Nutritional effects on carotenoid concentrations in the fat of beef cattle

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ABSTRACT

Yellow fat reduces the acceptability and value of beef table cuts within the high priced Asian markets. The concentration of carotenoids in fat, leads to this yellowness. A systems experiment which ran for 2 years, studied the effects of nutrition and age on fat carotenoid concentration (FCC). In each year, rising 1-year (R1) and 2-year (R2) Angus steers were offered either full access to winter and spring feed (fast rotation, FR); or were nutritionally restricted during winter (slow rotation, SR) and then given full access to feed during spring. Fat biopsy samples were collected every 4 months and carotenoid concentration determined.

FCC increased as animals became older. The effect of the nutritional growth path was to increase FCC during winter where feeding was restricted, particularly in the R1 steers. In both years, the SR systems compensated during spring, with both live weight and FCC being similar for the 2 nutrition treatments by the end of spring. From a practical perspective, farmers who seek to supply beef with satisfactory fat colour should not restrict feeding during the period of 3-4 months prior to slaughter.

The experiment also provided data which allowed FCC to be followed from weaning through to slaughter for individual animals. These data provided the opportunity to investigate the prediction of carcass FCC based on earlier fat measurements. Correlations (r) ranged from 0.31 at 24 months to 0.71 at 3 months before slaughter. Correlations are not sufficiently strong to justify early selection of cattle for targeted markets and growth paths. However, there is opportunity for processors to use fat biopsy and objective colour measurement techniques in the selection and purchase of cattle for high priced markets.

Keywords: Fat colour; carotenoids; nutrition; prediction.

INTRODUCTION

The New Zealand beef finishing industry relies predominantly upon pasture feeding. This forage diet contains high levels of carotenoids when compared to the grain diets predominantly fed within the Australian and North American beef finishing systems. Carotenoids, especially ß-carotene accumulate within the fat of cattle causing yellow pigmentation (Morgan and Everitt, 1969). This yellowing in turn reduces the acceptability of New Zealand beef to certain high priced markets such as Japan. Changes in the yellow coloration of body fat in beef cows have been linked to the rise and fall of body weight experienced within many breeding systems (Barton, 1959; Hammond, 1960). However, other research by Morgan and Everitt (1968) showed no carcass fat colour differences when identical twins sets were split and either held near maintenance over winter, or continuously grown and then slaughtered in good condition at 22 months of age. These conflicting findings highlight the need for a better understanding of the effects of grazing management on fat carotenoid concentrations (FCC) for beef cattle.

Another management tool which could assist in the consistent production of high quality beef product, would be the ability to predict at an early stage in an animals lifetime, the carcass FCC at slaughter. This would allow the early selection of cattle for specific markets and growth paths. Within any herd there is appreciable variation (up to 5 fold) in both plasma and fat carotenoid concentrations (Morgan *et al.*, 1969; Newman *et al.*, 1994). Further, Knight *et al.* (1993) found there was a strong correlation (r = 0.94) in the ranking of plasma carotenoid concentrations within a herd, when using 2 assessments taken 5 months apart. However, even though Morgan *et al.* (1969) reported a significant correlation (r = 0.58) between plasma concentration and carcass FCC at slaughter, they concluded that in practice the former was unlikely to be a useful predictor of the latter. There is no information on the use of fat biopsies to predict carcass FCC.

The experiment reported in this paper investigated the effects of two nutritional growth paths on FCC. It also provided an opportunity to assess the reliability of fat biopsy FCC as an early predictor of carcass FCC.

MATERIALS AND METHODS

Experimental Design

A systems experiment was run for two years at Whatawhata Research Centre with a 2 x 2 factorial design and 2 replicates. This gave a total of 8 self contained farmlets. Treatments involved rising 1-year (R1) vs rising 2-year (R2) Angus steers which were either offered full access to winter and spring feed (fast rotation, FR); or were nutritionally restricted during winter (slow rotation, SR) and then given full allocation during spring. This latter treatment maintained body weight over winter and allowed the system to compensate during spring. To achieve these treatment contrasts, winter grazing residuals (mean of 2 years) were 1273 and 914 kgDM/ha for fast and slow rotation treatments respectively.

Land and Stock

Each farmlet contained a balance of easy and steep hill land with the R1 steer farmlets consisting of 7.2 ha and the R2 farmlets being 11.9 ha. Farmlets were stocked with 15 Angus steers and either 30 or 50 Romney ewes for the R1 and R2 farmlets respectively. The trial commenced in April, 1993 and farmlets were destocked in March, 1994 when the R2 steers were slaughtered. Previous R1 steers were rerandomised (April 1994) for the following year (ie: new R2 steers), while a new generation of R1 steers were randomised on the smaller farmlets. Pre/post grazing herbage mass during winter (mean of 2 years) was 1973/1273 kgDM/ha for FR treatments and 2416/914 for SR treatments while calculated green leaf intakes were 87% and 76% for FR and SR treatments respectively. The second year finished with the slaughter of 2 year old steers in March (1995). To ensure as little genetic change as possible between generations, all 3 generations of Angus steers were accessed from the same breeding herd.

Fat Sampling

Samples of fat were taken from all steers during April, August and December of each year. The sample site was above the coccygeus muscle (below the tail head), where approx 1 gram of fat was surgically removed after anaesthetising the area with 10 ml of local anaesthetic. The sample was washed in water, swab dried and frozen until analysis. For R2 cattle which were slaughtered, fat samples were collected from the hot carcass at the same site approximately 20 minutes after slaughter. After 24 hours in the chiller, carcass fat colour scores were assessed using Japanese reference chips (scale 0-7) and again fat was sampled below the tail head and also over the 12th rib.

Fat analysis

The carotenoid concentration of the fat samples was analysed by the method of Kirton *et al.* (1975). Fat (0.5 g) was saponified with 3 ml of 20% KOH in ethanol at 60°C for 45 minutes then cooled to room temperature. Water (2 ml) was added before extracting the sample with 2 ml of petroleum ether which was then removed and dried with anhydrous sodium sulphate. The absorbency of the extract at 450 nm was measured on a spectrophotometer, and the total carotenoid concentration was determined using an absorption coefficient ($A^{1\%}$) of 2550 (Zhou *et al.*, 1993). This assay gives the combined concentration of both ß-carotene and most of the lutein, since 450 nm is near the optimum absorbency for lutein.

Statistical analyses

Analysis of variance was used to compare treatment differences. Correlations were derived by the use of a stepwise regression with variables of rotation length, year and replicate taken into account. In all correlation analyses, the FCC of the hot carcass sampling was used as the slaughter variable.

RESULTS AND DISCUSSION

Animal systems response

In the first year of the trial, steer liveweights on the SR (slow rotation) treatments were on average 23 kg lighter at the end of winter (Table 1), and farmlet pasture mass was on average 550 kgDM/ha higher than the FR (fast rotation) treatments. During the spring, SR steers were given full access to their farmlet feed through the use of a fast rotation, but because of very favourable pasture growing conditions, pasture quality limitations were encountered earlier than on the FR farmlets. Thus, the SR system did not fully compensate, with SR steers being 15.5 kg lighter than FR in December.

At the end of winter in the second year, steer liveweight and pasture mass differences were similar to the first year. However, during the spring period of this second year, pasture control was more complete and the SR systems compensated to a greater extent. This was reflected in similar liveweights for SR and FR steers in December

TABLE 1: Mean steer liveweights (kg) for R1 and R2 steers subjected to two nutritional treatments

	April		August		December		March	
Age/Treatment	1993	1994	1993	1994	1993	1994	1993	1994
1 Year FR[1]	189	185	215	229	316	333	335	353
1 Year SR	186	185	195	213	304	327	324	359
2 Year FR	374	333	406	391	502	500	524	519
2 Year SR	371	334	374	363	483	491	507	517
SED	3.73	4.17	4.01	4.24	4.95	5.46	5.27	5.64

[1] FR, SR = fast and slow rotation nutritional treatments respectively

Carotenoid concentration at slaughter

Figures 1 and 2 show the mean FCC for each of the experimental years. There is an underlying trend of FCC increasing with age which is consistent with the findings of other researchers (Barton, 1959). When the 2-year cattle were slaughtered in March, FCC in the hot rump samples were slightly lower than for the 2 sample types taken from the cold carcass (Table 2). This occurred in both years and is most likely a response to a higher moisture percentage diluting the hot rump samples.

To help place the slaughter data of this experiment in context, the 1 year old cattle that remained at the completion of the experiment were split into 2 mobs. One mob continued to graze pasture at Whatawhata and the other was relocated to 5 Star feedlot in Canterbury where they were fed a 75% barley and 25% maize silage ration for 245 days. Both mobs were slaughtered at 30 months of age. The Whatawhata mob had an FCC mean and variance of 1.63 ± 0.36 µg/g and the "5 Star mob" an FCC mean and variance of 0.56 ± 0.23 µg/g. The feedlot cattle all recorded a Japanese fat reference score of 3.

Nutritional effect on carotenoid concentration

At the end of the winter, the mean FCC for the SR treatments was higher ($P<0.001$) than the mean of the FR

FIGURE 1: Fat carotenoid concentration (µg/g) for the 1993/94 experimental year.

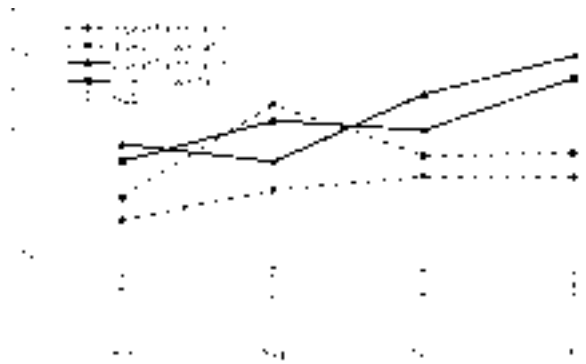

FIGURE 2: Fat carotenoid concentration (µg/g) for the 1994/95 experimental year.

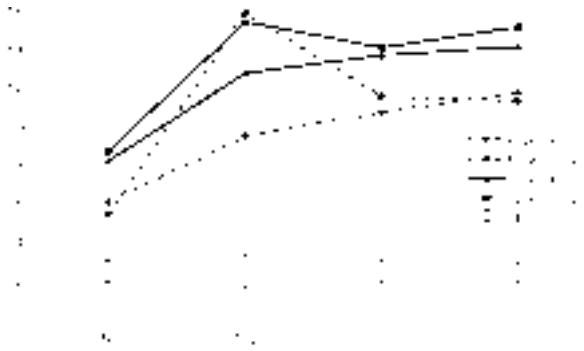

TABLE 2: Fat carotenoid concentration (µg/g) and fat colour score (0-7) of carcass samples taken from slaughtered 2 year steers

	1994		1995	
Sample Site	Mean	SD	Mean	SD
Hot Carcass Rump	1.34	0.34	1.48	0.27
Cold Carcass Rump	1.45	0.42	1.59	0.29
Cold Carcass 12th Rib	1.47	0.39	1.56	0.31
Fat colour score	5.35	0.47	5.12	0.57

groups. Feed restrictions during winter resulted in increased FCC in both years, this effect being most noticeable in the R1 steers.

The mean liveweight for SR cattle was 23 kg lighter at August. While no estimates of fat depth were made at that time, it can be assumed that a large proportion of this weight difference was a reduction in total body fat reserves. This reduction would be relatively greater in the younger cattle. These findings could support suggestions by Yeates (1965), that as fat is mobilised, carotenoids are left behind, becoming more concentrated.

In both years, no significant FCC differences remained between treatments by December. This finding supports those of Morgan and Everitt (1968), and has significance to much of the NZ beef industry which relies on compensatory gain when moving from winter to spring. As long as growing cattle are allowed to reinstate fat reserves after periods of feed restriction, there will be no lasting effect on carcass FCC.

With the beef processing/marketing industry increasing incentives to farmers who supply cattle on contract during spring, there is a temptation for farmers to grow stock to slaughterable weights during autumn and then reduce feeding levels. In this way they are placed in a position to receive improved schedule payments during spring. This procedure will not provide carcasses with optimum fat colour. Beef producers who seek to improve the likelihood of supplying beef with satisfactory fat colour should ensure that feed is not restricted 3-4 months prior to slaughter.

Early prediction of slaughter carotenoid concentrations

In the first year of the trial, randomisation of steers to treatment was on the basis of liveweight and at the April assessment some variation in mean FCC existed between treatments (Figure 1). However, this relative ranking of farmlet means remained in all assessments other than in August. This indicates the strong repeatability of group mean carotenoid ranking even after different treatments had been imposed.

The ability to predict carcass FCC ranking of individual animals within a group by earlier biopsy sampling improved as assessment time was closer to the slaughter date (Table 3). The exception to this in both years was at the August assessments (7 and 19 months from slaughter) when correlations were lower. The ability to predict carcass FCC with any reliability did not occur until 3 months from slaughter (r = 0.71). An alternative way to considering early prediction was to split the herd into quartiles on the basis of biopsy FCC at 3 months from slaughter (Figure 3). For individual animals within the top

TABLE 3: Correlation coefficients between biopsy and carcass fat carotenoid concentrations of individual animals.

Months from slaughter	23	19	15	11	7	3
Correlation (r)	0.31	0.21	0.51	0.58	0.52	0.71
Age (months)	7	11	15	19	23	27
Number of cattle analysed	60	60	60	120	120	120

FIGURE 3: The quartile distribution of fat carotene concentration (µg/g) at slaughter and 3 months prior to slaughter.

or bottom quartiles, there was an 87% probability that they remain within that upper or lower half at slaughter.

A period of 3 months from slaughter is unlikely to be long enough to warrant biopsy sampling for the purpose of selecting cattle for differing growth paths which align to targeted markets. It does though, highlight the opportunity for processors to select and purchase cattle using biopsy techniques. Combining this with objective colour measurement could provide "on the spot" results. At present, cattle fat biopsy sampling is tedious, but investigation is underway to design equipment and techniques that could make this procedure realistic.

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