VISUAL vs INSTRUMENTAL EVALUATION OF ORANGE JUICE COLOR. A CONSUMER'S PREFERENCE STUDY

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Abstract

This study determine the instrumental evaluation of color, color attributes (lightness, chroma and hue) quantified by trained assessors and the color preferences evaluated by consumers, in orange juices from five varieties. The samples were evaluated by image analysis (DiyiEye System) and spectroradiometer. The trained panel consisted of eighteen panellists, with normal color vision and experience in both visual assessments of color and Tristimulus Colorimetry concepts. All of them were asked to classify the samples in increasing order of hue (yellowish-reddish), chroma (dull-vividness) and lightness (clear-dark). They were also asked to score the colorimetric parameters on a continuous scale of 10 cm, anchored at the ends. Results showed that judges were able to order the orange juices correctly based on hue and lightness and significant score differences *($p<0.05$)* were found for hue and lightness, but not for chroma. The consumer panel consisted of 111 panelists. They were asked to order the samples according to their colour preferences. A significant preference *($p<0.05$)* was observed for the sample with intermediate hue and lightness values (Valencia Midnight), while the least preferred was the variety with the lowest value for lightness and the highest hue value (the most yellowish) (Navel Foyos). Cluster analyses showed consumers' segmentation.

Practical applications

Instrumental colour measurement in orange juice is very useful for industry because is an easy, fast and cheap measurement of one important quality parameter: color.

Correlation between visual evaluation and instrumental measurement of color has demonstrated that trained panels can value effectively orange juice color.

Consumers' preference suggests that preferred hues are the most orangish against other more reddish or yellowish. Anyway, there are different segments of population that showed preference for varieties more reddish.

Key words: color, orange juice, visual evaluation, consumers' preference.

Introducción

Citrus juices are among the most heavily consumed fruit juices worldwide due to their combination of desirable flavor, appealing color, and health benefits (Rouseff *et al.*, 2009). The natural bright color of the citrus juices have been considered traditionally as one of their main advantages over other juices (Barron R.W. *et al.*, 1967).

Orange juice (OJ) color is due to carotenoids which belong to one of the main classes of natural pigments. OJ has a complex carotenoid profile that comprises carotenes and xanthophylls. Some of these compounds (β-carotene, α-carotene and β-cryptoxanthin) has provitamin A activity and they may exhibit other biological activities, like antioxidant and anticarcinogenic activity (Krinsky *et al.*, 2004).

OJ color may range from pale yellow at the beginning of the season to red-orange at the end, but besides the stage of maturity, other factors, such as, species, variety and climate, among others may affect the color of orange juices (Casas A and Mallent D, 1988). In industrial orange juices, changes in color can be used as a quality indicator related to carotenoids deteriorations during the thermal process (Fernández-Vázquez R. *et al.*, 2010;Meléndez-Martínez *et al.*, 2009).

The relevance of color as a quality attribute in the food industry is undoubtedly. The color of citric beverages in general, is related to the consumer's perception of flavour, sweetness and other quality characteristics of these products (Huggart *et al.*, 1977;Tepper B.J., 1993;Rose Marie Pangborn, 1960).

It is long known that the color of orange juice directly prejudices the consumers' opinion about such taste factors as sweetness, thickness, and other quality characteristics. However, when studying consumer preferences´ for OJ, color has not usually been included as a sensory attribute to consider (Birdsall L, 1955;Joandre Hoegg and Joseph W.Alba, 2007;Luckow and Delahunty, 2004).

The most natural way of improving the color of orange juice is to add other juices, which provide a more intense coloration. Certain varieties of oranges, whose pulp has a peculiar reddish color, are becoming increasingly important (Lee, 2001;Lee, 2002). In this sense, Valencia orange juices are worldwide appreciated due to their deep orange color (Francis and Clydesdale, 1975;Robards and Antolovich, 1995), however few studies have been conducted to characterize the color of other varieties. Moreover, color besides a sensory attribute is also related to the nutritional value of OJs, since studies in our group (Meléndez-Martínez *et al.*, 2007) have proved a relationship between color measured by tritimulus colorimetry and the Vitamin A activity.

Color measurement can be done by visual evaluation or instrumental analysis. The visual evaluation of color is included within the sensory analysis. Comprehensive information concerning the sensory evaluation of food color, including guidelines for panel selection, physical requirements for visual assessments and types of sensory tests, can be found in the literature (Hutchings JB, 2011). As a result of the visual analysis, a particular description of color is obtained, for which there is a certain vocabulary. Nevertheless, it must be always taken into account that this kind of analysis is subjective, since it is influenced by several factors (illumination, type of container, volume...). For that reason, implementation of instrumental measurement of color within the orange juice industry is very important for quality control purposes (Meléndez-Martínez *et al.*, 2005). In certain countries, such as the United States, color is one of the attribute visually evaluated for the commercial quality classification of orange juices (Tepper B.J., 1993) by comparison with a collection of six standard plastic tubes. A more precise evaluation of colour can be done by instrumental methods as reviewed in (Meléndez-Martínez *et al.*, 2005).

Traditional instrumental colour measurement of food products is done by using a colorimeter or spectrophotometer. In these methods, only a limited area of the product is measured, with subsequent data being an average color of the selected area, though these are restrictive measurements. Besides total appearance of food consist of visual structure, surface texture and distribution of color (Hutchings *et al.*, 2002). When correlating with visually perceived attributes, it has been suggested that spectroradiometric rather than spectrophotometric measurement should be used (Martínez *et al.*, 2001). However, recent advances in image acquisition technology offer the possibility of using technically sophisticated apparatus available at relatively low cost to evaluate color in terms of millions of pixels. The advantage, in comparison with the traditional light sensors, is that they allow to make a detailed evaluation of a wider area of a food products, with inhomogeneous color possible, and every different color present in the image of the analyzed food matrix can be accounted for by one or more pixels (Antonelli *et al.*, 2004). This is based upon digital cameras which can quickly capture images in digital format without film processing. Application of digital image (DigiEye analysis) offers a more reliable measurement of the food colour, which can be more related to sensory analysis. Up to its utility to evaluate OJ colour in comparison with other traditional methods and how it correlates with visual color attributes.

The objectives of this study were to characterize the color of the juice from five orange varieties and to explore the relationship between instrumental and sensory evaluation of the color attributes (lightness, chroma and hue) quantified by trained assessors. The instrumental measurement techniques used were a spectroradiometer and a calibrated digital camera. CIELAB color space was used for color specifications. Besides, consumer's preferences for color were also evaluated. The relationship between color preferences in relation to the nutritional value (provitamin A activity) of the OJs was also explored.

Material and Methods

- Samples

Five orange varieties were harvest in an agricultural experimental field situated in the south of Spain in November 2009. At the harvesting date, a sample of about three kg of each variety of oranges was taken randomly from several trees of each variety. Orange juices were obtained at the laboratory using a kitchen juicer. The main characteristics of the OJs are summarized in Table 1. The samples were kept at -21ºC until its analysis in the laboratory. Thawing was carried out at room temperature (23ºC) for 24 h. Acidity and total soluble solids were measured according to AOAC methods (1997). The ratio was calculated by dividing the total soluble solids by the acidity.

- Colour Instrumental Measurements

For colour specifications, the OJs were placed in 75 mL capacity, transparent plastic bottles. The samples were measured against a grey surround and white background using two different techniques: spectroradiometer and image analyses. Reflection measurement were done in a CAS 140 B spectroradiometer (Instrument Systems, Munich, Germany) with an external incandescent lamp, equipped with a Top 100 telescope optical probe (Instrument Systems, Munich, Germany) and a Tamron zoom mod. SP 23A (Tamron USA, Inc., Commack, NY, USA). All the instrumental measurements were carried out in a dim ambient illumination to avoid possible interferences from other external sources. In addition to this, the bottles were placed inside a cabin with grey walls to which the external illumination source of the spectroradiometer was attached. The zoom, to which the probe was attached, was held at a fixed distance of 50 cm in a straight line from the sample. As far as geometry of presentation, 45º incident illuminations were used throughout the experiment. The spectroradiometer was set to take three consecutive measurements of each sample, so colour coordinates obtained were averages of three measurements. The whole visible spectrum (380–770 nm) was recorded and Illuminat D65 and 10º Observer were considered as references. Blank measurements were made using distilled water.

Digital images were made in order to obtain the total appearance of juice at depths observed by consumers. The DigiEye imaging system (Luo *et al.*, 2001) was used to capture digital images. The latter system includes a digital camera Nikon D-80, a computer (provided with appropriate software), a colour sensor for calibrating displays, and an illumination box designed by DigiEye Plc. The computer software included the functions of camera characterisation, colour measurement, monitor characterisation and various specialised functions such as colour texture mapping, colour selection and fastness grading (Hutchings *et al.*, 2002). In these measurements, the samples were illuminated by a diffused D65 simulator. A GretagMacbeth ColourChecker DC chart was used for calibration purposes (Li.C. *et al.*, 2003).

From the uniform colour space, the psychological parameters of chroma (C^*_{ab}) and hue (h_{ab}) are defined:

$$C^*_{ab} = [(a^*)^2 + (b^*)^2]^{1/2}, \quad h_{ab} = \arctan(b^*/a^*)$$

Chroma (C_{ab}) is used to determine the degree of difference of a hue in comparison to a grey colour with the same lightness, and is considered the quantitative attribute of colourfulness. Hue (h_{ab}) is the attribute according to which colours have been traditionally defined as reddish, greenish, etc and is used to define the difference of a colour with reference to a grey colour with the same lightness. This attribute is related to the differences in absorbance at different wavelengths and is considered the qualitative attribute of colour.

Colour differences, which are very important to evaluate relationships between visual and numerical analyses (Melgosa *et al.*, 1997), are calculated as the Euclidean distance between two points in the three-dimensional space defined by L^*, a^* and b^*:

$$\Delta E^*_{ab} = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2}$$

- Assessment of vitamin A activity trough objective colour measurements

The vitamin A activity of the samples was expressed in terms of retinol activity equivalents (RAE), considering the equivalences 1 RAE = 12 μg of dietary all-*trans*-*β*-

carotene = 24 μg of other dietary provitamin A carotenoids (*dietary*) (TRUMBO *et al.*, 2001).

Estimation was done as explained elsewhere (Meléndez-Martínez et al., 2007) according to the following equation:

$$RAE = -8.8961 \times h_{ab} + 781.8687$$

- Sensory analysis

A trained panel, consisting of eighteen panellists aged between 30 and 45 with normal colour vision (which was verified using the Farnsworth-Munsell 100 Hue Test) and experienced in both visual assessments of colour and Tristimulus Colorimetry concepts, was used to establish the correlation between instrumental and sensory evaluation of orange juice color.

Visual analyses of the samples were carried out within a well-illuminated room provided with a VeriVide CAC Portable cabinet with D65 source to control illuminantion and observation conditions. Five bottles of transparent plastic fulfilled with 75 ml of the OJs were placed in each cabin randomly. Before each visual analysis all the bottles were vigorously shaken to avoid pulp sedimentation and randomly distributed for. All of them were asked to classify the samples in increasing order of hue (yellowish-reddish), chroma (dull-vividness) and lightness (clear-dark). They were also asked to score the colorimetric parameters on a continuous scale of 10 cm, anchored at the ends.

- Consumer preference study

Consumer test was performed by 111 panelists recruited among students and personnel of the Faculty of Pharmacy in Seville. They were grouped in six categories based on gender (male and female) and age (<20 years old, 20–29 years old, and over 30 years old) (Table 2). The consumer test was carried out in sensory boots under white light (ISO 1988). The consumers were given two sets of questionnaires. Prior to sample presentation, they answered a questionnaire designed to collect demographic data and consumer habits related to orange juice consumption.

In the second questionnaire consumers were asked to order the OJs samples for the overall liking related to color. The ranking decision was based only on the color, without further information.

- Data analysis

Instrumental color measurements data were subjected to analysis of variance (ANOVA) and the Tukey least significant difference multicomparison test to determine significant differences among orange juice samples.

To analyse differences in the color parameters evaluated by the panellists and the consumer preference-ranking test, the Friedman rank sum was performed (O'Mahony, 1986), using a significance level ($p<0.05$) to determine whether the panellists were able to discriminate between samples. Then, Fisher Test served to determine whether significant differences ($p<0.05$) existed between orange juice samples. Cluster analysis was applied to determinate segmentations in the consumers' panel.

These analyses were performed using the Statistica program for Windows (StatSoft, 2007;StatSoft, 2007).

Results and Discussion

The orange varieties included in this study were collected in the optimum maturity stage. As shown in Table 1 the mean value for soluble solid content was very close and no adjustment was needed. Due to the influence of the pulp content in the final color, the OJs were sieved in order to have a similar pulp content (mean = 4.65% ± 1.63).

- Instrumental color characterization

In Figure 1 the CIELAB color space (a*b* and C_{ab}*L* planes) is used to illustrate the color of the 5 orange varieties included in this study and measured by both methods (spectroradiometer and DigiEye). The values of the coordinate L* ranged from 56.09 in the lighter OJ to 61.34 in the darker one; C^*_{ab} ranged from 54.03 in the dullest OJ to 60.29 in the most vivid, and h_{ab} ranged from 66.43 for the most reddish to 81.99 in the most yellow, measured by image analyses.

In the spectroradiometer analyses, values ranged from 56.58 to 60.66 for L*, from 63.11 to 66.02 for C^*_{ab} and from 66.43 to 81.99 for h_{ab}. ANOVA (Table 3) showed that the five varieties were significantly different in h_{ab}, the qualitative component of color, but not in C^*_{ab}, the quantitative component of color, or in ligthness. In CIELAB, considered as the most uniform color space recommended by CIE, the samples presented significant differences ($p<0.01$) for the rectangular chromaticity coordinate a*, but not for the coordinate b*, indicating that color differences were more related to the proportion of red (represented by the positive axis a*), than to the proportion of yellow (represented by positive axis b*). Slight variations were observed in the color coordinates values obtained by both methods, they were significant (p<0.05) only in the case of the rectangular chromaticity coordinates b* and C^*_{ab}.

Previous studies (Martínez *et al.*, 2001) have reported significant differences between spectrophotometric and spectroradiometric color measurement related mainly with differences in the thickness of the measured sample and other secondary factors such as illumination set ups, or the effect of the surface of the container. In this particular case, these differences are difficult to explain and must be restricted to the illumination setups, since the same container was used in both measurements. As expected, good correlations between color coordinates obtained by both methods were found, the parameter best correlated between spectroradiometric and Digieye measurements was h_{ab} (r=0.96), followed by C*ab (r=0.90) and L* (r=0.82).

Table 3 shows the mean ΔE^*_{ab} value calculated among samples in the two measurement systems used. It was confirmed that the color differences exceeded the threshold of visual discrimination (measured in red wine) in all cases (Martínez *et al.*, 2001). It is considered that the CIELAB color difference ΔE^*_{ab} has three components, or can be split in three parts, called lightness (ΔL^*), chroma (ΔC^*), and hue differences (ΔH^*). Figure 2 shows the contribution (as percentage) of each component to the color differences detected in each comparison. It can be observed that the main contribution to the whole color difference was related to the qualitative component of colour (h_{ab}), as previously dicussed.

- Sensory evaluation of OJs color : simple ranking test

Table 4 shows the average scores given by the trained panel to the different samples. The judges scored significantly different all the OJs according to h_{ab} (from the most yellowish (NF) to the most reddish, (RL)), and L* (from the highest (NF) to the lowest lightness (RL)) but as expected they only found significant differences in C^*_{ab} among some varieties. In accordance, the judges were able to order correctly the OJs' color based on hue (h_{ab}) and lightness (L*), but not according to chrome (C^*_{ab}). When analyzing in detail how the panellist scored hue (yellowish-reddish), we can observe that only those samples which Δh_{ab} was higher than 2.04 were correctly ordered. In relation to L*, only 17% of the panel was able to order all the samples correctly, while the resting 83% ordered correctly only the samples with $\Delta L^* > 0.66$. This could be explained by the low contribution of this parameter to the color differences. Similarly, chrome (C^*_{ab}) contribution to the total color differences was low (ΔC^*_{ab} ranged 1.03-2.77) and only 17% of the OJs were ordered properly.

The correlations between the score values given by the panellist and instrumental measurements were explored (Table 5). The qualitative color attribute h_{ab} was better correlated with the spectroradiomer measurements than with Diyi-eye while for Lightness the correlations were the other way round. The visual evaluation of C^*_{ab} was not significantly correlated with any of the instrumental measurements.

- Consumers' OJ color preferences study

A consumer panel was used to investigate color preferences. 77.5 % of consumers declared to be habitual consumer of orange juice, of these, 73% showed a clear preference for freshly squeezed, while the 22.5% rest preferred the commercial orange juice and 5% consumed both.

Preference Scores

Figure 4 shows the frequencies of the preference rank for each sample and the chi-square value of the comparison with the expected frequencies assuming normal distributions. None of these distributions can be considered as normal. For the varieties NF, F, NP, and VM the mode is unique but the frequencies are not normally distributed. For RL two modes are observed, which suggests a mixture of two distributions rather than a unique distribution, this means that the group of 111 consumers could be divided into subgroups, one who prefers the colour's sample and one who does not.

Sample ranking test

Table 6 shows the preference data for the consumers' panel and the rank sums grouped by age, sex and consumption habits The preferred samples were the most orangish variety VM, followed by F (without significant differences between them), while the least rated was sample NF, clearly different of the rest, because it was the lowest punctuated in all groups of population. A significant preference *($p<0.05$)* was observed for the OJs with intermediate h_{ab} and L* values: VM and F. On the other hand, the least preferred OJ was the one with the highest lightness and hue values, the most yellowish, the NF variety, clearly different from the rest. Moreover this sample showed the lowest RAE value (Table 1).

According to sex, it was observed that the most preferred variety in both groups was one with orangish hue (VM), followed by the most reddish (RL) in the men's group, and the one with an intermediate hue in women (F). Women and men under age 20 didn't find significant differences between samples. Regular and non regular consumers of OJs also showed significant differences in preferences. While the first group significantly preferred a variety with an orangish hue VM, the second one didn't show a significant preference for any variety, but for three of them equally: F, VM and RL.

Consumers under 20 and over 30 years showed a clear preference for the most reddish (RL) sample which was also the sample with highest RAE value (Table 1) and so with the highest nutritional value. The intermediate group (20 to 29) preferred other varieties and the most reddish (RL) was the least preferred.

Consumers' segmentation

Ranking test was applied above to analyze the general preference data of all consumers considered as a unique group. To find out if there were groups of consumer differing in their preferences for OJ color, a segmentation of the panel group was done by Cluster analysis (Vigneau *et al.*, 2007). The results are shown in Figure 5. Three groups of consumers were clearly identified. Mean scores for each segment are shown in Table 7. The first segment (21.62%) showed a clear preference for the sample NF followed by F while in the second segment (45.05%) significantly preferred RL and the worst evaluated was NF. Curiously these were the samples with higher and lower RAE values respectively (Table 1). The third segment (33.33% of consumers) gave a higher punctuation to the sample VM (with intermediate RAE value). These observations give additional information to the general results discussed above. For instance, although the most yellowish OJ (NF) was the worst evaluated for all the groups, one group of consumers (segment 1; 21.62%) showed a clear preference for this variety. Therefore there was a group of consumer that showed a preference for the yellowish samples, another more numerous that preferred samples with intermediate h_{ab} and L* values (VM) and another group (45.05%) for which the favorite sample was the most reddish (RL), with the highest RAE value.

Conclusions and implications

OJ can be evaluated by instrumental and sensory methods. Corelational associations between panelists' colour evaluation and the instrumental values showed that the qualitative color attribute h_{ab} is well correlated with the spectroradiomer measurement while for lightness sensory evaluation is better correlated with the DiyiEye measurement. The quantitative color attribute chroma, is not well evaluated by a sensory panel and no correlation with instrumental measurement was observed.

Sensory trained panel was able to ordered samples according to hue when Δh_{ab} between samples were higher than 2.04 and 83% of the panel ordered correctly the samples according to lightness when ΔL^* were higher than 0.67.

In evaluation of consumers' preference, it wasn't observed a clear preference for one of the varieties although in general, it seems that consumers prefer samples with orangish hue. We consider this study as an exploratory investigation since consumer panellists of this trial were university faculty, staff and students and may not be representative of a broader population.

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TABLES

TABLE 1. CHARACTERISTICS OF THE ORANGE VARIETIES STUDIED

Code	Variety	Acidity[1]	Total Soluble Solids[2]	Ratio	RAE [3]
NF	Navel Foyos	0.56	10.76	19.12	77.83
F	Fisher	0.52	10.76	20.51	115.02
NP	Navel Powell	0.49	10.12	20.27	99.72
VM	Valencia Midknight	0.77	8.16	10.62	129.79
RL	Rohde Late	0.92	11.41	12.37	185.30
Mean		0.66	10.24	16.58	121.53

[1]grams of citric acid/100 ml of orange juice
[2] expressed as ºBrix
[3] Retinol Activity Equivalent (RAE)/L

TABLE 2. COMPOSITION OF THE CONSUMER POPULATION SAMPLED

	Under 20	20-29	Over 30	Total
Female	15	50	13	78 (70%)
Male	4	24	5	33 (30%)
	19 (17%)	74 (67%)	18 (16%)	111 (100%)

TABLE 3: COLOUR COORDINATES AND MEAN ΔE^*_{ab} VALUES (OF EACH VARIETY IN RELATION TO THE REST) OF THE VARIETIES MEASURED IN THE SPECTRORADIOMETER (a) AND BY IMAGE ANALYSIS (b)

Varieties	**L***	**a***	**b***	**C^*_{ab}**	**h_{ab}**	**ΔE^*_{ab}**
NF	60.66 ± 0.121^{a}	12.40 ± 0.476^{a}	64.66 ± 0.356^{a}	65.84 ± 0.260^{a}	79.14 ± 0.465^{a}	6.518
F	57.99 ± 0.212^{b}	16.61 ± 0.180^{b}	61.80 ± 0.076^{b}	63.99 ± 0.027^{b}	74.96 ± 0.174^{b}	5.015
NP	59.96 ± 0.230^{a}	15.21 ± 0.238^{c}	64.24 ± 0.560^{a}	66.02 ± 0.490^{a}	76.68 ± 0.313^{c}	5.814
VM	57.41 ± 0.090^{bc}	18.29 ± 0.096^{d}	60.98 ± 0.143^{b}	63.66 ± 0.109^{b}	73.30 ± 0.120^{d}	4.484
RL	56.48 ± 0.723^{c}	24.60 ± 0.141^{e}	58.12 ± 0.150^{c}	63.11 ± 0.084^{b}	67.06 ± 0.171^{e}	8.388

(a)

Varieties	**L***	**a***	**b***	**C^*_{ab}**	**h_{ab}**	**ΔE^*_{ab}**
NF	61.34 ± 0.297^{a}	8.40 ± 0.513^{a}	59.70 ± 0.501^{a}	60.29 ± 0.529^{a}	81.99 ± 0.460^{a}	8.508
F	60.43 ± 0.284^{a}	10.48 ± 0.891^{b}	56.87 ± 0.484^{b}	57.84 ± 0.577^{bc}	79.57 ± 0.828^{b}	6.163
NP	59.77 ± 0.280^{ab}	12.77 ± 0.380^{c}	57.73 ± 0.365^{b}	59.12 ± 0.364^{ac}	77.53 ± 0.370^{c}	5.852
VM	58.75 ± 0.240^{b}	14.17 ± 0.487^{d}	55.01 ± 0.628^{b}	56.81 ± 0.605^{b}	75.55 ± 0.519^{d}	6.295
RL	56.09 ± 0.388^{c}	21.61 ± 0.483^{e}	49.52 ± 0.559^{c}	54.03 ± 0.626^{d}	66.43 ± 0.418^{e}	13.430

(b)

TABLE 4. MEAN SCORES FOR THE COLORIMETRIC PARAMETERS GIVEN BY THE PANEL

	RL	NF	F	VM	NP
h_{ab}	7.88^{a}	1.55^{b}	4.27^{c}	5.63^{d}	2.97^{e}
L*	7.98^{a}	2.34^{b}	4.39^{c}	6.12^{d}	3.92^{c}
C^*_{ab}	5.65^{a}	5.89^{a}	4.76^{ab}	3.64^{b}	4.67^{ab}

[a-e] Different superscripts within row indicates statistically significant differences ($p<0.05$)

TABLE 5. SIMPLE REGRESSION COEFFICIENTS (r) AND SIGNIFICANCE LEVELS (p) BETWEEN INSTRUMENTAL AND SENSORY EVALUATION OF COLOUR

Parameter	Spectroradiometer measurement	Image analyses
Lightness (L*)	-0.94 (0.018)	-0.96 (0.008)
Chroma (C^*_{ab})	0.22 (0.717)	0.069 (0.911)
Hue (h_{ab})	-0.98 (0.002)	-0.92 (0.026)

TABLE 6. PREFERENCE DATA: RANK SUMS GROUPED BY AGE SEX AND CONSUMPTION HABITS

	n	NF	F	NP	VM	RL
All	111	2.05 ^{a}	3.35 ^{b}	2.89 ^{c}	3.66 ^{b}	3.05 ^{bc}
By gender						
Women	78	2.10 ^{a}	3.46 ^{b}	2.92 ^{c}	3.67 ^{b}	2.85 ^{c}
Men	33	1.91 ^{a}	3.09 ^{bc}	2.82 ^{c}	3.67 ^{b}	3.51 ^{b}
By gender and sex						
W < 20	15	2.53 ^{a}	2.93 ^{a}	2.87 ^{a}	3.40 ^{a}	3.27 ^{a}
M < 20	4	2.00 ^{a}	2.75 ^{a}	2.75 ^{a}	3.50 ^{a}	4.00 ^{a}
W 20-29	50	2.00 ^{a}	3.62 ^{b}	2.78 ^{c}	3.72 ^{b}	2.88 ^{c}
M 20-29	24	2.04 ^{a}	3.13 ^{bc}	2.88 ^{c}	3.67 $^{b\,d}$	3.29 ^{cd}
W > 30	13	2.00 ^{a}	3.46 ^{bc}	3.54 ^{bc}	3.77 ^{c}	2.23 ^{a}
M > 30	5	1.20 ^{a}	3.20 ^{bc}	2.60 ^{b}	3.80 ^{bc}	4.20 ^{c}
By consumption habits						
Regular Consumers of OJ	86	2.16 ^{a}	3.28 ^{b}	2.90 ^{b}	3.71 ^{c}	2.95 ^{b}
Commercial OJ	19	2.37 ^{a}	3.00 ^{ab}	3.11 ^{ab}	3.47 ^{b}	3.05 ^{ab}
Fresh Home squeezed OJ	63	2.17 ^{a}	3.37 ^{b}	2.84 ^{c}	3.78 ^{b}	2.84 ^{c}
Any	4	1.00 ^{a}	3.25 ^{b}	2.75 ^{b}	3.75 ^{b}	4.25 ^{b}
No regular consumer	25	1.64 ^{a}	3.60 ^{b}	2.88 ^{c}	3.52 ^{bc}	3.36 ^{bc}

Ranking preference: 1 the lowest, 5 the highest. $^{a\text{-}d}$Different superscripts in column indicates statistically significant differences ($p<0.05$)

TABLE 8. RANK SUMS FOR DIFFERENT SEGMENTS OF CONSUMERS

	SEGMENTS		
Samples	1 (n=24) 21.62%	2 (n=50) 45.05%	3 (n=37) 33.33%
NF	4.33 a	1.20 a	1.70 a
F	3.58 a	2.78 b	3.97 b
NP	3.25 b	2.14 c	3.68 b
VM	2.13 c	4.10 d	4.08 b
RL	1.71 d	4.78 e	1.57 a

FIGURES

FIG. 1. COLOR COORDINATES OF OJ SAMPLES IN THE a*b* AND C^*_{ab} L* PLANES. MEASUREMENTS MADE BY SPECTRORADIOMETRY ○ AND IMAGE ANALYSES ● TECHNIQUES

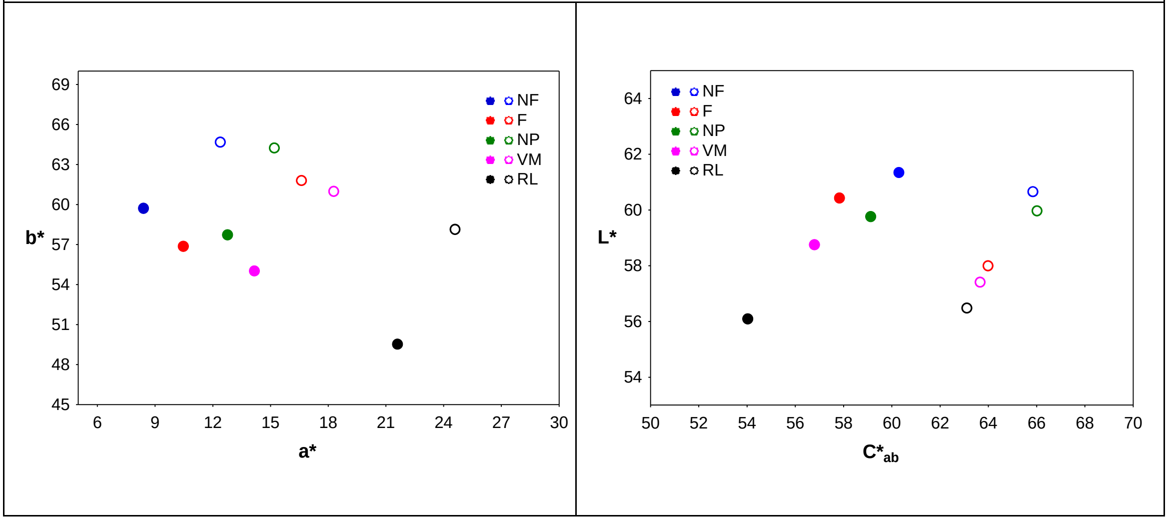

FIG. 2.CONTRIBUTION OF ΔC^*_{ab}, ΔL^* AND Δh_{ab} TO COLOR DIFFERENCES AMONG SAMPLES DIGIEYE (a) AND SPECTRORADIOMETER (b)

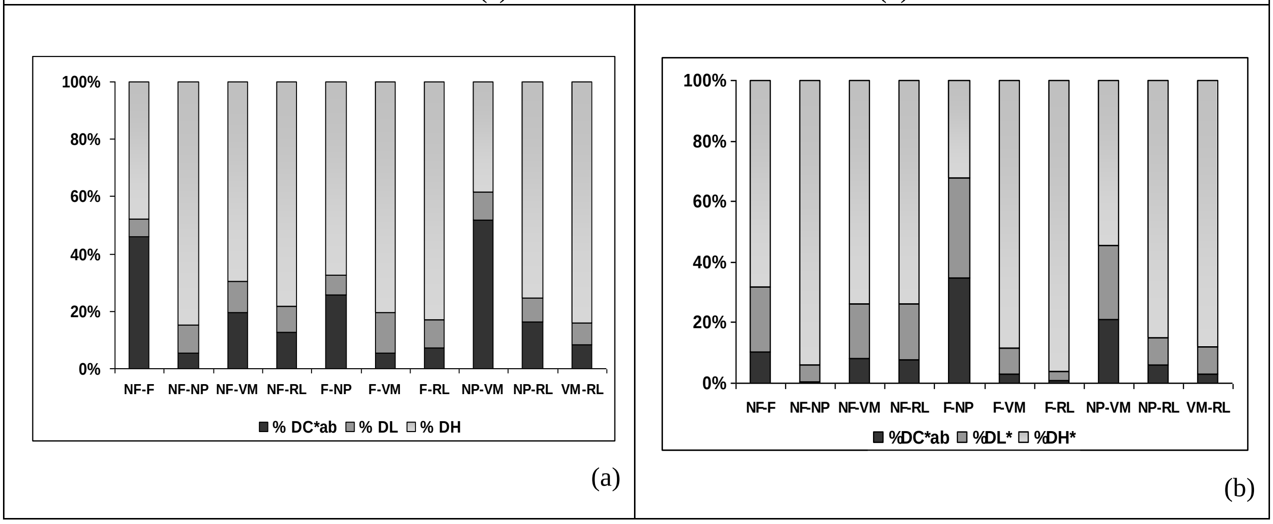

FIG. 4. FREQUENCY DISTRIBUTION OF OVERALL PREFERENCES FOR JUICE COLOR IN DIFERENT ORANGE VARIETIES. CHI-SQUARE VALUES OF PEARSON TEST TO CHECK THE FIT OF THE OBSERVED FREQUENCIES TO THE NORMAL DISTRIBUTION. SAMPLES CODES IN TABLE 1

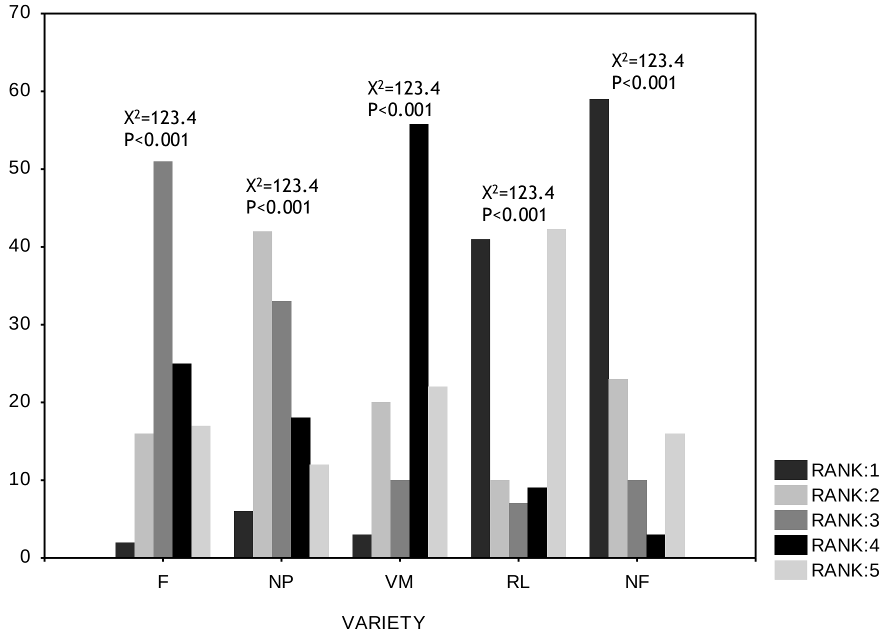

FIG. 5. DENDOGRAM OF CONSUMERS (N=111)