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The relationship between carotenoid concentration and fat colour in beef carcasses

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ABSTRACT

Relationships between carotenoid concentration, chromameter (L* a* b*), and subjective measurements of fat colour were calculated from 15 mobs of cattle. Carotenoid concentration accounted for 60% of the variation in b* (n=514), but b* accounted for only 16% of the variation in subjectively measured fat colour (n=732). Neither the inclusion of other variables (e.g. carcass weight or fat depth) nor transformation of the data substantially improved these relationships.

Keywords: beef; fat colour; objective measurements.

INTRODUCTION

The yellow colour of beef fat limits access to some Asian markets. Some beef processors provide farmers with subjective assessments of the fat colour of their cattle but to be of value to farmers the fat colour measurements must be accurate. Fat colour can be measured objectively using a chromameter which measures the brightness, yellowness and redness respectively of the fat using the L* a* b* colour numeration system. It has been suggested that chroma and hue, which use a combination of a* and b*, may provide better measures of perceived colour (Rigg 1987). Yellow colour in beef fat is caused by the accumulation of carotenoids (Morgan & Everitt 1969) and Zhou *et al.* (1993) found 62% of the variation in b* accounted for by carotenoid concentration in beef fat.

This paper presents the relationships between fat carotenoid concentration, chromameter measurements and subjectively measured fat colour, and determines how these relationships are influenced by other carcass measurements, combinations of L* a* b*, and data transformation.

MATERIALS AND METHODS

Data on 972 cattle in 15 experimental mobs (13-368 cattle/mob) from 1992 to 1997 were analysed. This included data on 911 steers, and 61 bulls, and of these cattle 817 were pasture fed and 155 grain fed. Carotenoid concentration (CRIB C) and b* (CRIB b*) were measured on subcutaneous (sc) fat over the 12-13 rib of chilled carcasses, 24 hours after slaughter. On 118 steers, the carotenoid concentration and b* values were also measured on rump sc fat immediately after slaughter (HRMP C and HRMP b*) and after the carcasses had been chilled for 24 hours (CRMP C and CRMP b*). A further 17 chilled steer carcasses at Manawatu Beef Packers Ltd (MBP), selected across a range of fat colour, had b* values measured on the sc fat at the 12-13 rib, shoulder, brisket, flank, P8 site, and the fat pad near the tail. The same Minolta CR-200b chromameter with an $8mm^2$ measuring aperture and CIE illuminant C was used on all carcasses. Measurements were made either on the carcasses in the chiller or on the samples collected for carotenoid analysis. The mean of 3 measurements on each carcass taken within a 5 cm radius was used in the analyses. Chroma = $\sqrt{a^{*2} + b^{*2}}$ and hue = arctan b*/a* (Rigg 1987). The assay for measuring carotenoid concentration was described by Knight *et al.* (1996). An estimate of the amount of fat in the tissue of each animal was obtained in some mobs by placing a weighed sample in a test-tube in a 150 °C airflow oven for 24 hours, and then reweighed the sample. The carotenoid concentration, b* and FCS were then be corrected to 100% fat. Fat colour scores (FCS) were visually assessed in the chillers 24 hours after slaughter by trained staff at MBP, using Japanese colour chip as standards (1 = ‘pure white’; 7 = ‘creamy yellow’). Carcass weight and fat cover score were supplied by MBP.

Statistical analysis

GLM procedures (SAS, 1987) were used to determine the variation in CRIB b* and FCS accounted for (R^2) by CRIB C and CRIB b* respectively. Data were tested for improvement of fit following data transformation, correction to 100% fat, using chroma and hue in place of CRIB b*, and after including CRIB L* and a* with the CRIB b* in the models. HRMP C, CRMP C, and CRIB C, and HRMP b*, CRMP b*, and CRIB b* were compared using analysis of variance. Since all variables were not measured in all mobs, comparisons are made using a common group of animals, and only the change in R^2 will be presented.

RESULTS

Carotenoid concentration and b* values

Mean values for CRIB C, and CRIB b* are presented in Table 1. Highest values were from 27 5-year-old Jersey bulls which had mean values of 3.12 µg/g fat and 25.7 respectively for CRIB C and CRIB b*. CRIB C accounted for 60% (range among mobs of 1% to 74%) of the variation in CRIB b* and this relationship was not improved by excluding bulls from the analysis. Replacing CRIB b* in

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TABLE 1: Mean cold rib carotenoid concentration (CRIB C), b* (CRIB b*) and fat colour scores (FCS).

	No. cattle	Mean	Std dev.	Min.	Max.
CRIB C	514	1.16	0.74	0.18	6.04
CRIB b*	968	17.7	3.9	7.6	38.8
FCS	732	5.1	0.7	3	7

the model with chroma and/or hue, or including CRIB L* and/or CRIB a* after CRIB b*, did not improve the relationship. The $\log_e$ of CRIB C accounted for more of the variation in CRIB b* than the non-transformed CRIB C (R^2 = 64.8%), but only when the 5-year-old Jersey bulls were included in the data set. Other transformations (CRIB b* squared, $\log_{10}$ CRIB C and inverse of CRIB C) failed to further increase R^2. Correcting CRIB C, and CRIB b* to 100% fat increased the R^2 by 4.5% points (n=300). After the inclusion of mob and CRIB C in the model estimating CRIB b*, there were still effects from including fat cover score ($P<0.001$) and carcass weight ($P<0.001$), with R^2 increasing by 3.3% points (n=224). None of the models removed the significant ($P<0.001$) difference in CRIB b* among mobs.

CRIB b* values and FCS

The 9 mobs with recorded FCS had a mean of 5.1 (Table 1), but 4 of the mobs had a range of only 2 scores. CRIB b* only accounted for 16% (range among mobs of 2% to 45%) of the variation in FCS and this relationship was improved by only 2% points when bulls were excluded. None of the transformations of CRIB b* or FCS, or the replacement of CRIB b* with chroma and/or hue, improved the relationship. The inclusion of CRIB L* after CRIB b* in the prediction equation for FCS increased R^2 by 3.2% points (n=340; $P<0.001$), while correcting CRIB b* and FCS to 100% fat increased the R^2 by 2.6% points (n=185). Including carcass weight in the model for estimating FCS from mob and CRIB b*, increased R^2 by 1.4% points ($P<0.01$; n=595). For the 283 cattle in which CRIB C, CRIB b*, and FCS were all measured, CRIB C accounted for 4.2% more of the variation in FCS than CRIB b*.

Hot versus cold carcass, and measurement site

In the 118 cattle on which additional measurements were made, carotenoid concentration and b* on the rib and rump of the cold carcass were similar, but cold carcass measurements were higher ($P<0.05$ and $P<0.001$ respectively) than hot carcass measurements (Table 2). HRMP C and HRMP b* accounted for 49% and 63% respectively of the variation in CRMP C and CRMP b*, which in turn accounted for 54% and 39% respectively of the variation in CRIB C and CRIB b*.

TABLE 2: Mean (± SEM) for hot rump (HRMP), cold rump (CRMP) and cold rib (CRIB) carotenoid concentration (C μg/g) and b* in 118 cattle.

	C	b*
HRMP	$1.23^a \pm 0.03$	$17.89^a \pm 0.24$
CRMP	$1.32^b \pm 0.03$	$18.99^b \pm 0.24$
CRIB	$1.32^b \pm 0.03$	$19.24^b \pm 0.24$

Values with different superscript are significantly different ($P<0.05$)

The 17 steers selected at MBP Ltd had a mean FCS of 5.2 ± 1.0 (SD) and a range of CRIB b* of 12-25. The mean b* was higher ($P<0.05$) for the brisket than the other sites, but there were no differences among the other 5 sites (Table 3). The within animal within site variation was 32% of the between site within animal variation, which in turn was 8% of the between animal variation. CRIB b* and shoulder b* accounted for more of the variation in FCS than the other sites (Table 3).

TABLE 3: Mean (± SD) b* measured at 6 sites on the carcasses of 17 steers and the percentage of the variation (R^2) in fat colour score accounted for by b*.

Site	b*	R^2
Tail pad	18.5 ± 3.3	40% *
P8	19.1 ± 2.3	22%
Flank	19.1 ± 3.1	40% *
Rib (CRIB)	18.6 ± 3.0	62% **
Shoulder	18.1 ± 2.9	79% ***
Brisket	21.2 ± 2.7	42% *

* $P<0.05$, ** $P<0.01$, *** $P<0.001$

DISCUSSION

The b* provided the best objective measure of fat colour, and there was a good relationship with carotenoid concentration, but it was poorly related to FCS. Corrections for carcass weight, fat cover score, and fat content of the sample, and the exclusion of bulls from the analysis, resulted in only small improvements in these relationships. The relationships were linear except at very high carotenoid concentrations when there appeared to be a reduced increase in b* with increasing carotenoid concentration. This was apparent when the $\log_e$ transformation of CRIB C improved the prediction of CRIB b* only when the 5-year-old Jersey bulls with the high CRIB C were included.

Subcutaneous fat is not a homogeneous yellow colour as indicated by the variation in b* over a small area of the carcass and the variation between sites on the carcass (Tables 2 and 3). Carotenoid concentration was only measured on 0.3-0.4 g fat, and the b* were the mean of 3 measurements, each of 8 mm^2. This small sampling size could account for some of the unexplained variation in the relationship between fat carotenoid concentration and b*.

Some measurements were made on the carcass in the chiller while others were made on fat samples at room temperature. Temperature, however, has no effect on the chromameter measurements and there was no difference in b* between the inside and outside surfaces of fat samples (Knight unpublished). Therefore the difference in measurement technique on b* were likely to be minimal. There was likely to be some differences in the analysis of carotenoid concentration since three laboratories were used for the analyses. Problems with the stability of the ß-carotene standards resulted in the absorption coefficient ($A^{1\%}$) of 2550 (Zhou *et al.* 1993) being used in some mobs

to calculate carotenoid concentration. However even when carotenoid concentration in steers from different farms were determined in the one assay, there was a significant relationship between carotenoid concentrations and b* on one farm but not the other (Knight unpublished). Similarly Knight *et al*. (1996) reported a decrease in b* between days 62 and 104 in steers on a feedlot which was not accompanied by a decrease in carotenoid concentration. These results support the suggestion of Forrest (1981) that the subcutaneous fat could contain compounds, other than the measured carotenoids (ie ß-carotene and lutein), which influenced b*.

Overall the relationship between b* and FCS was low, the exception being for the selected group of steers with a good range of FCS which were assessed by the same MBP staff on one day. These results reflect the problems of subjective measurements where there are likely to be variations between staff assessing FCS, and variation over time for the same staff member. FCS was assessed from a combination of the sc fat colour and the colour of the intermuscular fat at the 12th rib. A better relationship many occur if video imaging could be used to obtain a mean b* measured over the total carcass.

Carotenoid concentration and b* in sc fat increased as the carcass cooled in the chiller over 24 hours. This was likely to be caused by the loss of moisture and carcass shrinkage (Morgan & Everitt 1969) and not to the decrease in temperature of the carcass per se.

CONCLUSION

While neither of the objective measures nor the subjective measure of fat colour were ideal, the measure of the b* values over the shoulder or rib with a chromameter provides the simplest and best objective measure of fat colour. This measure may be improved if video imaging could be used to provide a mean b* for the whole surface of the carcass.

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