
THE PROCEEDINGS OF THE
NEW ZEALAND SOCIETY
OF
ANIMAL PRODUCTION
VOLUME 62 2002

ISSN 0370-2731/2000 Proceedings of the New Zealand Society of Animal Production **60:** 143-146

Reducing fat colour in beef by grazing steers on turnip bulbs

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ABSTRACT

Feeding steers for 10 weeks on the residual turnip bulbs left after grazing the green tops off with lambs plus low carotenoid supplements, reduced carotenoid concentrations in the carcass fat by 38-43% and fat colour by 14-31% compared with steers grazing pasture. The steers on the turnip bulbs were fed a daily supplement of 0.5 x 10^{-1} IU of vitamin A in pelleted barley grain plus pasture silage, hay, and malting corms. The turnip bulbs comprised approximately 42-47% of the diet. The growth rate of the steers on turnip bulbs was higher ($P < 0.001$) than for steers on pasture (0.71 kg head^{-1}day^{-1} versus 0.45 kg head^{-1} day^{-1}). There were no effects of grazing the steers on turnip bulbs on the other meat characteristics measured, including the odour and taste.

Keywords: beef; fat colour; carotenoids; turnip bulbs.

INTRODUCTION

Carotenoids (ß-carotene and lutein) are integral components of the photosynthetic mechanism of green plants, but when the green plants are grazed by cattle, the carotenoids accumulate in the fat causing the yellow colour that can reduce the acceptability of the beef in some markets (Bauernfeind *et al.*, 1981; Yang *et al.*, 1992). Turnip bulbs are one of the few crops used by New Zealand farmers that have low carotenoid concentrations. In a preliminary trial (Knight, 1998), young cattle grazed the green turnip tops and the mature steers that grazed the residual turnip bulbs had a reduced plasma carotenoid concentration (PC), indicating reduced carotenoid absorption. There were problems, however, because the steers fed on only turnip bulbs lost weight. This was possibly due to the low fibre (15%) and protein (7.5%) content of turnip bulbs. These deficiencies in the diet could be rectified by feeding silage or hay and by supplying a high-protein supplement, or by increasing the protein content of the turnip bulbs by applying nitrogen fertiliser (Pearson & Thomson, 1996).

Daily supplements of 0.5-1 x 10^6 IU vitamin A reduced carotenoid absorption and produced a 30-50% reduction in PC but no reduction in the fat colour of steers grazing pastures (Knight & Death, 1999). This was possibly because PC was still higher than the 1-2 μg ml^{-1} found in feedlot cattle (Knight *et al.*, 1996). The vitamin A supplements could be effective, however, in reducing fat colour if given as a supplement to steers fed diets with a low-moderate carotenoid content. The high-density lipoproteins in cattle carry 80-95% of both the carotenoids and cholesterol in plasma (Grummer & Carroll, 1991; Yang *et al.*, 1992). Reducing the lipid content of the diet reduces both PC and plasma cholesterol concentration (PChol) by a reduction in the absorption of these hydrophobic compounds from the small intestine (Bauernfeind *et al.*, 1981; Ashes *et al.*, 1982).

The aim of the experiment presented in this paper was to demonstrate that grazing mature steers, supplemented with vitamin A, on residual turnip bulbs left after lambs graze the green turnip tops, can reduce carcass fat colour while maintaining growth rates similar to steers grazing pasture.

MATERIALS AND METHODS

Animals

On Day 0 (23 February 1999), thirty 18-month old Angus and Angus crossbreed steers were randomly allocated to pasture (PS) and turnip (TS) groups. Both groups initially remained in the same pasture paddock but were separated using an electric tape. TS received a daily supplement of 0.8 kg per head of pelleted barley grain containing 0.5 x 10^6 IU of vitamin A. TS were introduced on Day 16 to the turnip bulbs remaining after lambs had removed the green tops and fed a daily supplement comprising 4 kg of pasture silage, 1 kg of malting corms (the residue after malting barley), and 0.8 kg of hay head^{-1}. While on the turnip bulbs, the TS were given 2-3 day breaks behind an electric tape. There was no back fencing because the steers needed access to a water trough. PS grazed pasture paddocks adjacent to the turnip paddocks and received 4-5 day breaks. TS grazed turnip bulbs until Day 83 when they joined PS on pasture before a final weight on Day 85. Both groups were trucked to Manawatu Beef Packers Ltd (MBP) for slaughter on Day 86. Vitamin A supplement ceased on Day 60, although the barley grain pellets continued to be fed until Day 83.

Grazing of Turnips

In early November 1998, 2.5 ha of Barkant and 2.5 ha of Barabas turnips were planted in adjacent paddocks at AgResearch, Flock House, New Zealand. The fertiliser application was 120 kg ha^{-1} of N:P:K (15:10:10) fertiliser at cultivation and 20 kg ha^{-1} of sulphur super fertiliser at planting. Drought conditions from late November to January prevented the application of herbicide and urea after the emergence of the turnips.

Ten days before the steers were to commence grazing turnip bulbs, the paddocks were divided into thirds and the green turnip tops were removed progressively by grazing each area of the paddock with 100 – 200 lambs. Once most of the green top and weeds had been removed in an area, the division was removed to give the lambs access to a new area of turnips. To control the regrowth of leaves on the grazed turnips, the lambs were not back fenced. TS entered the second paddock on Day 70 and only utilised 0.7 ha of the paddock.

Estimates of the total feed dry matter (DM) before grazing with lambs in the turnip paddocks were made on Days 6 and 63 for paddocks 1 and 2, respectively. Six, 45 x 45 cm quadrats were randomly taken every 20 paces while walking diagonally across the whole paddock. The weeds within the quadrat were cut to ground level and the turnips pulled up. The samples were separated into green weeds, dead matter, turnip tops (leaves and stems) and bulbs, and the dry weights determined after drying in an oven for 2 days at 60°C. Post-lamb grazing DM, measured immediately after the lambs had grazed the areas, were made on Days 16, 44, and 70. An estimate of the post-grazing residuals left by the steers was made on Day 70 by randomly selecting four sites on the area that had been recently grazed by the steers and counting and weighing the turnip bulbs in a 25 m^2 area. Samples of all the supplements, and turnip bulbs and tops were taken on Day 44, and pasture samples, plucked to grazing height, were taken on Days 16 and 44 for analyses of ß-carotene content and feed quality.

Measurements

All steers were weighed and/or blood samples collected on Days –12, 0, 16, 31, 44, 58, 72, and 85. Blood samples were collected by tail venipuncture and after centrifugation, the plasma was stored at –20°C until analysed for PC and PChol. Channel fat samples were collected immediately after slaughter for colour and carotenoid concentration analysis. Carcasses were chilled for 24 hours and subcutaneous fat depth was measured over the 12th rib at a point over the *M. longissimus lumborum* (LD), and approximately one-quarter of the distance from its lateral edge. A second measure of fat depth was made at a site (GR) midway over the *M. serratus dorsalis*. Both measurements were made on each side of the carcass and the mean calculated. Subcutaneous fat samples were collected from over the 12th rib for colour and carotenoid concentration analyses. A length of striploin starting from the 13th rib was removed for taste panel analyses. Standard measurements made by MBP included carcass weight, pH, and scores for carcass fat cover (1= no fat; 5 = good fat cover), fat colour (1 = white fat; 7 = very yellow fat), and meat colour (1 = bright red; 7 = dark red-purple).

Sample Analyses

PC was determined by the method of Knight *et al.* (1994) and concentrations of carotenoids in channel and subcutaneous fat, and the ß-carotene concentrations in feed were determined by the methods of Knight *et al.* (1996). PChol was determined on plasma samples from Days –12, 0, 16, 31, 58, and 85, by the method of Siedel *et al.* (1983). Feed quality was determined by near infrared reflectance spectroscopy. Objective measurements of fat colour (b*) were made using a Minolta Chromameter (model CR-200b) after the fat had been thawed and placed on a white mat. Taste panel measurements were made on a random selection of 5 TS and 6 PS striploins. A 12-member panel (MIRINZ Food Technology and Research Ltd, Hamilton) evaluated the samples using a 10-point category scale (0 = absent and 9 = intense) and the samples were evaluated for 'beef' and 'other' odour and flavour intensities.

Statistical analyses

PROC MIXED procedures (SAS Institute. 1990) were used to analyse the repeated measures over time of PC and PChol concentrations using PC and PChol concentrations on Day 0 as covariates. Analysis of variance was used to compare other traits.

RESULTS

Turnips

There was a large range of weeds that varied in density over the paddocks and made it difficult to obtain accurate estimates of herbage mass. There were large areas of 1-1.5m tall willow weed (*Polygonum persicaria*) and stinking mayweed (*Anthemis cotula*) that in some areas swamped the turnips. Therefore, the estimates of kg DM ha^{-1} before grazing with either lambs or steers were only approximations of the feed available (Table 1). The lambs reduced the amount and proportion of green turnip tops and weeds from 34% to 10%. To get this reduction in green weeds and turnip tops, the number of lambs and duration of grazing was increased until the lambs had started to eat the turnip bulbs. Visually, it appeared that the lambs were eating about 10-20% from most of the large turnip bulbs and damage to these bulbs resulted in some of them rotting. TS were initially reluctant to eat turnip bulbs but, once they started to eat them, they first consumed the smaller bulbs and only ate the larger bulbs down to ground level at the end of their break. The residual amount of bulbs left on Day 70 by TS was 17 ± 7 turnip bulbs per 25 m^2 and 170 ± 129 kg DM ha^{-1}. The nutrient content and the ß-carotene concentrations in the turnip bulbs and tops, the pastures grazed by PS and in the supplements fed to TS are presented in Table 2. Turnip bulbs had lower lipid, crude protein, and ß-carotene content than the turnip leaves and pasture.

TABLE 1: Mean (±SD) weight and proportion of total feed available for herbage and turnip bulbs, and number of turnip bulbs per m^2 measured over the turnip paddocks before grazing with lambs, and in selected areas after grazing with lambs but before grazing with steers.

	Pre-sheep grazing		Pre-cattle grazing	
	kg DM ha^{-1}	%	kg DM ha^{-1}	%
Turnip bulbs	6420 ± 2301	53	8580 ± 4881	81
Turnip tops	2760 ± 1602	23	483 ± 406	5
Weeds	1354 ± 857	11	557 ± 1339	5
Dead Matter	1669 ± 816	14	1002 ± 582	9
Total DM	12203 ± 5576	100	10622 ± 7208	100
Number of bulbs	36 ± 30		30 ± 20	

Live weight

The growth rate from Day 0 to 85 of TS was higher ($P < 0.001$) than for PS (Table 3). This resulted in TS being heavier than PS on Day 85 ($P < 0.001$). This difference, combined with a higher ($P < 0.01$) dressing-out percentage for TS than for PS, was reflected in a 13-kg difference ($P < 0.001$) in carcass weight (Table 3).

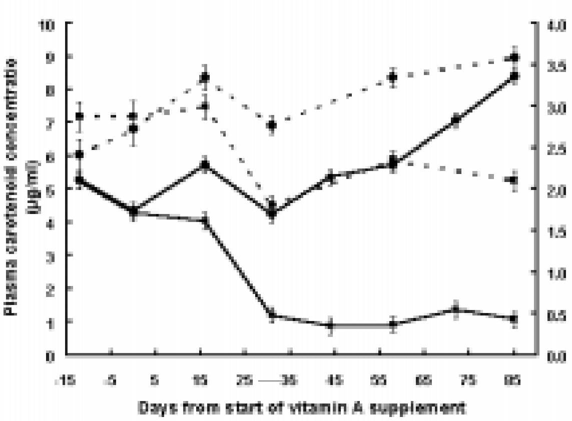
TABLE 2: The percentage of DM, lipids, crude protein, acid detergent fibre (ADF), and neutral detergent fibre (NDF), the metabolic energy (MJ ME kg^{-1} DM), and the ß-carotene concentration (mg kg^{-1} DM) in the turnip tops and bulbs, the pasture, and in the supplements.

	% DM	% Lipid	% Crude protein	% ADF	% NDF	Metabolic energy	ß-carotene mg kg^{-1} DM
Pasture silage	55	3.8	12.3	36.8	60.3	10.5	75
Hay	90	2.8	16.3	31.2	50.8	9.5	169
Malting corm	97	0.8	32.5	12.8	34.9	17.9	3.8
Barley pellets	93	1.6	13.1	3.1	9.9	14.0	2
Turnip bulbs	11	0.8	7.5	19	18.4	13.8	4.8
Turnip tops	14	2.9	26.9	19.6	15.2	12.6	339
Pasture:							
Day 16	28	3.3	23.2	20.6	35.0	10.6	317
Day 44	26	3.8	26.8	21.8	38.8	11.0	420

TABLE 3: Mean (±SEM) live weight, liveweight change, carcass weight, and carcass characteristics for steers grazing pasture (PS) and turnip bulbs (TS). NS = not significant; ** = P < 0.01; *** = P < 0.001.

	PS	TS	SEM	Signf.
Live weight (kg)				
Day 0	449	445	2	NS
Day 85	485	505	3	***
Liveweight change (kg head^{-1} day^{-1})	0.45	0.71	0.03	***
Carcass wt (kg)	262	275	2	***
Dressing out %	56.1	57.7	0.3	**
Channel fat b*	14.1	12.1	0.43	**
Subcutaneous fat b*	14.3	9.9	0.6	***
Carotenoid conc. in				
Channel fat (µg g^{-1} fat)	0.77	0.48	0.05	***
Subcutaneous fat (µg g^{-1} fat)	0.69	0.39	0.04	***
Fat colour score	4.4	3.7	0.2	**
Fat depth over rib eye (mm)	6.9	8.8	0.7	NS
GR depth (mm)	11.2	15.3	1.0	**
Fat cover score	4.1	4.5	0.4	NS
Meat colour score	4.9	5.1	0.2	NS
pH	5.61	5.74	0.07	NS
Mean taste panel scores for:				
Beef flavour	5.3	5.2	0.7	NS
Beef odour	5.2	5.0	0.4	NS
Other flavour	2.4	2.7	0.9	NS
Other odour	2.3	2.4	0.9	NS

Figure 1: Mean (± SEM) PC (____) and PChol (……) in TS (□) and PS (●). Vitamin A supplementation of TS started on Day 0 and ended on Day 60. TS started grazing the turnip bulbs on Day 16.



Plasma carotenoid and cholesterol concentrations

There were no differences in PC between TS and PS on Days –12 and 0, but 16 days after the start of the vitamin A supplement the PC was lower (P < 0.001) for TS than for PS. This difference increased after TS started grazing the turnip bulbs on Day 16 (Fig 1). PChol was similar in both groups of steers on Days –12, 0 and 16, but was lower (P < 0.001) for TS than for PS once the TS started grazing turnip bulbs (Fig 1).

Carcass characteristics

Feeding turnip bulbs in combination with the vitamin A supplement produced a significantly lower fat colour in TS than in PS (Table 3). The b* for channel fat and subcutaneous fat were 14% (P< 0.01) and 31% (P < 0.001) lower, respectively, in TS than in PS. These differences in objectively measured fat colour were reflected in the subjectively measured fat colour score, which was lower (P < 0.01) in TS than in PS (Table 3). Channel and subcutaneous fat carotenoid concentrations were 38-43% lower (P < 0.001) in TS than in PS (Table 3).

The GR measurement was thicker (P < 0.01) for TS than for PS and fat depth over the rib also tended to be thicker (P < 0.07) for TS than for PS (Table 3). There were no differences between TS and PS in pH, meat colour score or in the taste panel scores for 'beef' flavour and odour or for 'other' flavour and odour for the striploin (Table 3).

DISCUSSION

Lambs successfully removed most of the green turnip tops and weeds to provide a low-carotenoid diet of turnip bulbs for mature steers to graze. Ten weeks of grazing the residual turnip bulbs together with 60 days of vitamin A supplement and the supplementation with silage, hay, barley grain pellets, and malting corms produced a reduction in fat colour (14-31%) and in the carotenoid concentration in the fat (38-43%). The accompanying reduction in PC to low concentrations in TS indicated that there was a reduced absorption of carotenoids from the small intestine. The faster growth rate and heavier carcass weight and fatness of TS compared with PS may have contribution to the difference in fat colour but it would have been of minor importance since both groups of steers were gaining in weight throughout the experiment. Differences in fat carotenoid concentration can occur when steers lose weight because carotenoids fail to leave the adipose tissue with the fat that is being catabolised (Boom & Sheath, 1997).

The lower carotenoid absorption in the TS was due to a combination of the low carotenoid content of the diet, and the vitamin A supplement reducing carotenoid absorption (Knight & Death, 1999). The lower PChol for TS than for PS suggests the lipid content of the diet of TS was lower than for PS and this would have further reduced carotenoid absorption (Bauernfeind *et al.*, 1981; Ashes *et al.*, 1982). Based on the live weight and growth rate of TS, there was a requirement for 99-108 MJ ME head^{-1} day^{-1} DM (Ulyatt *et al.*, 1980) and the silage, hay, barley grain pellets, and malting corms provided approximately 57 MJ ME head^{-1} day^{-1}. Therefore turnip bulbs provided about 42-47% of the DM intake for TS. The daily intake of turnip bulbs was about 3.0-3.6 kg DM head^{-1} and the total ß-carotene content of the diet was 37-40 mg kg^{-1} DM. This was much less than the 317-420 mg ß-carotene kg^{-1} DM found for the pasture and less than the 339-mg ß-carotene kg^{-1} DM found for the turnip tops. The lipid content of the diet of TS was about 1.8 –1.9 g $100g^{-1}$, which was almost half that found in the pasture.

The reduction in the fat colour of TS could probably have been obtained without the vitamin A supplement, especially if the turnip paddocks had been sprayed so there was less of the green weeds that lambs failed to graze. Also, back fencing would have prevented TS grazing the regrowth, while feeding hay rather that pasture silage would also have reduced the lipid concentration of the diet. The lower lipid content of the hay would have offset the higher ß-carotene content relative to pasture silage. ß-carotene concentrations in pasture silage and hay are variable but hay usually has a lower ß-carotene concentration than pasture silage (P. D. Muir pers. com.).

The feeding of the hay, pasture silage, malting corms, and barley pellets overcame the problems of weight loss found in the preliminary trial (Knight, 1998) and TS grew faster than PS, which were given the best pasture available in the drought conditions. The inclusion of the malting corms resulted in the total diet for TS having about 13 % crude protein. Pearson & Thomson (1996) obtained similar crude protein concentrations in turnip bulbs when 100-200 kg nitrogen as urea was applied ha^{-1} about a month after sowing the turnips. The drought prevented the application of urea in this trial, necessitating the feeding of the malting corms to increase the crude protein content of the diet of TS. Turnip bulb residuals were low after grazing with TS and growth rates may have been higher if there had been a lower utilisation of the turnip bulbs.

The higher growth rate of TS was reflected in higher carcass weights and a tendency for the carcasses to be fatter than PS. There were no adverse effects of grazing turnip bulbs for 10 weeks on the meat characteristics measured or on the flavour and odour of the meat.

The total DM herbage mass in the turnip paddocks before grazing with sheep was similar to values found in the preliminary trial (Knight, 1998) and those found by Pearson & Thomson (1996). However, the leaf to bulb DM ratios were low compared to the values of Pearson & Thomson (1996), and suggest the amount of turnip bulb DM measured before grazing with lambs may have been over estimated. This was possibly due to the variable but prolific growth of weeds in the turnip paddocks and the fact that a small 45 x 45 cm quadrat was used to sample the turnip paddock. Pearson & Thomson (1996) used a 1 m^2 frame. The increase in the mass of turnip bulbs measured in the areas after grazing by sheep and before grazing with steers was due to the inaccuracy of measurement caused by the weeds and the small quadrat.

CONCLUSIONS

A management strategy has been demonstrated for reducing the fat colour of steers by grazing them for 10 weeks on the turnip bulbs left after the removal of the green turnip tops with lambs. The reduction in fat colour score would increase the proportion of carcasses suitable for the Asian market, which requires a fat colour score of less than five. Increasing the duration of time the steers grazed the turnip bulbs would result in further reductions in the fat colour (T W Knight unpublished). Supplements of vitamin A and protein may not be necessary, but a supplement of hay or silage would be necessary to prevent the weight loss found in previous trials. Beef-cattle farmers with flat areas on their farm could use this strategy, especially where a re-grassing program is planned. Further research is required to accurately determine the feed available to lambs and steers, and to evaluate the economics of this management strategy.

ACKNOWLEDGEMENTS

We thank the staff at Manawatu Beef Packers Ltd for their assistance in this project and acknowledge funding from Foundation for Research, Science, and Technology.

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