A case study on the flavor properties of melon (*Cucumis melo* L.) cultivars

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Abstract — **Introduction**. The aim of our study was to evaluate the effects of sugar and citric, malic, succinic and ascorbic acid levels on melon flavor perception, and to infer about consumers' preferences based on instrumentally measured characteristics. **Materials and methods**. Fully ripened melons belonging to the 'Branco' (Brazilian), 'Pele de Sapo' (Spanish) and winter 'Tendral' (Portuguese) melon cultivars were analyzed using five fruits with three replicates for each treatment. Quality parameters (weight, height, diameter, solid shape, volume, internal appearance, texture and flavor), sugars (glucose, fructose and sucrose), total soluble solids content, sweetness, organic acids (citric, malic, succinic and ascorbic) and sourness were measured. **Results and discussion**. Flavor was the most important parameter for the consumers' decision, regarding the different melon cultivars studied. It was also detected that it correlated well with sweetness (thus, with sucrose content) and sourness. The obtained data supports that sugars and organic acids enhance human perception of specific flavor notes in melon.

Portugal / *Cucumis melo* / fruits / flavor / sweetness / acidity

Étude de cas sur les caractéristiques de la saveur de cultivars de melon (*Cucumis melo* L.).

Résumé — **Introduction**. Le but de notre étude a été d'évaluer les effets des sucres et de différents niveaux d'acide citrique, malique, succinique et ascorbique sur la perception de l'arôme du melon, et d'évaluer comment s'établissent les préférences du consommateur à partir de caractéristiques mesurées expérimentalement. **Matériel et méthodes**. Des melons à pleine maturité appartenant aux cultivars de melons 'Branco' (brésilien), 'Pele de Sapo' (espagnol) et 'Tendral' d'hiver (portugais) ont été analysés à partir de cinq fruits et de trois réplications par analyse. Des paramètres de qualité (poids, taille, diamètre, forme, volume, aspect interne, texture, saveur), les sucres (glucose, fructose et sucrose), le contenu de solides solubles totaux, la suavité, les acides organiques (citrique, malique, succinique et ascorbique) et l'acidité ont été mesurés. **Résultats et discussion**. La saveur a été le paramètre le plus important pris en compte par les consommateurs pour choisir entre les différents cultivars de melon étudiés. Elle a été bien corrélée avec la suavité (donc avec la teneur en saccharose) et l'acidité. Les données obtenues supportent le fait selon lequel les sucres et les acides organiques augmenteraient la perception humaine des notes de saveurs spécifiques dans le melon.

Portugal / *Cucumis melo* / fruits / flaveur / douceur / acidité

1. Introduction

The intense fruit quality of melons is related to the high internal sugar levels and to the good flavor [1]. Soluble solids content of netted and non-netted melons usually reaches c.a. 9–10% [2–4]. In fact, sweetness is a quality characteristic that limits consumer acceptability of melon fruit [5].

In general, all melons show a similar pattern of sugar accumulation, with a rapid rise in the accumulation of sugars as the fruit reaches full size [1]. This is essentially a phenomenon of sucrose accumulation [6]. It is widely believed that the Cucurbitaceae crops synthesize galactosyl-sucrose (raffinose and stachyose) in their leaves, rather than sucrose, during ripening [7]. These carbohydrates may be the main source of sucrose synthesis [8, 9].

The aim of our study was to evaluate the effects of sugar and citric, malic, succinic and ascorbic acid levels on melon flavor perception, and to infer about consumers' preferences based on instrumentally measured characteristics.

We studied the three main cultivars of melon fruit (*Cucumis melo* L.) commercialized in Portugal between June and December, which have a huge acceptance [10].

2. Materials and methods

2.1. Plant material

Fully ripened melons (*Cucumis melo* L.) belonging to the 'Branco' (Brazilian), 'Pele de Sapo' (Spanish) and winter 'Tendral' (Portuguese) melon cultivars, without defects, from a local producer, were analyzed using five fruits with three replicates for each treatment. Fruits of the Branco cultivar are silvery white, smooth and round; they usually have green or white flesh. Pele de Sapo ones are oval, sometimes with a rough and somewhat sculptured skin, while the flesh has a greenish color and a crunchy texture. Tendral-type cultivars, with their dark skin, very rough, hard ring and greenish flesh, are the last to ripen [11].

2.2. Morphological analysis

Fruit weight was determined using a digital balance. Diameter (D) and height (H) were measured using a specific ruler and the ratio [H/D] was calculated to describe the global fruit shape. Volume was also determined through liquid displacement. All these measurements were carried out using ten fruits for each cultivar.

2.3. Physicochemical analysis

The analysis of flesh firmness, total soluble solids content and titratable acidity were carried out according to Barreiro *et al.* [12].

2.3.1. Flesh firmness

Flesh firmness was estimated in the equatorial hypodermal mesocarp tissue, using a Bellevue penetrometer, by the resistance of the flesh to the penetration of a standard plunger with a diameter of 8 mm, and expressed in Newtons.

2.3.2. Total soluble solids

An Atago ATC-1 hand refractometer was used for measuring total soluble solids (TSS) in extracted juice. The refractometer measures the refractive index, which indicates how much a light beam will be slowed down when it passes through the fruit juice, the values being expressed in °Brix.

2.3.3. Titratable acidity

Titratable acidity (TA) was determined by titrating 10 mL of fruit juice with 0.1 N NaOH, to an end point of pH = 8.2, as indicated by a CD 7000 WPA pH meter. The volume of NaOH needed was used to calculate the titratable acidity, applying a multiplication factor of 0.64 (because citric acid is the major acid present).

2.4. Physiological analysis

2.4.1. Sugar and organic acid quantification

Sugar extraction followed Hudina and Stampar's method [13]. Samples of 20 g from

10 fruits' flesh were dissolved with 100 mL distilled water and centrifuged at 15000 × *g* for 15 min at 4 °C. Filtration was carried out with Whatman No. 4 filters and Millipore 0.45-m filters. Sugars were identified and quantified by HPLC, using a Waters R401 refractive index detector and a Sugar-Pack (Waters) column kept at 90 °C. A flow rate of 0.5 $mL \cdot min^{-1}$ was applied to an aqueous mobile phase of EDTA-Ca (50 $\mu L \cdot L^{-1}$).

The extraction of citric, malic and succinic acids was similar to that of sugars, but, thereafter, for the isolation and characterization, a Beckman Gold 168 diode-array detector and an Aminex HPX 87H (BioRad) column were used. A flow rate of 0.5 $mL \cdot min^{-1}$ was applied, at room temperature, to a mobile phase of 5 mM H_2SO_4.

The concentration of ascorbic acid was determined following Smith [14]. Samples of 20 g from 10 fruits' flesh were homogenized with 30 mL of 6% metaphosphoric acid, and then centrifuged at 15000 × *g*, for 25 min, at 4 °C. Filtration was carried out with Whatman No. 4 filter papers twice. Volume was brought to 100 mL with 6% metaphosporic acid, and samples were again filtered with Millipore 0.45-m filters. For ascorbic acid quantification, HPLC, with a Waters 440 detector and a Spherisorb ODS2 5 µm (Waters) column, was used. A flow rate of 0.4 $mL \cdot min^{-1}$ was applied, at room temperature, to a mobile phase of H_2SO_4 (pH 2.3).

Sweetness was determined according to Whitney *et al.* [15], multiplying by 1, 1.7 and 0.7 factors the sucrose, fructose and glucose, respectively.

Sourness was determined according to Furukawa *et al.* [16], multiplying by 1, 1.33, 1.14 and 0.47 factors for citric, malic, succinic and ascorbic acids, correspondingly.

2.4.2. Quality parameters

The quality characteristics of melon flesh were determined at especial facilities housing a number of individual booths by a 10-member tasting preference panel [17]. Each station displayed melon cubes of middle-mesocarp tissue, taken from the equatorial region of the fruit. The panellists were randomly selected. The only prerequisite for inclusion was that the person should be a regular consumer of melon. The panellists judged the internal appearance, texture and flavor of the melons. A continuous scale of 5 was used for each parameter (1: bad; 3: acceptable; 5: very good). Global acceptance was determined by multiplying by 3, 7 and 10 factors the external appearance, texture and flavor, respectively [10].

2.5. Statistical analysis

Data were statistically analyzed using one-way ANOVA ($P \leq 0.05$) applied to the studied parameters. Based on the ANOVA results, Tukey's test was performed for mean comparison, for a 95% confidence level. Different letters indicate significant differences in a multiple range analysis for a 95% confidence level.

2.6. Correlation analysis

Correlation is a measurement of the relation between two or more variables. Correlation coefficients range from –1.00 to +1.00; the value of –1.00 represents a perfect negative correlation, while a value of +1.00 represents a perfect positive correlation. A value of 0.00 represents a lack of correlation.

3. Results and discussion

The cultivars considered in this study were morphologically characterized (*table I*). Although there were significant differences between cultivar weight and height, the fruit form was characteristic. Tendral melons were smaller and, consequently, heavier than the two other melons.

The consumer panel evaluated the melon flesh's internal appearance, texture, flavor and overall acceptance using a 5-point hedonic scale (*table II*). As regards the attributes considered, Tendral was the least preferred, as previously described [11]. On the other hand, Branco showed the highest overall acceptance. As reported earlier [18, 19], flavor becomes the key factor to determine melon fruit acceptability.

Flavor is the sum of the taste plus aroma and this parameter is mainly composed of sweetness, sourness and aroma, which correspond to sugars, acids and volatiles,

Table I.
Melon morphological parameters. Each value is the mean of five fruits with three replicates. Results present mean ± standard errors.

Cultivar	Weight (kg)	Height (cm)	Diameter (cm)	Form[1]	Volume (dm^3)
Pele de Sapo	2.86 ± 0.13 a	24.18 ± 0.57 a	15.50 ± 0.42 a	1.57 ± 0.07 a	2.92 ± 0.13 a
Branco	3.06 ± 0.05 a	24.08 ± 0.31 a	15.42 ± 0.25 a	1.56 ± 0.04 a	2.99 ± 0.10 a
Tendral	2.46 ± 0.11 b	21.83 ± 0.59 b	15.48 ± 0.33 a	1.41 ± 0.02 a	2.48 ± 0.11 b

[1] The global fruit form was described by the ratio [height/diameter].

Different letters in the same column indicate significant differences, in a multiple range analysis, for a 95% confidence level.

Table II.
Melon quality parameters. A continuous scale of 5 was used for each parameter (1: bad; 3: acceptable; 5: very good). Overall acceptance was determined by multiplying by 3, 7 and 10 factors the internal appearance, texture and flavor, respectively [10]. Each value is the mean of a 10-member tasting preference panel. Results present mean ± standard errors.

Cultivar	Internal appearance	Texture	Flavor	Overall acceptance
Pele de Sapo	3.9 ± 0.1 a	4.0 ± 0.2 a	3.4 ± 0.3 ab	3.78 ± 0.17 a
Branco	3.4 ± 0.3 a	4.1 ± 0.2 a	4.3 ± 0.2 a	3.94 ± 0.20 a
Tendral	2.4 ± 0.6 b	3.2 ± 0.3 b	2.7 ± 0.3 b	2.75 ± 0.23 b

Different letters in the same column indicate significant differences, in a multiple range analysis, for a 95% confidence level.

Table III.
Sugar and total soluble solids (TSS) content in melon cultivar samples. Each value is the mean of of five fruits with three replicates. Results present mean ± standard errors.

Cultivar	Sucrose	Fructose	Glucose	TSS (°Brix)	Sweetness[1]
	($mg \cdot g^{-1}$ fresh weight)				
Pele de Sapo	22.9 ± 2.1 a	11.7 ± 0.8 a	10.2 ± 1.6 a	9.47 ± 0.38 ab	50.1 ± 2.4 a
Branco	65.3 ± 2.0 b	20.9 ± 0.3 b	12.9 ± 0.2 a	11.77 ± 0.61 a	109.9 ± 2.7 b
Tendral	32.3 ± 0.7 a	17.3 ± 0.6 c	13.8 ± 0.2 a	9.36 ± 0.91 b	71.3 ± 1.9 c

[1] Sweetness was determined according to Whitney *et al.* [15], multiplying by 1, 1.7 and 0.7 factors the sucrose, fructose and glucose, respectively.

Different letters in the same column indicate significant differences, in a multiple range analysis, for a 95% confidence level.

respectively [20]. However, the main component dictating melon fruit eating quality is sweetness [6], being affected by different sugar compositions. All the melon cultivars revealed a high content in sugars, mostly glucose, fructose and sucrose, as already reported [21, 22] (*table III*).

The relative proportions of the different sugars may account for differences in the taste, for equal amounts of total sugars [22]. Sugars have different degrees of sweetness, as they have different weights. A high positive correlation was established involving sucrose content and sweetness (0.989).

Table IV.
Organic acid content in melon cultivar samples. Each value is the mean of five fruits with three replicates ± standard errors.

Cultivar	Citric acid	Malic acid	Succinic acid	Ascorbic acid	Sourness[1]
	($mg \cdot g^{-1}$ fresh weight)				
Pele de Sapo	1.60 ± 0.26 ab	1.15 ± 0.36 a	1.23 ± 0.68 a	4.52 ± 0.04 b	6.65 ± 1.53 b
Branco	2.19 ± 0.03 a	1.41 ± 0.01 a	1.47 ± 0.02 a	9.99 ± 0.91 a	10.42 ± 0.48 a
Tendral	1.29 ± 0.15 b	0.48 ± 0.07 a	0.79 ± 0.35 a	5.14 ± 0.25 b	5.25 ± 0.53 b

[1] Sourness was determined according to Furukawa *et al.* [16], by multiplying by 1, 1.33, 1.14 and 0.47 factors for citric, malic, succinic and ascorbic acids, correspondingly.

Different letters in the same column indicate significant differences, in a multiple range analysis, for a 95% confidence level.

Table V.
Correlation coefficients between the sourness of melon and some studied fruit parameters.

Parameter	Total soluble solids (TSS)	Titratable acidity (TA)	[TSS/TA] ratio	pH
Sourness	0.975	0.480	0.967	0.849

Indeed, sucrose is the main contributor to sweetness, approximately accounting for 50% or more, among total soluble sugars [8, 10, 23–25]. Even so, no significant correlation was found between individual sugars and flavor, or between sweetness and flavor.

Sugar content is commonly accepted to be synonymous with TSS and producers often select this parameter for higher TSS, in an attempt to increase sweetness [20]. However, in some fruits, such as oranges, TSS relates to sweetness, while in others such as tomato and mango, the relationship is not linear [26, 27]. In the studied melon fruits, although TSS varied among the cultivars, as already shown in previous studies [28–30] (*table III*), the parameter was not only positively correlated with sweetness (0.921) but, furthermore, also became correlated with flavor (0.911), which may be a result of the panellists' interpretation.

Organic acids give to fruits their sour flavor. Different acids can affect sourness perception, depending on the chemical structure [20]. In this context, an increase in carboxyl groups decreases acidity, while an increase in molecular weight or in hydrophobicity increases sourness [31]. Melon fruits have a very limited organic acid content [31], mostly restricted to citric, malic, succinic and ascorbic acids [10, 20, 21] (*table IV*).

Table VI.
Correlation coefficients between studied parameters for different melon cultivars.

Parameter	Flavor	Sweetness	Sourness
Firmness	– 0.932	– 0.899	– 0.986
Total soluble solids	0.911	0.921	0.975

Like sugars, organic acids also have different relative sourness values. According to Furukawa *et al.* [16], sour taste is mainly associated with pH and, to a lower extent, with the degree of acid dissociation. There was a clear correlation involving the individual organic acids studied, and sourness, varying between (87.1 and 99.7)% for malic and citric acids, respectively. In addition, a very high correlation was found with total organic acids and sourness (about 0.986). Sometimes TSS, the ratio [TSS/TA] and the pH correlate better with sourness than TA itself [26, 27], which we found in our study (*table V*).

Sensory attributes, preferences and decisions can be statistically related to chemical components in foods [32]. Correlation of physical measurements with sensory analysis gives meaning to instrumental data, as already shown for apple and tomato [26]. Our data agrees with those findings, and we concluded that the flavor was the most important parameter for consumers' decisions. In this context, regarding different melon cultivars, a correlation was found with sweetness, and an even better interaction was detected with sourness. Therefore, our conclusion is that sugars and organic acids enhance human perception relating to specific flavor notes in melon, including aromatics, as already pointed out for other fruits, such as mango [33]. Our findings are further supported by the TSS or firmness determinations, which have long been known to be useful predictors of consumers' acceptance (*table VI*).

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Estudio de casos sobre las características del sabor de cultivares de melón (*Cucumis melo* L.).

Resumen — **Introducción**. El objetivo de nuestro estudio fue evaluar los efectos de los diferentes tipos de azúcar así como el de los diferentes niveles de ácido cítrico, málico, succínico y ascórbico en la percepción del aroma del melón y evaluar el modo en el que se establecen las preferencias del consumidor a partir de características medidas de forma experimental. **Material y métodos**. Se analizaron a partir de cinco frutos y de tres replicaciones por análisis melones en plena madurez, que pertenecían a los cultivares de melón 'Branco' (brasileño), 'Piel de Sapo' (español) y 'Tendral' de invierno (portugués). Se midieron unos parámetros de calidad (peso, tamaño, diámetro, forma, volumen, aspecto interno, textura, sabor), los azúcares (glucosa, fructosa y sacarosa), el contenido de sólidos solubles totales, la suavidad, los ácidos orgánicos (cítrico, málico, succínico y ascórbico) así como la acidez. **Resultados y discusión**. Fue el sabor el parámetro más importante tomado en cuenta por los consumidores para la elección entre los distintos cultivares de melón estudiados. Se correlacionó bien con la suavidad (es decir: con el contenido en sacarosa) y con la acidez. Los datos obtenidos sostienen el hecho según el cual los azúcares y los ácidos orgánicos aumentan la percepción humana de las notas de sabores específicos en el melón.

Portugal / *Cucumis melo* / frutas / sabor / dulzura / acidez