Spectroradiometry vs. image analysis in colour measurement in juices from different orange and mandarin varieties

Espectrorradiometría vs. digitalización y análisis de imágenes en la medida del color de zumos de diferentes variedades de naranja y mandarina

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ABSTRACT:

In this work the colour of orange and mandarin juices from different varieties was evaluated by two instrumental methods: spectroradiometry and digital image analysis. The effect of the deepness and the background, and the validity of the colorimetric parameters obtained by both methodologies were explored to discriminate between groups. It was concluded that both methods allowed the discrimination between orange and mandarin juices, being spectroradiometry which provides the best classification.

Key words: Orange Juice, Mandarin Juice, Colour, Digital Image Analysis, Spectroradiometry.

RESUMEN:

En este trabajo se evalúa el color de zumos de naranja y mandarinas de distintas variedades medidos por dos métodos instrumentales: espectrorradiometría y digitalización y análisis de imagen. Se estudia el efecto del espesor y del fondo, y se explora la utilidad de los parámetros colorimétricos medidos por ambos métodos para diferenciar entre grupos. Se concluye que ambas técnicas permiten la discriminación entre zumos de naranja y mandarina siendo la espectrorradiometría la que proporciona la mejor clasificación.

Palabras clave: Zumo de Naranja, Zumo de Mandarina, Color, Digitalización y Análisis de Imagen, Espectrorradiometría.

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1. Introduction

Colour is one of the most important sensory attributes, which have direct influence in acceptance and perception of the quality by consumers [1-3]. Orange and mandarin juice colour ranges from pale yellow at the beginning of the harvest to red-orange at the end. Each variety has a characteristic colour, although this can vary depending on agronomic and climatic factors [4,5].

Instrumental colour measurements are simple, accurate and versatile, and moreover they eliminate the subjectivity associated with visual measurements. There are different instruments for evaluating juice colour, such as colorimeters, spectrophotometers and spectroradiometers, but, independently of the instrument used, it is very important to define measurements conditions correctly. CIE (International

Commission on Illumination) recommends observers [6], illuminants [7], and colour spaces [8] in order to normalize objective colour measurement. It must be also taken into account sample position, system geometry, light source intensity, sample deepness, blank measurement, background and surrounding [9,10].

Digital image analysis (DIA) is being used increasingly for instrumental food colour specification. This methodology is based on the acquisition of an image and its post analysis, through which it can be obtained not only the colour but also the appearance of the sample, giving much more detailed information, as the colour distribution in the sample.

The objectives of this study were to check, the differences between spectroradiometry (SP) and digital image analysis (DIA) to characterize juice colour from different orange and mandarin

TABLE I
Orange and mandarin varieties analyzed.

Mandarins		Oranges			
M1	Orogranue	V1	Navelina	V12	Navel Barnfield
M2	Beatriz	V2	Fukumoto	V13	Rhode Summer
M3	Prenules	V3	Fisher	V14	Nave late
M4	Loretina	V4	Navel Foyos	V15	Navel Lane Late
M5	Clemen Rubí	V5	Cadenera	V16	Navel Chislett
M6	Mioro Coppola	V6	Salustiana	V17	Sanguinelli
M7	Arrufatina	V7	Ambersweet	V18	Valencia Midnight
		V8	Navel Cara Cara	V19	Rhode Late
		V9	Pera	V20	Valencia Delta
		V10	Navel Powell	V21	Barberina
		V11	Shamoutti	V22	Hamlin

varieties and to determine which methodology offers a better discrimination among samples.

2. Material and methods

2.1. Samples

22 orange and 7 mandarin varieties cultivated in Spain in 2010-2011 were analysed (Table I). Juices were obtained using a domestic squeezer.

2.2. Colour measurement: Spectroradiometry (SP)

Juice colour was measured in a CAS 140 B spectroradiometer (Instrument Systems, Munich, Germany) with an external incandescent lamp, equipped with a Top telescope optical probe (Instrument Systems, Munich, Germany) [11] and a Tamron zoom mod. SP 23A (Tamron USA, Inc., Commack, NY, USA) using a grey surrounding ($L^* = 50$) and white and black backgrounds in two different containers: 10 mm pathlength (deepness) plastic cuvettes and 29 mm deepness bottles (Fig. 1) [12].

2.3. Colour measurement: Digital image analysis (DIA)

The DigiEye® imaging system including a calibrated digital camera Nikon D80 (Nikon Corporation, Tokyo, Japan) connected to an illumination box designed by VeriVide Ltd. (Leicester, UK) was used to capture the digital images [13].

Samples placed in transparent plastic bottles of 29 mm deepness (Fig. 1) [12] and illuminated by a diffuse D65 simulator were measured against a

Fig. 1. Characteristics of the bottles used for containing the samples in colour measurements.

grey surrounding ($L^* = 50$) and white and black background. From each image, CIELAB parameters were obtained using DigiFood® software [14] which allows the transformation of RGB values into the CIELAB colour parameters [15].

3. Results and discussion

3.1. Instrumental colour measurement

Figures 2 and 3 show the distribution in the a^*b^* colour diagram of the orange and mandarin juices analyzed by SP (Fig. 2) and DIA (Fig. 3)

under the usual conditions (grey surrounding, $L^*=50$, and white background, and cuvette of 1

mm in SP and bottles of 29 mm deepness in DIA). Lightness is also shown.

It can be observed that all the juices were located in the first quadrant, in the yellowish and orangish zone. While in SP measurements (Fig. 2(a)) both groups of juices appeared well differentiated (excepting some orange varieties), in DIA the separation was not so clear (Fig. 3(a)). When measured by SP (Fig. 2(b)) Sanguinelli variety was the darkest ($L^*=33.33$) followed by all mandarin varieties ($L^*=63.49-66.54$). This method allowed a defined separation between orange and mandarin juices except Sanguinelli variety. When colour samples were determined by DIA, separation according to lightness was not so evident (Fig. 3(b)).

Fig. 2. (a) a^*b^* colour diagram and (b) L^* for SP measurements.

Fig. 3. (a) a^*b^* colour diagram and (b) L^* for DIA measurements.

In both methodologies, Sanguinelli variety was the juice with less chroma, followed by mandarin juices and some orange varieties. In respect to hue, measured by SP, both types of samples were separated with the exception again of Sanguinelli which showed a hue of 17° , an atypical colouring due to its high content of anthocyanins (pigments responsible of the red colour) [16]. This separation in hue was not appreciated when samples were measured by DIA.

In general, mandarin juices were darker, less vivid and more orangish, and among the orange juices, Fukumoto and Navelate varieties showed the highest values for hue, which means they were the most yellowish by both methods.

3.2. Relationship between DIA and SP measurements

In order to evaluate the effect of the methodology (DIA or SP) and the different deepness used (10 and 29 mm), simple correlations between L^* , a^* , b^* , C^*_{ab} and h_{ab} were determined.

In all the cases studied, correlations were significant (Table II). Independently of the background used, it was observed that the best correlations were obtained comparing values from both deepness with SP. When comparing the two methods SP and DIA, with the same deepness, the best correlation was obtained for hue ($r^*>0.97$), and the lowest correlation was obtained for chroma ($r^*>0.75$). Finally, comparing different methods and deepness, the lowest correlation was also found for chroma ($r^*>0.61$), while the highest was for hue ($r^*>0.97$). Regarding the backgrounds, in general, better correlations were obtained in white background.

Obviously, differences between methods must be due mainly to the way the colorimetric coordinates are calculated, since the samples suffer scarce handling. DIA implies the transformation of the image into RGB coordinates and then, into CIELAB coordinates using mathematical models. On the other hand, SP uses the spectral distribution of radiant energy and, from it, CIELAB coordinates are obtained mathematically, according to CIE

TABLE II
Simple correlation coefficients.

White background			
Method Deepness	SP 10/29 mm	SP/DIA 29/29 mm	SP/DIA 10/29 mm
L^*	0.97	0.94	0.90
a^*	0.90	0.93	0.91
b^*	0.99	0.85	0.80
C^*_{ab}	0.98	0.79	0.69
h_{ab}	0.99	0.98	0.98

Black background			
Method Deepness	SP 10/29 mm	SP/DIA 29/29 mm	SP/DIA 10/29 mm
L^*	0.93	0.92	0.80
a^*	0.93	0.97	0.93
b^*	0.95	0.83	0.72
C^*_{ab}	0.94	0.75	0.61
h_{ab}	0.98	0.99	0.97

recommendation [8]. Anyway, it is important to highlight DIA and SP correlate better when the same deepness is used. Previous studies concluded that the slight variations observed in the colour coordinates values measured by both techniques could be also due to differences in the deepness of the sample, and to other secondary factors such as illumination conditions, or the effect of the surface of the container [17].

3.3. Linear discriminant analysis (LDA)

To check if it is possible to discriminate mandarin and orange juices attending to colour, multivariate analyses (LDA) were done with colorimetric parameters obtained by DIA and SP (Fig. 4). The aim was to determine which of the measurements lead to the best discrimination between both types of samples studied.

LDA done with values obtained by SP in cuvette of 10 mm deepness in both backgrounds resulted in a mathematical model which included five variables (L^* , a^* , b^* , C^*_{ab} and h_{ab}) and a 100% correct classification ($p < 0.001$). When the analyses considered 29 mm deepness, the model selected also the same five variables but only a^* , b^* and C^*_{ab} for white background and L^* , a^* , b^* and C^*_{ab} for black background were significant. In both analyses the model allowed a 97% correct classification ($p < 0.001$) being the Cara Cara variety the one which was wrongly classified. This variety is characterised by its more reddish colour, because it contains lycopene [18].

For measurements done by DIA in 29 mm deepness, the model included the five variables (L^* , a^* , b^* , C^*_{ab} and h_{ab}) being a^* , b^* and C^*_{ab} significant for white background and only a^* for the black one, with percentages of 83% and 90%

Fig. 4. Scatterplot of the samples in planes defined by the canonical function when type of citric is considered for discrimination.

of correct classifications respectively. In this case, the samples wrongly classified did not show any highlighted characteristics.

4. Conclusions

In conclusion, although DIA and SP have a good correlation, according to the results obtained, SP in cuvette (10 mm deepness) provides the best discrimination between orange and mandarin juices. These results confirm the utility of this technique for colour measurements in homogeneous colour samples.

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