ELSEVIER

Food Research International, Vol. 28, No. 4, pp. 373–377, 1995
Elsevier Science Ltd

0963–9969/95 $9.50 + .00

0963-9969(95)00008-9

Proposal of an index for the objective evaluation of the colour of red table grapes

J. Carreño & A. Martínez

Departamento de Viticultura y Enología, Centro de Investigación y Desarrollo Agroalimentario, Consejería de Agricultura, Ganadería y Pesca, E-30150 La Alberca (Murcia), Spain

L. Almela

Departamento de Química Agrícola, Geología y Edafología, Facultad de Química, Universidad de Murcia, E-30071 Murcia, Spain

&

J. A. Fernández-López†

Departamento de Ingeniería Química Cartagena, Escuela Politécnica Superior, Universidad de Murcia, E-30203 Cartagena (Murcia), Spain

A colour index for the objective determination of the colour in red table grapes is described. This index is based on the CIELAB values. A statistical study revealed a high correlation between L^* and b^*, while a^* was not a representative parameter. The usefulness of this index is investigated to classify the red grapes depending on their external colour. The proposed colour index for red grapes (CIRG) is based on the parameters L^* (lightness), H (hue angle) and C (chroma) and its expression is "$(180-H)/(L^* + C)$". All the colour indexes previously proposed were defined in fruits whose colour varied between yellow and red, and, therefore, were not suitable for red grapes which show a dark violet colour. This new index showed a good linearity with the visual colour of the berries and distinguished between sample groups of different external colour.

Key words: Red grape, table grape, *Vitis vinifera* colour measurements, CIELAB data, colour index.

INTRODUCTION

The quality of fruits is traditionally based on the sensory attributes flavour, odour, taste, texture and colour. Several studies along with demographic observations demonstrate the importance of colour as a single quality indicator on which fruit acceptance is based (Clydesdale, 1993). Fruits vary in colour upon ripening, ranging from greens to reds, oranges and blues.

The mature berries of red grapes usually possess a dark violet colour. Unfortunately, even when ripe, the berries frequently do not acquire the typical violet colour, and take on yellow, pink, red or violet tints of greater or lesser intensity. To study this problem and to commercially classify these fruits an objective measurement index of their external colour is needed.

The CIELAB colour system (Commission Internationale de l'Eclairage, 1986) is extensively used to evaluate food colours. The L^*, a^* and b^* values describe a uniform three-dimensional colour space, where L^* is the vertical axis and defines the lightness; and a^* and b^* are the horizontal axes defining the red-greenness and blue-yellowness, respectively (Bakker *et al.*, 1986). L^* can range from 0 to 100, while a^* and b^* vary between −60 and +60. Also defined in this system are the hue angle (H) and the chroma (C), calculated as $H = \arctan b^*/a^*$ (degrees) and $C = [(a^*)^2 + (b^*)^2]^{0.5}$. Hue angle can be distributed in the four quadrants of the a^*b^* plane, and chroma will be higher the further it is from the origin of the coordinates.

†Author to whom correspondence should be addressed.

Several authors have directly employed the colour values of the CIELAB system or those of the Hunter Lab system (Hunter, 1948) to study the colour of different fruits and beverages (Shewfelt *et al.*, 1984; Bakker *et al.*, 1986; Sapers & Douglas, 1987; Gigleux-Spitz, 1988; Hayes *et al.*, 1988; Brown & Walker, 1990; Robertson *et al.*, 1990; Tsantili, 1990; Abbal *et al.*, 1992; Da Porto *et al.*, 1992; Bakker *et al.*, 1993; Echavarri *et al.*, 1993; Iñarrea *et al.*, 1993). Other authors have proposed colour indexes which permit a direct correlation with the visual appearance. Usually these indexes are mathematical expressions that include the CIELAB or Hunter Lab parameters. Thus, the ratio *a/b* has been used as a colour index in tomatoes, apples, citrus and carambola fruits (Stewart & Wheaton, 1971; Little, 1975; Ferre *et al.*, 1987; Campbell *et al.*, 1989). In tomato fruits, the index COL = $(2000 \times a) / (L \times (a^2 + b^2)^{0.5})$ is frequently used (Hobson, 1987; Dodds *et al.*, 1991). For citrus fruit degreening, the index CCI = $(1000 \times a) / (L \times b)$ has been proposed (Jimenez-Cuesta *et al.*, 1981). All these indexes are characterized by showing a high correlation with the external visual colour of the fruits and can be used in studies of maturation, preservation or storage.

The main objective of this study was to propose a colour index for red grapes (CIRG) which can be applied to the objective evaluation of their external colour. For this, we used the CIELAB colour measuring system and studied the correlations between the visual colour, tristimulus parameters and colour indexes considered.

MATERIALS AND METHODS

Grape samples

The experiment was carried out on grapes (*Vitis vinifera*) cv. Don Mariano harvested from 11-year old vine plants conducted in the form of vine arbour. When the grapes were ripe (October 1992), samples of 100 berries were harvested from each of the 93 plants of the vineyard chosen for this investigation. To avoid irregularities in the colour determination (due to the presence of dust or pesticide residues) the berry surfaces were carefully cleaned with cotton wool. The visual colour of the samples was determined under daylight in front of a dark background with a viewing angle of 2° and then they were classified into five groups: yellow, pink, red, violet or dark violet. For this classification a panel of five assessors, pre-tested for normal colour vision, was used.

Colour measurements

The numerical determination of the colour was carried out with a Minolta CR-300 Chroma Meter (Minolta Corp., Osaka, Japan) coupled to a Minolta DP-301 data processor. The measuring area had a diameter of 8 mm. Standard illuminant C (Y_0 = 100; X_0 = 98·072; Z_0 = 118.225) was used as reference. Three measurements were made around the equatorial belt of each berry and the mean value is reported in the data. L^*, a^*, b^*, H (hue angle) and C (chroma) were calculated. In the evaluation of H we used the most widely accepted international criterion of assigning the angle of 0° to the semiaxis $+a^*$ (redness), the angle of 90° to the semiaxis $+b^*$ (yellowness), the angle of 180° to the semiaxis $-a^*$ (greenness) and the angle of 270° to the semiaxis $-b^*$ (blueness). To facilitate the calculations and subsequent mathematical analysis, we considered as negative the H values included between 360° and 270° (e.g. 346° was taken as –14°) (Bakker *et al.*, 1986).

Statistical calculations

For the statistical study of the different parameters and colour indexes an analysis of variance (ANOVA) was carried out, the means separation was performed by Duncan's test, and the correlation between the visual colour and the colour parameters and colour indexes was studied by means of Pearson's correlation matrix. All these statistical studies were realized with the statistical packages Systat (Systat Inc., USA) and Statgraphic (Statistical Graphics Corp. & STSC, USA).

RESULTS AND DISCUSSION

Relation between tristimulus parameters and visual colour

Table 1 presents the mean values of L^*, a^*, b^*, H and C corresponding to the five groups of grapes studied. It can be appreciated that L^*, b^*, H and C decreased when the visual colour of the berries was more intense. This could be attributed to the fact that the fruits become darker and take on a red-violet tint. These results are in agreement with those reported in Tempranillo grapes (Iñarrea *et al.*, 1993), apples (Ferre *et al.*, 1987; Singha *et al.*, 1991) and plums (Giglaux-Spitz, 1988). There were high negative correlations between the visual colour and L^*, b^* and H (–0·965, –0·966 and –0·959, respectively). Chroma did not distinguish between the pink and red groups although the correlation coefficient was quite high (–0·907). Visual colour and a^* only showed a linear correlation in the yellow, pink and red samples (0·927). A similar behaviour has been reported in other fruits, which showed a yellow, orange or red coloration (Jimenez-Cuesta *et al.*, 1981; Hobson *et al.*, 1983; Brown & Walker, 1990; Tsantili, 1990). Therefore, a^* is a representative parameter in fruits or juices whose colour lies between yellowish and reddish (Chiralt *et al.*, 1987; Brown & Walker, 1990; Tsantili, 1990).

Table 1. L^*, a^*, b^*, hue angle (H) and chroma (C) values in each group of samples considered†

Visual colour	L^*	a^*	b^*	H	C
Yellow	41·97 ± 0·92a	−1·87 ± 1·08a	8·39 ± 0·84a	102·06 ± 6·36a	8·64 ± 0·99a
Pink	38·90 ± 1·26b	2·55 ± 1·33b	5·98 ± 0·88b	67·08 ± 11·19b	6·62 ± 0·89b
Red	34·66 ± 1·09c	5·36 ± 0·81d	3·10 ± 0·57c	30·40 ± 7·40c	6·23 ± 0·60b
Violet	30·94 ± 0·55d	4·62 ± 0·66c	0·91 ± 0·28d	10·96 ± 1·94d	4·71 ± 0·70c
Dark violet	29·86 ± 0·24e	2·43 ± 0·59b	0·05 ± 0·18e	0·24 ± 4·68e	2·44 ± 0·59d
r‡	−0·965	0·527	−0·966	−0·959	−0·907

†Means ± standard deviation. Means separation by Duncan's new multiple range test. Means within a column followed by a different letter are significantly different at 5% level of significance. Data represent the mean of 3 determinations.
‡r = Linear correlation coefficient between visual colour and each of the CIELAB parameters.

In our experiment, as the grapes presented violet tints, a^* was not a representative parameter.

Interrelation between tristimulus parameters

In Table 2 the Pearson correlation coefficients for all the tristimulus parameters measured can be observed. It should be appreciated that there was a very high linear correlation between L^* and b^* (0·996); also between b^* and the hue angle (0·985) and between L^* and the hue angle (0·978). As could be expected the correlations of chroma with L^*, b^* and hue angle were slightly lower (0·876, 0·889 and 0·847, respectively) since L^*, b^* and hue angle decreased as the grapes took on their colour, while chroma did not present significant differences between pink and red grape berries. The correlations between a^* (redness) and the other parameters were relatively weak, since L^*, b^*, hue angle and chroma decreased as colour increased, while a^* increased between the yellow and red colours and decreased between the red and dark violet colours.

Determination of a colour index for red grapes

It would be of commercial interest to describe the colour of a fruit by means of a standardized and optimized index (a single numerical datum), principally in those fruits whose quality is directly related to their external colour.

Initially, we applied to red grapes the colour indexes reported previously for other fruits. Thus, we calculated the following colour indexes: a^*/b^*, CCI = $(1000 \times a^*)/(L^* \times b^*)$ (Jimenez-Cuesta *et al.*, 1981) and COL = $(2000 \times a^*)/(L^* \times C)$ (Hobson, 1987). Of all these indexes, those that presented b^* in the denominator (a^*/b^* and CCI) showed very weak correlations with the visual colour (Table 3). This can be attributed to the fact that dark violet samples presented b^* values very near or even lower than 0, and so the quotients tended towards very high values (positive or negative). These indexes can be used in tomatoes, citrus fruits or fruits whose coloration has no violet tints. The COL index proposed for tomato fruits, showed a higher correlation with the visual colour of the grape berries (0·939), although it did not show significant differences ($p > 0·05$) between violet and dark violet samples. It was therefore not considered suitable for red table grapes.

For a new colour index to be proposed for red table grape, it has to be considered that in a three-dimensional system, colour is defined in the space with three parameters. These three parameters can be L^*, a^*, b^*, or L^*, hue angle and chroma. Since a^* did not have a high correlation with the rest of the colour parameters and b^* showed values near 0 in dark violet samples, which resulted in great numerical differences, we preferred to use L^*, H and C, which showed a high correlation among themselves and also with the visual colour.

Table 2. Matrix of Pearson correlation coefficients for CIELAB values and colour indexes considered

	Colour	L^*	a^*	b^*	H	C	a^*/b^*	$(1000 \times a^*)/(L \times b^*)$	$(2000 \times a^*)/(L^* \times C)$	$(180-H)/(L^* \times C)$	$(180-H)/(L^*+C)$
Colour	1·000										
L^*	−0·965	1·000									
a^*	0·527	−0·621	1·000								
b^*	−0·966	0·996	−0·642	1·000							
H	−0·959	0·978	−0·709	0·985	1·000						
C	−0·907	0·876	−0·335	0·889	0·847	1·000					
a^*/b^*	−0·062	0·028	0·106	0·032	0·035	0·127	1·000				
$(1000 \times a^*)/(L^* \times b^*)$	−0·064	0·030	0·103	0·034	0·037	0·128	1·000	1·000			
$(2000 \times a^*)/(L^* \times C)$	0·939	−0·973	0·760	−0·978	−0·995	−0·815	−0·013	−0·016	1·000		
$(180-H)/(L^* \times C)$	0·819	−0·737	0·102	−0·743	−0·730	−0·890	−0·232	−0·232	0·666	1·000	
$(180-H)/(L^* + C)$	0·984	−0·984	0·553	−0·985	−0·979	−0·912	−0·070	0·071	0·960	0·829	1·000

Table 3. Values of the different colour indexes considered†

Visual colour	a^*/b^*	$(1000 \times a^*)/(L^* \times b^*)$	$(2000 \times a^*)/(L^* \times C)$	$(180–H)/(L^*+C)$	$(180–H)/(L^* \times C)$
Yellow	−0·22 ± 0·11a	−5·10 ± 2·68a	−9.84 ± 5.10a	1.55 ± 0.17a	0.22 ± 0.04a
Pink	0·44 ± 0·25a	11·53 ± 6·68a	19.80 ± 9.35b	2.49 ± 0.29b	0.45 ± 0.09a
Red	1·82 ± 0·57a	52·92 ± 18·46a	49.53 ± 5.26c	3.66 ± 0.25c	0.70 ± 0.06b
Violet	5·32 ± 0·99a	172·52 ± 34·18a	63.44 ± 1.47d	4.75 ± 0.20d	1.19 ± 0.21c
Dark violet	−11·12 ± 67·23a	−376·56 ± 2259·40a	66.78 ± 0.58d	5.57 ± 0.26e	2.65 ± 0.80d
r‡	−0.062	−0.064	0.939	0.984	0.819

†Means ± standard deviation. Means separation by Duncan's new multiple range test. Means within a column followed by a different letter are significantly different at 5% level of significance.
‡rLinear correlation coefficient between visual colour and each one of the indexes.

Figure 1 shows the representation of hue angle and chroma values in all the samples analyzed. It can be observed that samples with a more intense colour presented a lower hue angle. In order that the increase in colour coincided with an increase in the proposed index, we used 180–H (degrees) instead of H. To obtain a similar effect, other authors changed the origin of hue angle to another axis (Little, 1975). L^* and chroma decreased progressively as visual colour increased. Their presence in the denominator of the proposed indexes [$(180–H)/(L^* + C)$ and $(180–H)/(L^* \times C)$] caused them to increase when the colour changed from yellow to dark violet.

Figure 2 shows the evolution of L^*, C and $(L^* + C)$ with the visual colour of the samples. It can be appreciated that the plot of $(L^* + C)$ against the visual colour gave the most linear representation and that its presence in the mathematical expression led to a higher degree of linearity in the index.

Of the two new indexes considered, $(180–H)/(L^* + C)$ presented the highest linear correlation (0·984) (Table 3) and was the most suitable for evaluating the colour of the red table grape. In our experiment the CIRG reached a mean value of 1·55 in the yellow samples, 2·49 in the pink samples, 3·66 in the red samples, 4·75 in the violet samples and 5·57 in the dark violet samples, being remarkable that it was significantly different at the 5% level of significance for the five groups of samples considered. According to these data, we think that in this cultivar, grape berries with an optimum commercial colour should present a CIRG ≥ 5.

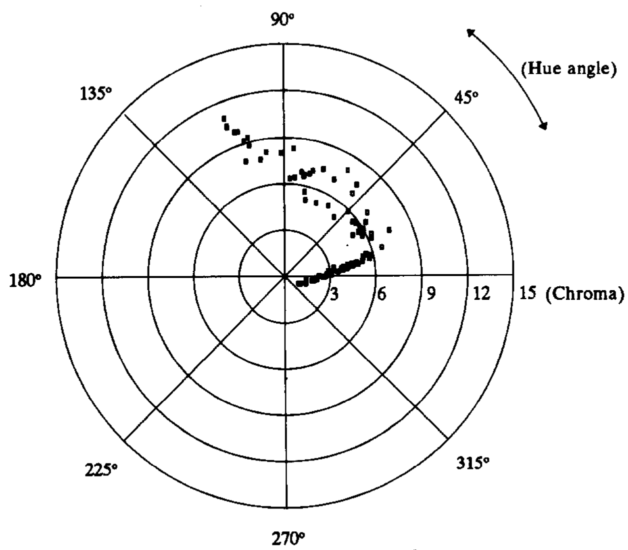

Fig. 1. Hue angle and chroma of the mature red table grapes analyzed.

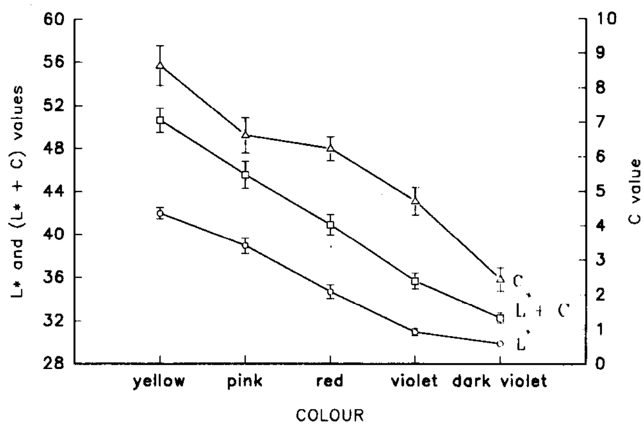

Fig. 2. Changes in the mean values of L^*, chroma (C) and $L^* + C$ in the different sample groups considered.

ACKNOWLEDGEMENTS

Thanks are due to INIA (proyect SC93-013) and to 'Consejería de Agricultura, Ganadería y Pesca de la Región de Murcia' (proyect 93-10) for financial support. The authors are also grateful to the anonymous reviewer for valuable suggestions.

REFERENCES

Abbal, P., Boulet, J. C. & Moutounet, M. (1992). Utilisation de parametres physiques pour la caracterisation de la véraison des baies de raisin. *J. Int. Sci. Vigne et Vin*, **26**, 231–7.

Bakker, J., Bridle, P. & Timberlake, C. F. (1986). Tristimulus measurements (CIELAB 76) of port wine colour. *Vitis*, **25**, 67–78.

Bakker, J., Picinelli, A. & Bridle, P. (1993). Model wine solutions: colour and composition changes during ageing. *Vitis*, **32**, 111–18.
Brown, G. S. & Walker, T. D. (1990). Indicators of maturity in apricots using biplot multivariate analysis. *J. Sci Food Agric.*, **53**, 321–31.
Campbell, C. A., Huber, D. J. & Koch, K. E. (1989). Postharvest changes in sugars, acids and color of carambola fruit at various temperatures. *Hortiscience*, **24**, 472–5.
Chiralt, A., Maestud, P., Fito, P. & Giner, J. (1987). Estudio del color de vinos blancos varietales jóvenes de la D. O. Rueda. *Adv. Food Technol.*, **3**, 1677–88.
Clydesdale, F. M. (1993). Color as a factor in food choice. *Crit. Rev. Food Sci. Nutr.*, **33**, 83–101.
Commission Internationale de l'Eclairage. (1986). *Colorimetry*. Publication CIE no 15.2, Vienna.
Da Porto, C., Mastrocola, D. & Lerici, C. R. (1992). Valutazione per via colorimetrica dell'imbrunimento enzimatico nel succo d'uva. *Vignevini*, **19**, 51–4.
Dodds, G. T., Brown, J. W. & Ludford, P. M. (1991). Surface color changes of tomato and other solanaceous fruits during chilling. *J. Amer Soc. Hort. Sci.*, **116**, 482–90.
Echavarri, J. F., Negueruela, A. I. & Albaizar, T. (1993). Relaciones entre índices enólogicos y parámetros colorimetricos CIE. *Enologia*, **7**, 52–5.
Ferre, G., Massol, G., Le Fur, G. & Villeneuve, F. (1987). Couleur des pommes et maturité utilisation d'un colorimétre: perspectives. *Infos-Ctifl*, **30**, 19–24.
Gigleux-Spitz, C. (1988) Mirabelle. Evolution dans le temps et sur l'arbre de la couleur des fruits suivie par colorimetrie. *Infos-Ctifl*, **45**, 27–30.
Hayes, C. F., Chingon, H. T. G. & Young, H. G. C. (1988). Hunter b color measurements of Papaya using a two-filter system. *Hortiscience*, **23**, 399.
Hobson, G. E. (1987). Low-temperature injury and the storage of ripening tomatoes. *J. Hort. Sci.*, **62**, 55–62.
Hobson, G. E., Adams, P. & Dixon, T. J. (1983). Assessing the color of tomato fruit during ripening. *J. Sci. Food Agric.*, **34**, 286–92.
Hunter, R. S. (1948). Photoelectric color-difference meter. *J Opt. Soc. Amer.*, **38**, 661.
Iñarrea, M., Negueruela, A. I. & Perez, E. (1993). Estudio de la evolución del color de uva de la variedad Tempranillo durante su maduración. *Opt. Pur. Apl.*, **26**, 542–8.
Jimenez-Cuesta, M., Cuquerella, J. & Martinez-Javaga, J. M. (1981). Determination of a color index for citrus fruits degreening. *Proc. Int. Soc. Citriculture*, **2**, 750–3.
Little, A. C. (1975). Off on a tangent. *J. Food Sci.*, **40**, 410–1.
Robertson, J. A., Horvart, R. J., Lyon, B. G., Meredith, F. I., Senter, S. D. & Okie, W. R. (1990). Comparison of quality characteristics of selected yellow- and white-fleshed peach cultivars. *J. Food Sci.*, **55**, 1308–11.
Sapers, G. M. & Douglas, F. W. (1987). Measurement of enzymatic browning at cut surfaces and in juice of raw apple and pear fruit. *J. Food Sci.*, **52**, 1258–62.
Shewfelt, R. L., Heaton. E. K. & Batal, K. M. (1984). Non destructive color measurement of fresh broccoli. *J. Food Sci.*, **49**, 1612–13.
Singha, S., Baugher, T. A., Townsend, E. C. & D'Souza, M. C. (1991). Anthocyanin distribution in 'Delicious' apples and the relationship between anthocyanin concentration and chromaticity values. *J. Amer. Soc. Hort. Sci.*, **116**, 497–9.
Stewart, I. & Wheaton, T. A. (1971). Effects of ethylene and temperature on carotenoids pigmentation of citrus peel. *Proc. Florida State Hort. Soc.*, **84**, 264–6.
Tsantili, E. (1990). Changes during development of 'Tsapela' fig fruits. *Sci. Hortic.*, **44**, 227–34.

(Received 8 June 1994; accepted 7 September 1994)