Otago, Southland, Waikato	116	115
DairyNZ – *Making fodder beet sustainable for dairy cattle:* SFF 405512; DairyNZ CB1923	2019-2020	Canterbury, Southland	36	32
DairyNZ – *Participatory research:* enhanced research adoption: SFF 405892; DairyNZ CB2005	2020-2021	Otago, Southland	10	10

(i.e., representative of feed that could be offered to cows, rather than prior to this while the plants were still actively growing) within the Canterbury and Otago/Southland regions. The relationship between FB leaf and bulb for each variable across all cultivars and regions was investigated using a linear model and analysis of variance (ANOVA) using the “stats” package in R. The model included plant part (leaf, bulb) as a fixed effect, and region, season and month as blocking factors. Box plots of the raw data were generated to demonstrate differences in midpoint and variability (median and interquartile range) of CP and P content between plant parts (leaf or bulb) and cultivars.

To investigate the effect of plant breeding (for bulb DM content) on nutritive value, the above dataset was further refined by selecting one cultivar each from the groups marketed as “Low” DM and “Medium” DM cultivars. For this analysis, we selected the cultivars that had the largest number of samples in their respective group. Differences in average nutritional content between the two regions (Canterbury and Otago/Southland) and the two cultivars (“Low” DM cultivar vs the “Medium” DM cultivar) were analysed separately in both leaf and bulb data for DM, CP, P and soluble sugars (SS) using 2-way analysis of variance. The model included cultivar, region, and their interaction as fixed effects and was followed by a Tukey t-test for pairwise comparisons using the “emmeans” (Lenth 2022) and “car” (Fox and Weisberg 2019) packages in R. Box plots were used to illustrate the variation in nutritional content within each cultivar, region, and plant part.

To investigate the effect of cultivar within region, a subset of the dataset was created by selecting only FB leaf and bulb sampled between May and August within the Canterbury region for the four cultivars with the greatest number of data points. Differences in average nutritional content between cultivars for DM, CP, P and SS were analysed separately in both leaf and bulb using an analysis of variance. The model included cultivar as a fixed effect. Box plots were used to illustrate the variation in nutritional content for leaf and bulb between each cultivar.

For all analyses the assumptions of the analysis of variance were checked for each variable using diagnostic plots of residual variance and data were $\log_{10}$ transformed where necessary to achieve homogeneity of variance of the residuals. Differences in data were considered significant when $P<0.05$, and noted as a nutritionally meaningful trend when $0.10>P>0.05$.

Results

Feed quality and mineral concentrations in FB leaf and bulb samples in the whole database are presented in Table 3. These results reinforce that FB bulbs are typically very low in CP, NDF, P, S, Ca and Mg compared with dairy cow dietary requirements (Table 3, Table 4). The ANOVA for plant part showed that FB leaves had higher levels of CP, NDF, ash, P, K, S, Ca, Mg, Na and Cl, and lower levels of DM, ME, DOMD and SS than FB bulbs ($P<0.001$). Bulb and leaf nutritional composition data from Table 3 were combined based on typically observed bulb proportions of 75%, 80% and 85% to give weighted average estimates of the nutritional composition of the whole FB plant, as well as a scenario where whole fodder beet is fed with pasture silage (Table 4). For the three whole FB plant scenarios, CP, NDF, P, S and Ca concentrations were below recommended requirements for dairy cattle, and SS exceeded requirements. When nutrient composition was estimated for a combined diet of 60% FB (75% bulb) and 40% good quality pasture silage (feed value from DairyNZ’s Facts and Figures; DairyNZ 2021) recommended CP and NDF intakes for

Table 3 Nutritional composition of fodder beet leaf and bulb plant components from a database containing values from unpublished experimental data. N = number of values in database; Std Dev = standard deviation; Min = minimum value; Max = maximum value; CV = % coefficient of variation (Std Dev/Mean ×100). Means in **bold** are outside the recommended dietary intake range (Kolver 2000; DairyNZ 2021).

Feed component[1]	N	Mean	Std Dev	Min	Median	Max	CV (%)
Bulb							
Dry matter (DM; %)	279	17.0	2.8	9.4	17.1	25.4	16.3
Metabolisable energy (ME; MJ ME/kg DM)	277	12.9	0.4	10.7	13.0	13.6	3.0
Crude protein (CP; %)	320	**8.2**	2.7	3	7.85	18.1	32.6
Neutral detergent fibre (NDF; %)	289	**11.2**	2.6	6.9	10.7	24.8	23.3
Soluble sugars (%)	243	**65.4**	7.9	30.2	67.2	77.5	12.1
Ash (%)	289	5.3	1.7	1.4	5	11	31.1
Digestibility of organic matter in dry matter (DOMD; %)	285	90.9	4.2	69.2	91.9	96.2	4.6
Phosphorus (P; %)	240	**0.13**	0.04	0.06	0.13	0.27	29.7
Potassium (K; %)	240	1.60	0.62	0.40	1.50	3.80	38.9
Sulphur (S; %)	239	**0.06**	0.02	0.03	0.06	0.21	30.3
Calcium (Ca; %)	240	**0.13**	0.04	0.08	0.12	0.31	29.2
Magnesium (Mg; %)	240	**0.14**	0.03	0.08	0.14	0.25	19.2
Sodium (Na; %)	240	0.28	0.21	0.02	0.22	1.44	74.1
Chloride (Cl; %)	233	0.45	0.25	0.05	0.41	1.36	55.5
Leaf							
Dry matter (DM; %)	256	12.8	5.1	7.8	12.4	84.7	39.7
Metabolisable energy (ME; MJ ME/kg DM)	259	11.4	0.8	8.9	11.5	13.1	6.7
Crude protein (CP; %)	299	20.7	3.2	12.6	20.7	28.6	15.6
Neutral detergent fibre (NDF; %)	268	**26.2**	3.5	19.6	25.7	39.1	13.5
Soluble sugars (%)	227	20.5	4.9	7.8	20.6	34.9	24.0
Ash (%)	268	15.9	2.6	1.0	15.5	23.5	16.3
Digestibility of organic matter in dry matter (DOMD; %)	263	71.3	4.8	55.9	71.7	81.6	6.7
Phosphorus (P; %)	228	**0.28**	0.05	0.17	0.28	0.41	18.5
Potassium (K; %)	228	3.20	1.23	0.90	3.03	7.83	38.3
Sulphur (S; %)	227	0.33	0.08	0.20	0.31	0.76	25.1
Calcium (Ca; %)	228	0.98	0.33	0.34	0.92	1.92	33.7
Magnesium (Mg; %)	228	0.66	0.20	0.31	0.65	1.52	29.4
Sodium (Na; %)	228	1.54	0.66	0.44	1.41	4.60	42.8
Chloride (Cl; %)	222	1.96	0.72	0.56	1.87	5.20	36.6

[1]values are on a dry matter basis, unless otherwise specified.

Table 4 Estimated mean nutritional composition of fodder beet, either as a whole plant based on different bulb and leaf proportions (%), or when combined with good quality pasture silage, compared with recommended dietary intakes. Values in **bold** are outside the recommended dietary intake range (Kolver 2000; DairyNZ 2021).

Feed component[1]	75% bulb, 25% leaf	80% bulb, 20% leaf	85% bulb, 15% leaf	Pasture silage, good quality (DairyNZ 2021)	Combined diet of 60% FB (75% bulb with 40% silage)	Recommended dietary intakes (Kolver 2000; DairyNZ 2021)
Dry matter (DM; %)	16.0	16.2	16.4	23-28	19.8	
Metabolisable energy (ME; MJ ME/kg DM)	12.6	12.6	12.7	10-11	11.7	
Crude protein (CP; %)	**11.4**	**10.7**	**10.1**	17-18	13.8	14-18[2]; 12[3]
Neutral detergent fibre (NDF; %)	**14.9**	**14.2**	**13.5**	45	27	>27-33
Soluble sugars (%)	**54.2**	**56.4**	**58.6**	22	**41.3**	<38
Ash (%)	8.0	7.4	6.9	10	8.8	
Phosphorus (P; %)	**0.17**	**0.16**	**0.15**	0.30	**0.22**	0.3-0.45
Potassium (K; %)	2.00	1.92	1.84	2.30	2.12	>1
Sulphur (S; %)	**0.13**	**0.12**	**0.10**	0.24	**0.17**	0.23
Calcium (Ca; %)	**0.35**	**0.30**	**0.26**	0.80	**0.53**	0.6-0.8
Magnesium (Mg; %)	0.27	0.25	0.22	0.21	0.25	0.22-0.28
Sodium (Na; %)	0.59	0.53	0.47	0.10	0.40	
Chloride (Cl; %)	0.83	0.75	0.67	0.20	0.58	

[1]values are on a dry matter basis, unless otherwise specified; [2]lactating cows; [3]non-lactating cows

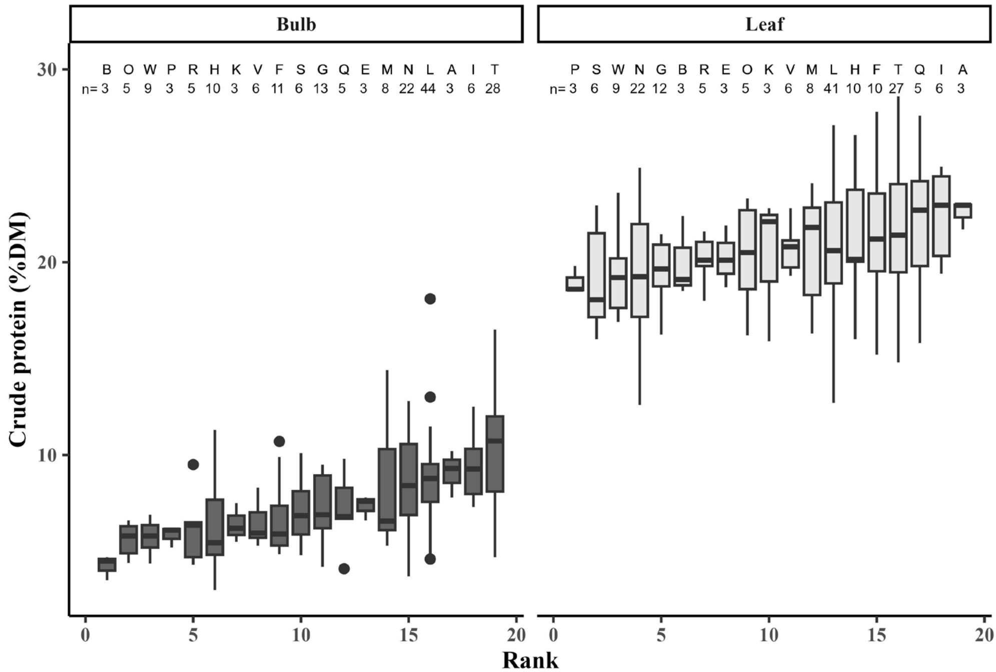

Figure 1 Box plot comparison of fodder beet bulb and leaf crude protein content between cultivars (different cultivars indicated by letters A to W) in the Canterbury and Otago/Southland regions of New Zealand, sampled between May and August. Cultivars are ordered by mean crude protein.

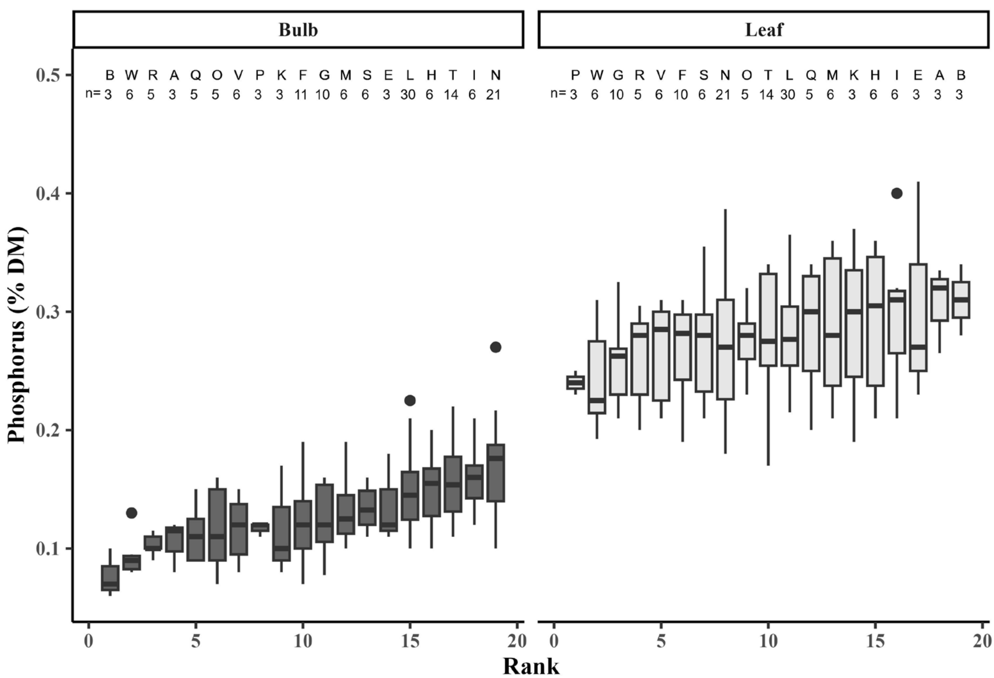

Figure 2 Box plot comparison of fodder beet bulb and leaf phosphorus content between cultivars (different cultivars indicated by letters A to W) in the Canterbury and Otago/Southland regions of New Zealand, sampled between May and August. Cultivars are ordered by mean phosphorus.

non-lactating dairy cattle were met. However, P, S and Ca remained below recommended intakes and SS still exceeded dairy cattle requirements (Table 4).

Large variation in bulb CP, ash, K, S, Na and Cl and leaf DM, K, Ca, Na, Cl were demonstrated by coefficients of variation greater than 30% (Table 3). Bulb NDF, P and Ca, and leaf soluble sugars, S and Mg were the next most variable with coefficients of variation between 20 and 30% (Table 3). The DOMD and ME were the most consistent nutritional components across the whole dataset.

The CP content for FB bulb and leaf of different cultivars sampled between May and August within the Canterbury and Otago/Southland regions is shown in Figure 1, with cultivars ranked from lowest to highest mean CP for bulb and for leaf, respectively. Phosphorus content is presented in the same manner in Figure 2. These boxplots highlight not only the variability between cultivars, but also the variability within each cultivar.

Dry matter, CP, P and SS content of bulb and leaf were compared for a cultivar marketed as "Low" DM and a cultivar marketed as "Medium" DM between the Canterbury and Otago/Southland regions (Figure 3). The ANOVA showed that mean bulb DM content was not different between the Canterbury and Otago/Southland regions but was affected by cultivar ($P<0.05$), being greater for the "Medium" DM cultivar (17.0%) than the "Low" DM cultivar (14.6%) (Figure 3a). Bulb DM content was more variable for the "Low" DM cultivar in the Canterbury region, compared with Otago/Southland, and in the Canterbury region there was less variability in bulb DM content for the "Medium" DM cultivar than the "Low" DM cultivar (Figure 3a). In contrast, leaf DM content was not significantly affected by cultivar and was affected by region ($P<0.05$), being greater in Canterbury (13.9%), than Otago/Southland (10.1%) (Figure 3a). Bulb CP was not affected by region, but there was a trend with cultivar ($P=0.08$) where bulb CP tended to be greater in the "Low" DM cultivar, than the "Medium" DM cultivar, with means of 10.3% and 8.8%, respectively (Figure 3b). Bulb CP content was also more variable for the "Low" DM cultivar than for the "Medium" DM cultivar (Figure 3b). There was no effect of cultivar on leaf CP content, however, there was a trend with region ($P=0.082$). Bulb P content was affected by region ($P<0.05$) but not cultivar and was greater in Canterbury than in Otago/Southland with means of 0.17% and 0.14%, respectively, though pairwise comparisons within each cultivar were not significantly different between regions (Figure 3c). Leaf P content (Figure 3c) and leaf and bulb SS content were not affected by region or cultivar.

Dry matter, CP, P and SS content of bulb and leaf were compared within the Canterbury region for four different cultivars (Figure 4). Bulb DM content was affected by cultivar ($P<0.01$) and was greater for cultivar F than cultivar T, whereas leaf DM was not affected by cultivar (Figure 4a). Bulb CP was affected by cultivar ($P<0.01$) and was greater for cultivar T (10%) than cultivar F (5.8%), whereas leaf CP was not affected by cultivar (Figure 4b). There was a trend for bulb P with cultivar ($P=0.09$) but pairwise comparisons showed no significant differences between cultivars and leaf P was not affected by cultivar (Figure 4c). There was no effect of cultivar on SS content of bulb and leaf.

Discussion

The mean nutritional composition of FB leaf and bulb for the whole dataset in the current study (Table 3) was in most cases comparable to the reported mid-point values from Hill Laboratories (2020) (Table 1), with bulb DM, CP, NDF, SS, ash, DOMD and Mg, and leaf DM, ME, CP, NDF, SS, ash, DOMD and P within 10% of the means in the present dataset. Only for bulb S and leaf Cl was there a difference greater than 25% between the means of this study and the Hill Laboratories reported mid-point values (Table 1 and Table 3). The estimated mean whole FB crop nutritional composition values presented in Table 4 for different proportions of bulb and leaf were all within the DM, CP and NDF ranges described for FB in DairyNZ's Facts and Figures (DairyNZ 2021). The only exception was for soluble sugars where the values from our dataset (54.2-58.6%) were lower than the 60-65% reported by DairyNZ (2021). The credibility of "book values" or feed nutritional compositions from the literature is important, whether they be used because data is not available, or for national scale modelling or predictions. However, this study has shown there is substantial variation in these nutritional values, for example between cultivars, and within cultivars both between and within regions, which is important to consider when optimising diets on individual farms.

Region affected some of the variables investigated, for example Canterbury had greater values of leaf DM content and bulb P content than Otago/Southland. Fodder beet leaves may be more affected by climatic conditions which differ between regions, than FB bulbs and this could influence leaf DM and CP content. Examples of these include frosts, droughts, and warmer humid conditions which promote fungal diseases and thus leaf loss. Chakwizira et al. (2016) described canopy formation processes for FB crops and showed that water stress and nitrogen supply affected leaf area expansion. In contrast, for the selected "Low" and "Medium" DM cultivars with the most data available, bulb DM, CP and SS, and leaf P and SS were shown to be similar between the Canterbury and Otago/Southland regions which

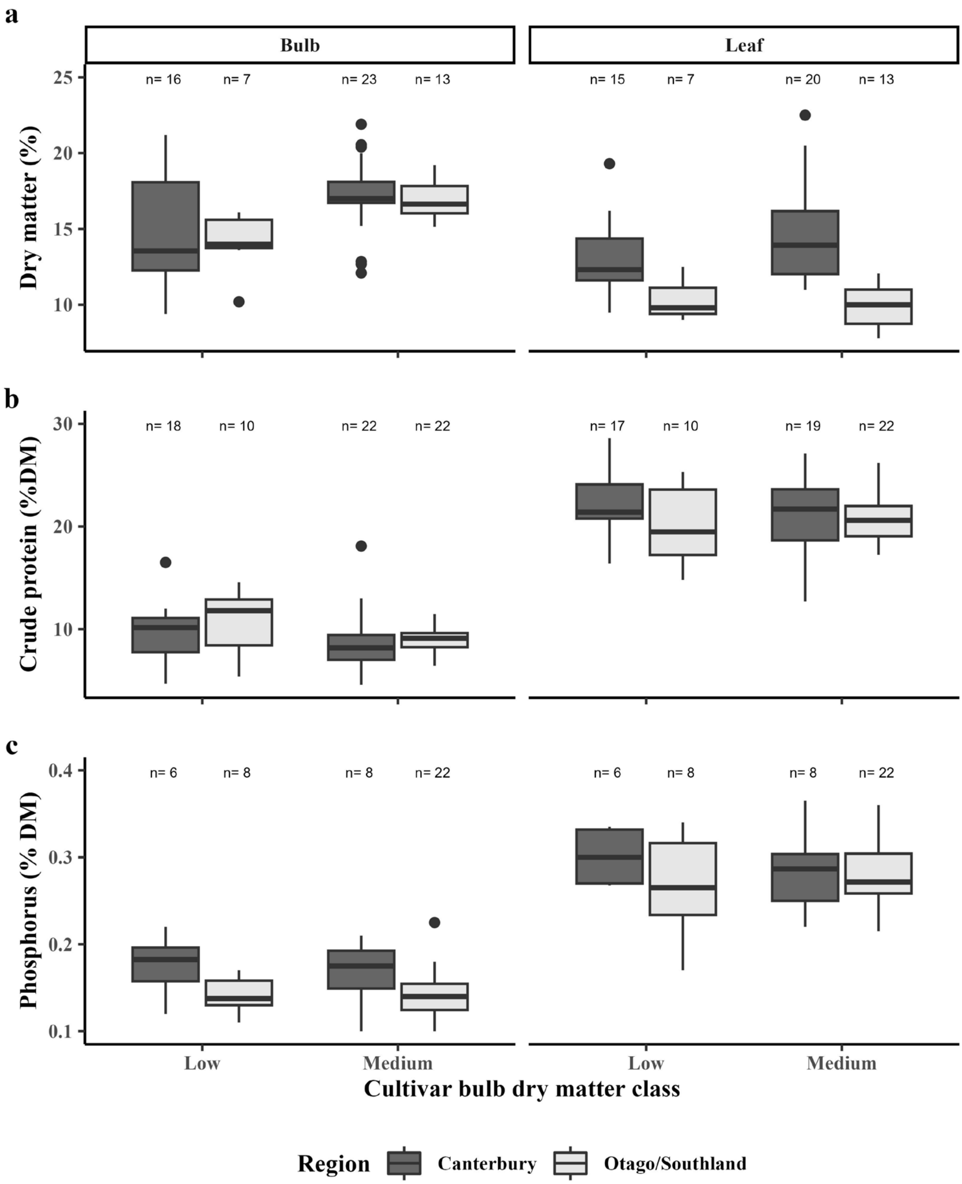

Figure 3 Box plot comparison of fodder beet bulb and leaf a) dry matter, b) crude protein, and c) phosphorus content between the Canterbury and Otago/Southland regions in New Zealand of a “Low” dry matter cultivar, and a “Medium” dry matter cultivar. Data were from crops sampled between May and August.

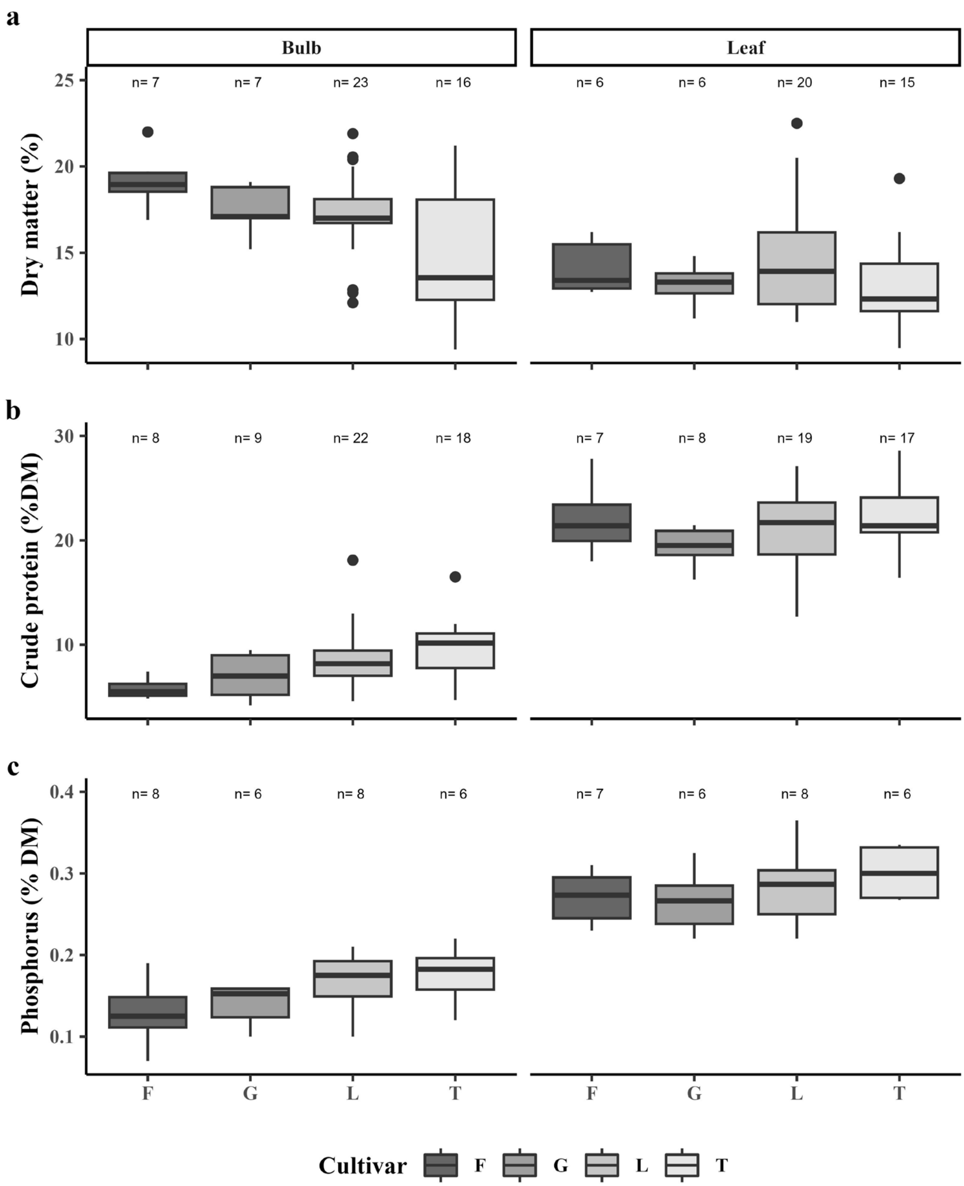

Figure 4 Box plot comparison of fodder beet bulb and leaf a) dry matter, b) crude protein, and c) phosphorus content between four different cultivars in the Canterbury region of New Zealand. Data were from crops sampled between May and August.

suggests that in some situations generic management/guidance may be appropriate. However, the range in values highlighted in Figure 3 for DM (bulb 9.4-21.9%, leaf 7.8-22.5%), CP (bulb 4.6-18.1%, leaf 12.7-28.6%) and P (bulb 0.1-0.23%, leaf 0.17-0.37%) support the recommendation for paddock-specific crop and batch-specific supplement nutritional testing.

Cultivars marketed as “Low” or “Medium” DM appear to largely conform to their prescribed DM% groupings, as indicated by Judson et al. (2016) although variation between regions was evident, particularly for leaf DM, and a wide range of bulb DM content for the “Low” DM cultivar in Canterbury (Figure 3a). Thus using “book values” or average DM classification values (e.g., Low = 12%, Medium = 17%) instead of actual DM content to estimate the yield of any singular crop is a risk in terms of inappropriate allocation and animal health issues.

The analysis of cultivar differences suggests that plant breeding plays a role in improving FB as a feed for dairy cows. Between-cultivar variation indicates an opportunity to make improvements in bulb CP and P content which could reduce the need for supplementation, but this is unlikely to be a complete solution. For example, cultivar T had the highest bulb CP (Figure 1) and the second highest bulb P content (Figure 2), although the boxplots for this cultivar showed quite a wide range in values. Cultivar choice is an important consideration to make, both in relation to specific farmer goals, and when it comes to feeding FB in relation to nutrient supply.

Researchers should collect and report additional details relating to agronomic practices when they are reporting feed quality and mineral results for FB and other forage crops. This would be valuable as these variables could help explain some of the variation observed which we were not able to explore in this study.

The results from this study confirm the general understanding that FB bulbs have low concentrations of CP, NDF, P, Ca, and S and when fed as a high proportion of the diet are unlikely to meet the needs of lactating dairy cattle. Leaf material contained a higher concentration of these nutrients which improves the feeding value of the overall crop as shown in Table 4. However, the volume of leaf typically reduces through the winter and can be extremely variable. Judson et al. (2016) found that on average, leaf made up 17% of this yield representing around 3.5 t DM/ha but varied from 5-40%. The range in bulb P content shown in Figure 2 is wide but even the highest values are still well below the 0.3-0.45% recommended for growing and lactating dairy cattle (Kolver 2000; DairyNZ 2021). Furthermore, the P, S and Ca content remained below the recommended levels even when calculated for a 60% FB diet combined with good quality pasture silage (Table 4).

The observed variation in FB nutritional composition between regions and cultivars can be overcome with individual nutritional testing at the paddock level. This allows diets to be tailored and appropriate supplementary feeds and mineral supplements to be combined with FB to meet animal nutritional needs and minimise the risk of metabolic disease and negative impacts on animal health and production. Although this analysis shows FB itself is unlikely to meet the nutritional needs of dairy cows, FB can be used successfully for liveweight and body condition score gain, and milk production (Dalley et al. 2020b) if care is taken in selecting appropriate supplementary feed sources and providing macro-nutrients and trace elements where necessary based on crop and supplement feed analyses.

Conclusions and practical implications

The variation in nutrient content between cultivars, and within cultivars between and within regions shown in this study highlights the importance of paddock-specific feed analyses, and the limitations of textbook values, particularly where whole plant values are reported. Knowledge of dietary nutrient concentrations will help inform supplementary feed and mineral supplementation requirements. This will ensure dairy cattle nutritional requirements are met when feeding diets containing FB, maximising the likelihood of positive outcomes for animal health and production. Specifically, care should be taken when only feeding FB bulbs to dairy cattle, to ensure adequate dietary supply of CP, fibre, P, S and Ca, as these are the most limiting nutrients in FB bulbs. The choice of supplementary feed/pasture and proportion of the diet as FB plays an important role in this.

We recommend farmers analyse their FB crops (leaf and bulb separately) and supplementary feeds prior to feeding. The DairyNZ FeedChecker calculator (https://www.dairynz.co.nz/tools/feed-checker/ has been updated to account for differences in FB leaf and bulb and is a useful tool that farmers can use to estimate the diet on offer relative to cow nutritional requirements.

Acknowledgements

This project was funded by the Sustainable Farming Fund (contract 405512), Ministry for Primary Industries, New Zealand; DairyNZ and PGG Wrightson Seeds. We would like to thank B. Kuhn-Sherlock for statistical advice and analysis. Access to Agricom trial sites to collect samples for nutritive value analysis and access to yield data significantly enriched the dataset used in this paper. We would like to thank Plant and Food Research and John de Ruiter for supplying their fodder beet feed quality data to this database.

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