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A comparison of two different instruments for measuring venison CIELAB values and colour assessment by a trained panel

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Abstract Venison colour was measured with a Minolta Chroma Meter CR200b portable filter colorimeter to give CIE (1976) $L^*a^*b^*$ (CIELAB) values; the results were compared with those obtained with a Hunter LabScan 6000 scanning reflectance spectrocolorimeter and a sensory evaluation panel. The values obtained depended on the instrument used, but the variations from one instrument to another were systematic, enabling the filter colorimeter to be calibrated against the reflectance spectrocolorimeter. Panel scores could be accurately predicted by a linear combination of CIELAB values (R^2(adj) = 0.86).

Keywords venison, colour, instrumental, CIELAB values, sensory evaluation

INTRODUCTION

Meat colour is important for product acceptability and is often critically appraised by consumers (Hunt and Kropf, 1985). Visual appearance is a sensory attribute of which colour is one aspect. Therefore instrumental evaluation of colour must relate to sensory assessment of appearance (Setser, 1984). Visual scoring by a trained panel is the preferred method for subjective colour assessment, and although it may be difficult to perform and control (Strange et al., 1974), it sets the benchmark for instrumental measurement comparisons (Hunt and Kropf, 1985). Satisfactory prediction of panel scores for venison colour has been demonstrated using CIE (1976) $L^*a^*b^*$ (CIELAB) values (CIE, 1978) obtained with a scanning reflectance spectrocolorimeter (Stevenson et al., 1989). However, such instrumentation is expensive and lacks portability.

The introduction of lower cost, portable filter colorimeters has made colour measurements more convenient for many industrial and applied scientific studies, such as those on meat quality. However, with some food commodities they have been shown to give numerical values which differ systematically from those obtained by reflectance spectrocolorimetric measurements (Baardseth et al., 1988). Results may vary due to different sample presentation methods (Hunter and Harold, 1987), but if the same presentation methods are used, variation may be attributed to the design of the instruments. This source dependence of colour measurements is known as instrumental metamerism (Billmeyer and Saltzman, 1981), and may be an impediment to the scientific comparison of data obtained by different workers, even though the consistency and reproducibility of one particular instrument may be high. If measurements are taken on a relatively restricted region of CIELAB colour space, as is the case with meat colour, results obtained from different instruments may be compared, provided that relationships between their measurements can be established (Billmeyer and Saltzman, 1981). In this way advantage may be taken of the special merits of a particular instrument, such as the portability of a filter colorimeter for field work, and still enable the comparison of results obtained with a more comprehensive but expensive spectrocolorimeter.

The purposes of the present study were: (1) to measure the CIELAB colour values for venison with a filter colorimeter, compare them with those from a scanning spectrocolorimeter, and test for instrumental metamerism; (2) to establish relationships between panel scores for venison colour and instrumental CIELAB values.

MATERIALS AND METHODS

The preparation of venison samples and the use of the Hunter LabScan 6000 scanning reflectance spectrocolorimeter (Hunter) have been described previously (Stevenson et al., 1989). Perceived colour was assessed by a trained panel of 13, who viewed the samples in a refrigerated retail display case under cool white fluorescent light (1800 lux). A scale of 1 to 5 was used with 5 = bright fresh venison colour to 1 = extremely dark or brown. On three of the four days on which Hunter and panel assessments were carried out, venison colour was also measured using a hand held Minolta Chroma Meter CR200b portable filter colorimeter (Minolta), which had an 8 mm optical port, diffuse illumination and 0° viewing geometry with specular component included.

A total of 52 samples were assessed, with readings made at 10 locations on the cut surface of each slice for both instruments. The L^*, a^* and b^* values were recorded and from these CIE 1976 a, b chroma and hue angle were calculated (Hunter and Harold, 1987). Expected correlation coefficients between CIELAB values of the two instruments were calculated from their sample covariances and within-sample variances (Altman and Bland, 1983), and these were compared with sample correlations. Regression relationships for predicting perceived colour from instrumental measurements and predicting Minolta values from Hunter values were fitted, with R^2(adj) values given by (1-[Residual mean square]/[total mean square]). This follows the recommendation of Example 2 of Cox (1968) for calibrating 'quick' against 'slow' measurements for samples evenly distributed over the range of interest.

Instrumental metamerism was investigated by using both colorimeters to measure the CIELAB values of the surface colour of an optically thick and homogeneous sample of red "Plasticine" modelling clay. This substrate was selected on the basis that it was uniform in colour and had a measured hue angle (CIE, 1978) similar to that of venison, as measured with the Minolta. It was covered with clear plastic food wrap in the same way as the venison samples, so as to imitate their surface specular reflectance characteristics. Twenty observations were taken with each instrument, and the variability of the two instruments was compared using Bartlett's (1937) test for the homogeneity of variance.

RESULTS

Within-sample variances and observed and expected correlation coefficients for the two sets of instrumental colour measurements are presented in Table 1 and the data are plotted with regression lines for each pair of CIELAB values in Figures 1 to 5. Within-sample variances were small compared to their ranges for a^*, chroma and hue angle, leading to strong correlations, while the weaker correlations for L^* and b^* can be attributed to within-sample variation rather than lack of relationship (Altman and Bland, 1983). All observed correlations are consistent with the hypothesis that both instruments are measuring the same property up to a linear transformation. The ranges of all CIELAB values except a^* were disjoint (Table 2) and the slope of the regression of Hunter a^* on Minolta a^* was greater ($P < 0.05$) than 1.

Perceived colour scores covered the range from bright fresh red venison colour to very dark or brown (Stevenson et al., 1989) and were strongly related to a^*, chroma and hue angle values for both instruments (Tables 3,4). Stepwise regression equations for perceived colour on CIELAB values from the Hunter are shown in Table 3 and from the Minolta in Table 4, and give high R^2(adj) values of 0.860 and 0.863, respectively, when L^*, a^* and b^* are included in the model. These are improvements ($P < 0.05$) over the single and double component models. The Cartesian coordinates, a^* and b^*, provided marginally better fits than the polar coordinates, chroma and hue angle.

There were significant differences between the two instruments for all mean surface colour CIELAB values for the optically homogeneous test substrate (Table 5). For all CIELAB values the Hunter was more precise ($P < 0.05$) than the Minolta, using Bartlett's test for homogeneity of variance.

DISCUSSION

The results clearly demonstrate a systematic instrumental difference in the CIELAB values assigned to venison colour, which can be expressed in terms of linear relationships. However, the colours occupy a restricted region in CIELAB colour space. The higher L^* values for the Minolta may be attributed to the inclusion of the specular component in measurements with that instrument. The optical design of the Hunter excludes the reflected specular component.

The lower range in b^* values observed by the Minolta may be attributed to the effect of its internal filters only approximating the CIE Standard Observer functions as shown in the manufacturer's technical specifications supplied with the instrument. With the Hunter exact values are used. The differences therefore appear to be due to instrumental metamerism rather than any other differences in experimental procedure associated with the nature of the substrate surface. Similar conclusions have been reached based on the results of metamerism observed with other food products (Baardseth et al., 1988).

The strong regression relationships obtained between perceived colour scores and measured a^* values are consistent with the attention placed by the panel on the attribute of "redness", which is the particular chromatic characteristic affecting a^* values.

Baardseth et al. (1988) also noted that the precision in predicting colour values from one instrument to another varied with food commodity and this seemed to be associated with the homogeneity of the food samples measured. The venison colours measured in the present study occupied a relatively small region of colour space. Linear regressions relating a^*, chroma and hue angle between instruments had high

R^2(adj) values, which is indicative of the relative homogeneity of the surface colour of venison, which has very little marbling compared to other meats (Stevenson et al., 1989).

Multiple regression modelling showed that subjectively perceived venison colour was closely related to CIE L^*, a^* and b^* values measured by both instruments. That the three component models were significant improvements on the one and two component models supports the findings of Hoke and Davis (1970) and Setser (1984). We consider it inappropriate to mix the Cartesian coordinates (a^* and b^*) with the polar coordinates (chroma and hue angle). CIELAB colour space is widely recognised and is convenient for other purposes such as the calculation of colour differences (Hunter and Harold, 1987).

CONCLUSIONS

Measurements made by a Minolta Chroma Meter CR200b portable filter colorimeter and a Hunter LabScan 6000 scanning reflectance spectrocolorimeter yielded internally consistent results, which differed linearly by a relatively small amount due to instrumental metamerism, illustrating that caution is necessary when comparing results obtained from two different instruments. The close relationship between perceived colour and CIE (1976) $L^*a^*b^*$ values suggests that both instruments can be used as a satisfactory substitute for a trained panel, provided they are calibrated appropriately.

The portability of the filter colorimeter makes it the instrument of choice for field work. Since the optical design of the Hunter LabScan conforms to CIE recommendations for the measurement of surface colours by reflectance spectrophotometry (Wright, 1969), it constitutes an appropriate reference instrument for future comparisons with other types. Its versatility makes it the instrument of choice for investigations of colour requiring the original spectral absorbance values, such as the computation of CIELAB values from various illuminant or observer functions, or studies on pigment types and concentrations.

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Table 1 Within sample variances for CIELAB values measured using a Hunter LabScan and a Minolta Chroma Meter, and observed and expected correlation coefficients between instrumental values.

CIELAB value	Within-Sample Variance		Hunter-Minolta Correlation	
	Hunter	Minolta	Expected	Observed
L*	0.716	1.358	0.437	0.448
a*	0.375	0.640	0.903	0.940
b*	0.349	0.211	0.495	0.365
Chroma	0.627	0.716	0.854	0.894
Hue angle (°)	0.947	2.741	0.915	0.952

Table 2 Ranges of CIELAB values for venison samples using a Hunter LabScan and a Minolta Chroma Meter (n=52).

CIELAB value	Hunter	Minolta
L*	24.7 - 32.1	33.1 - 39.1
a*	7.3 - 18.2	7.4 - 15.2
b*	11.0 - 17.7	5.0 - 7.4
Chroma	13.4 - 24.7	9.5 - 16.5
Hue angle (°)	40.5 - 58.0	20.0 - 38.7

Table 3 Equations for perceived colour regressed on CIELAB values measured using a Hunter LabScan (n=52)

Regression equation	R^2 (adj)
Single component	
-0.026 (0.084) L* + 3.98	0
0.332 (0.024) a* - 0.82	0.791*
0.372 (0.087) b* - 1.87	0.252*
0.306 (0.032) Chroma - 2.41	0.642*
-0.188 (0.014) Hue + 12.45	0.778*
Double component	
0.346 (0.023) a* + 0.100 (0.037) L* - 3.79	0.815*
0.410 (0.032) a* - 0.205 (0.061) b* + 1.07	0.827*
0.314 (0.032) Chroma + 0.067 (0.050) L* - 4.45	0.647
-0.199 (0.013) Hue + 0.118 (0.037) L* + 9.68	0.812*
-0.136 (0.019) Hue + 0.124 (0.034) Chroma + 7.63	0.822*
Triple component	
0.435 (0.029) a* - 0.228 (0.055) b* + 0.115 (0.032) L* - 2.14	0.860*
-0.148 (0.017) Hue + 0.123 (0.031) Chroma + 0.117 (0.033) L* + 4.91	0.856*

*Indicates that adding the last variable in the model is a significant improvement ($P<0.05$). Standard errors are bracketed after their parameter estimates.

Table 4 Equations for perceived colour regressed on CIELAB values measured using a Minolta Chroma Meter (n=52).

Regression equation	R^2 (adj)
Single component	
0.317 (0.109) L* - 8.17	0.127*
0.415 (0.030) a* - 1.58	0.794*
-0.266 (0.228) b* + 4.92	0.007
0.441 (0.039) Chroma - 2.59	0.718*
-0.176 (0.013) Hue + 8.30	0.789*
Double component	
0.400 (0.031) a* + 0.087 (0.055) L* - 4.53	0.800
0.424 (0.026) a* - 0.388 (0.090) b* + 0.73	0.848*
0.423 (0.041) Chroma + 0.085 (0.066) L* - 5.42	0.722
-0.168 (0.012) Hue + 0.178 (0.049) L* + 1.63	0.830*
-0.116 (0.019) Hue + 0.195 (0.050) Chroma + 3.99	0.835*
Triple component	
0.404 (0.026) a* - 0.416 (0.086) b* + 0.116 (0.046) L* - 3.06	0.863*
-0.123 (0.018) Hue + 0.151 (0.050) Chroma + 0.132 (0.048) L*	0.855*

*Indicates that adding the last variable in the model is a significant improvement ($P<0.05$). Standard errors are bracketed after their parameter estimates.

Table 5 Mean CIELAB values for the surface colour of an optically homogeneous test substrate.

CIELAB value	Hunter	SEM	Minolta	SEM
L*	44.44	0.011	48.40	0.037
a*	39.20	0.012	38.70	0.083
b*	25.70	0.014	20.86	0.078
Chroma	46.87	0.017	43.96	0.098
Hue angle	33.25	0.008	28.32	0.076

Figure Captions

Figure 1 CIE L^* values obtained from a Minolta Chroma Meter (M) compared to a Hunter Labscan Scanning Spectrocolorimeter (H).

Figure 2 CIE a^* values obtained from a Minolta Chroma Meter (M) compared to a Hunter Labscan Scanning Spectrocolorimeter (H).

Figure 3 CIE b^* values obtained from a Minolta Chroma Meter (M) compared to a Hunter Labscan Scanning Spectrocolorimeter (H).

Figure 4 CIE Chroma values obtained from a Minolta Chroma Meter (M) compared to a Hunter Labscan Scanning Spectrocolorimeter (H).

Figure 5 CIE hue angle values obtained from a Minolta Chroma Meter (M) compared to a Hunter Labscan Scanning Spectrocolorimeter (H).

Figure 1:

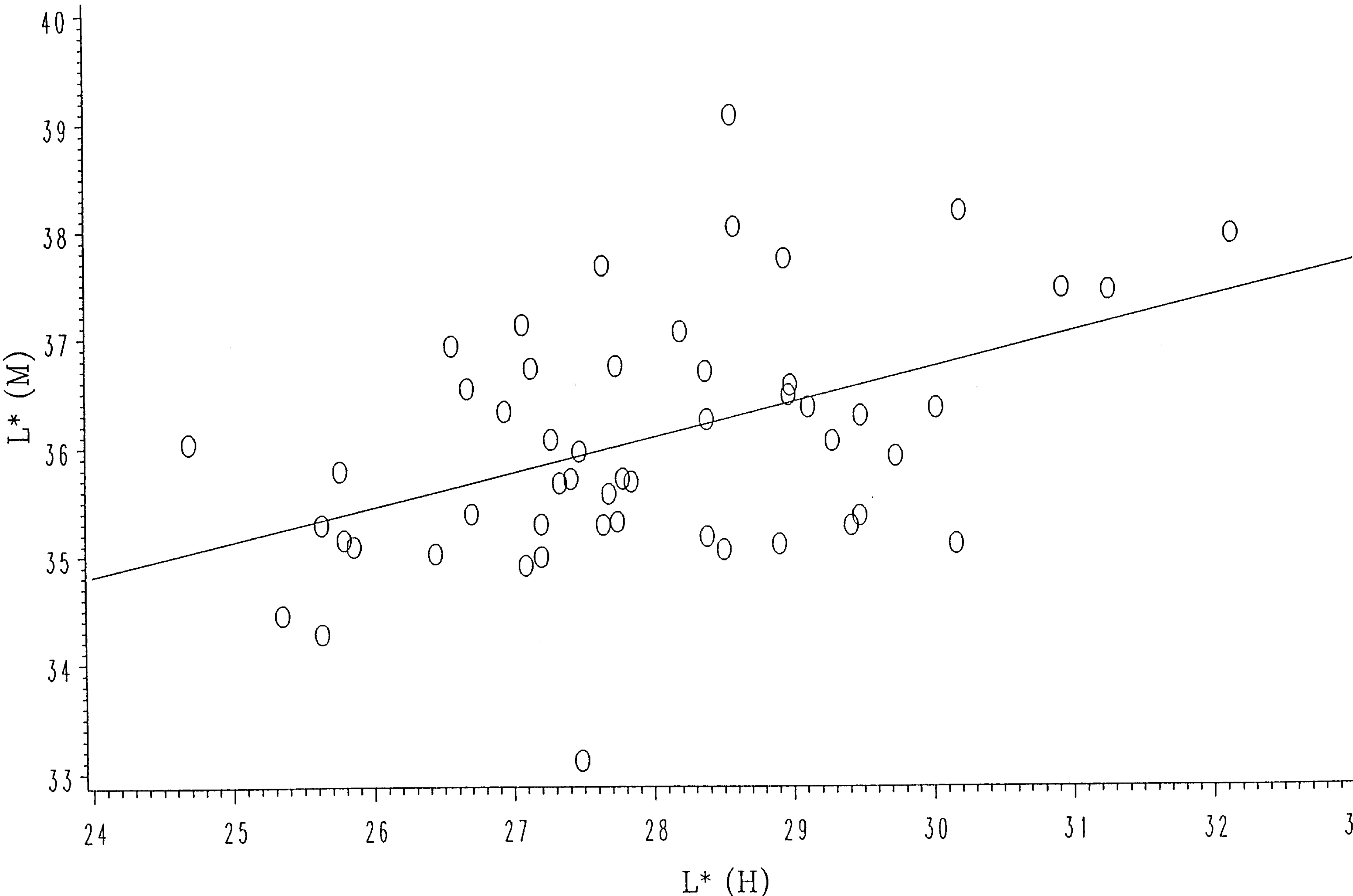


Figure 2:

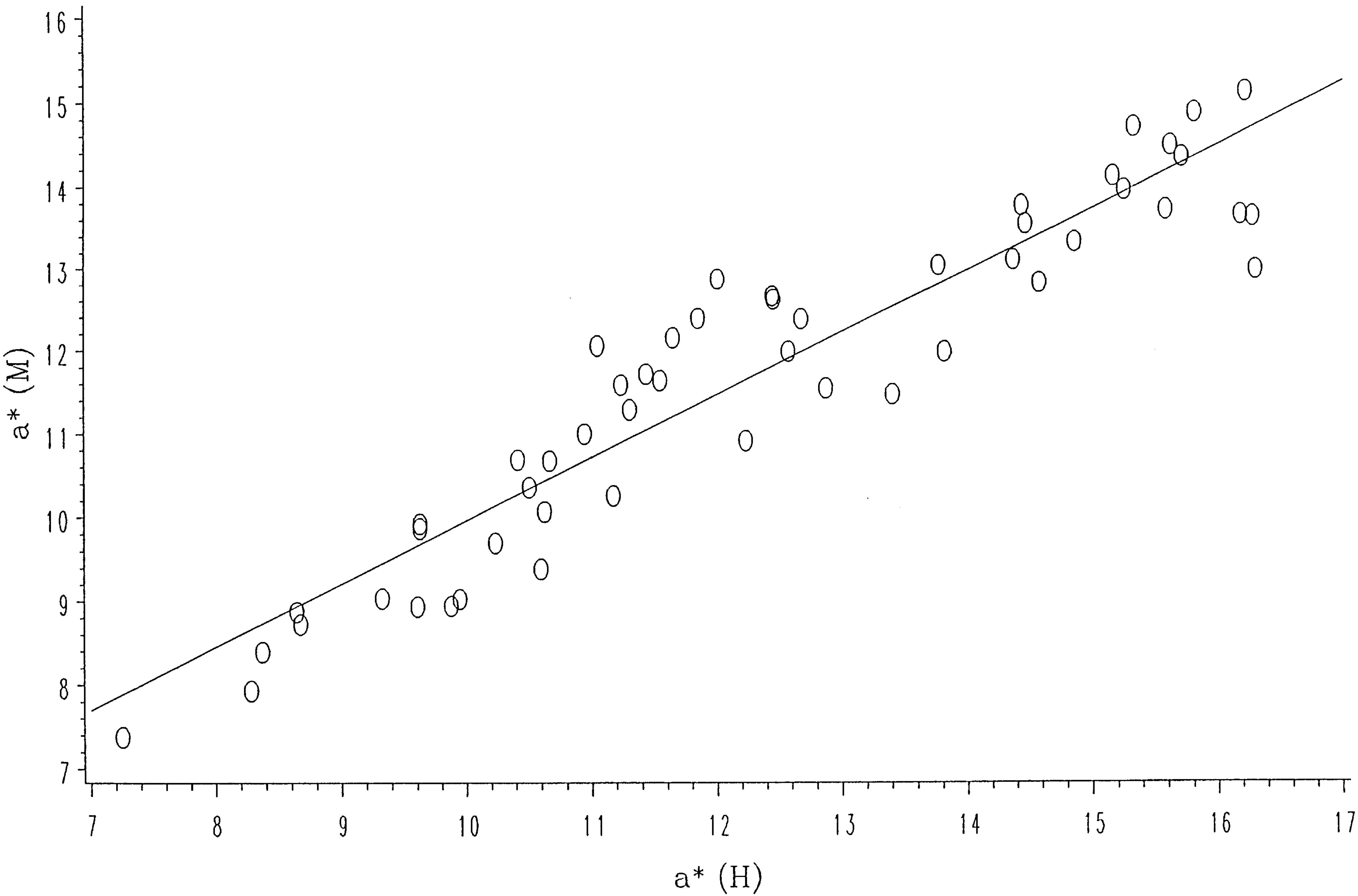


Figure 3:

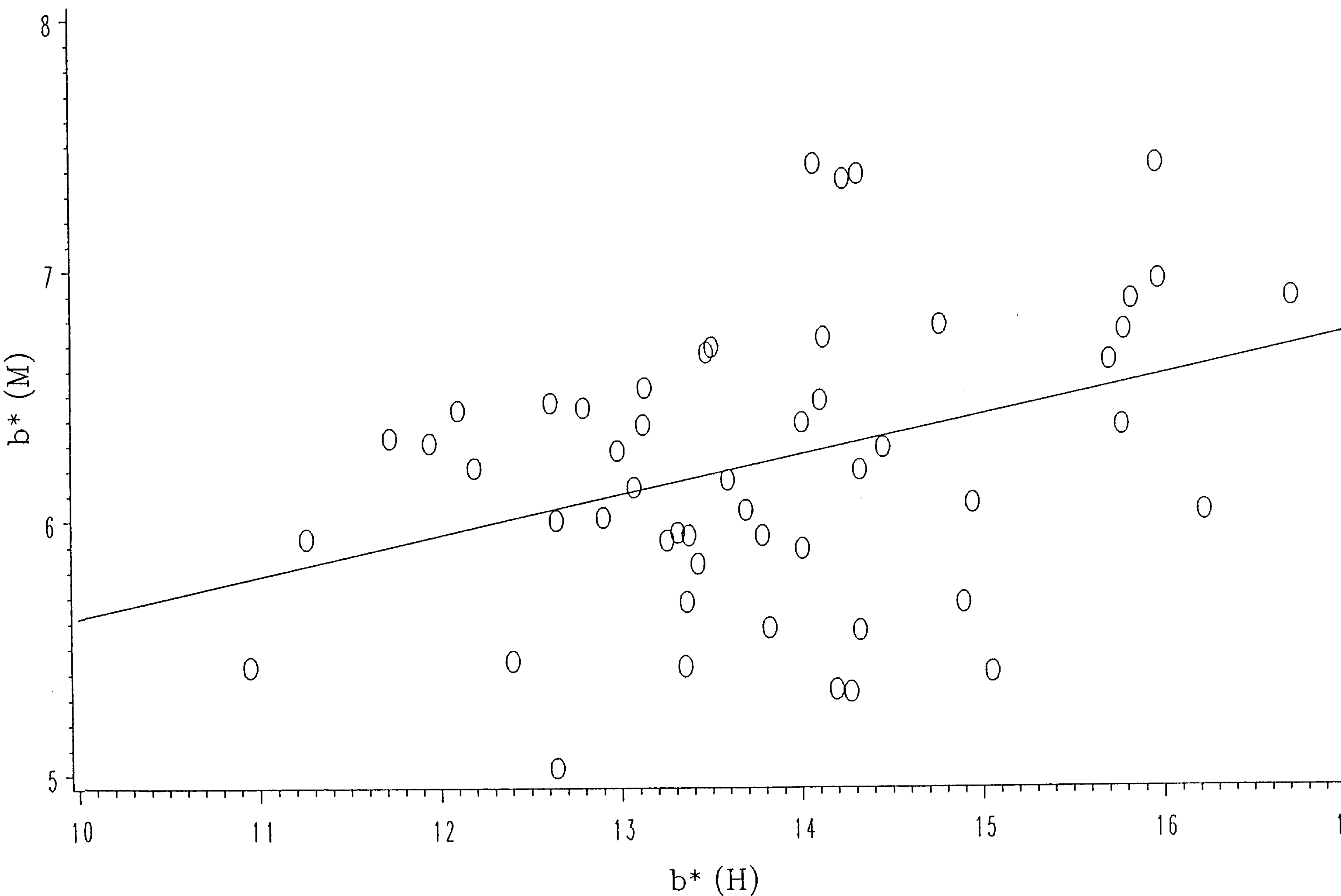
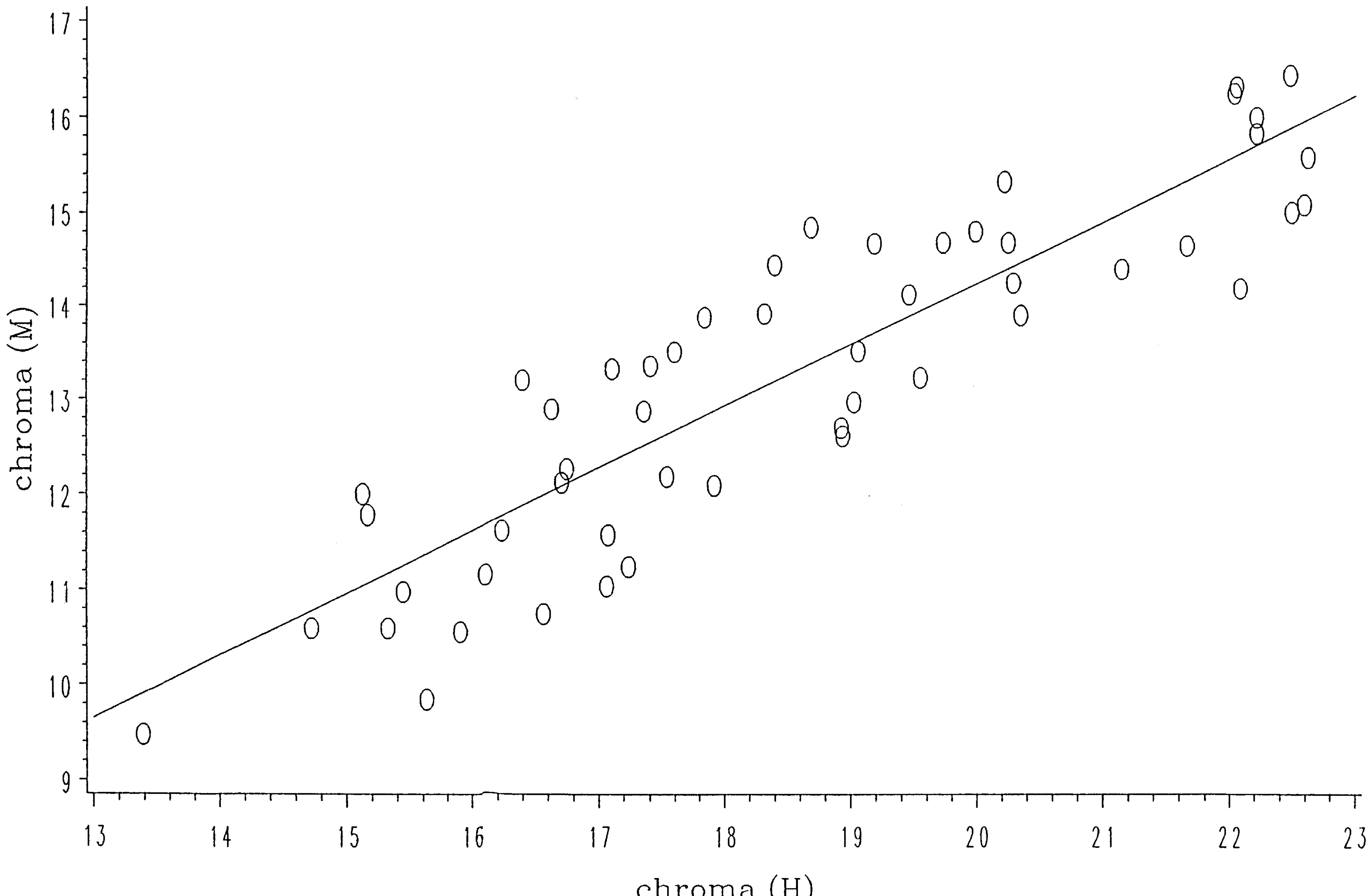


Figure 4: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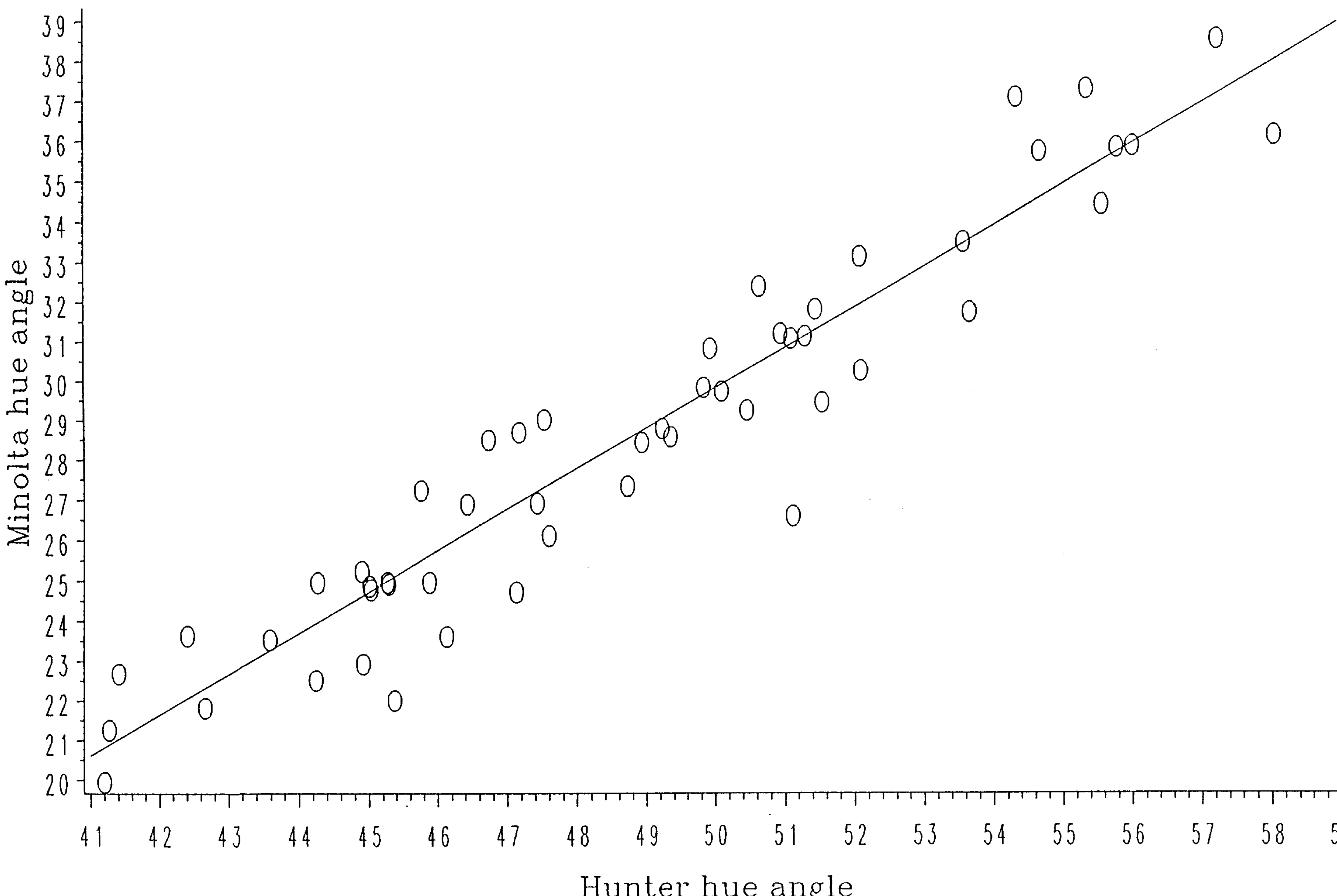
chroma (H)

Figure 5:


Minolta hue angle
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Hunter hue angle

Popular Summary

Traditionally trained panels of people have been used to assess the colour of consumer products such as venison. Nowadays instruments which measure colour objectively are available, and they are able to reproduce panel results to a satisfactory degree of accuracy. We used a trained panel and two instruments, a Hunter LabScan 6000 and a Minolta Chroma Meter CR200b, to assess the colour of venison steaks which had been aged to cover a wide colour range. Panel scores were predicted equally well by both instruments; while the instruments were internally consistent, they differed systematically from each other since they operate in somewhat different ways. The Hunter gives a more truly objective colour measurement, was experimentally less variable in measuring a uniform surface, and is suitable for laboratory work, while they Minolta, which is portable, is the instrument of choice for field work.