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Short Communication

Sensory analysis of broccoli over time: Consumer defined critical attributes and evaluation of digital photographs in comparison to real product appearance

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ABSTRACT

The objectives of the present work were: (a) define the critical attribute of broccoli from a consumers' perspective and (b) for broccoli compare the trained panel sensory evaluation of real products versus the sensory evaluation of the corresponding digital photographs. A panel of broccoli consumers evaluated appearance, aroma and flavor acceptability of broccoli with different storage times. Appearance acceptability was the only attribute where there were significant differences between storage times. Thus appearance was the critical attribute as evaluated by consumers. A panel of assessors measured the appearance of broccoli samples with different storage times using the quality scoring method (QSM). A month after having measured the real product the same assessors measured the appearance of digital photographs of the same samples using the QSM. Analysis of variance showed that there were no significant differences between evaluations of the real broccoli and the corresponding photograph.

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1. Introduction

The appearance of the product is the first impression a consumer has of a given food product. Color, as one aspect of appearance, has to be within an expected range for food acceptance and the degree of acceptability is judged within that range. If the appearance is unacceptable, the other two major quality factors, flavor and texture, are not likely to be judged at all, this is especially true for fruits and vegetables. Foods outside the normal range of acceptable appearance are rejected, sometimes rather emphatically (Francis, 1995).

Differentiation between individual fruits and vegetables by consumers is based primarily upon appearance (IFT, 1990), which often influences purchase (Baardseth et al., 1988). For broccoli and other green vegetables, the retention of green color during storage is generally considered a measure of quality (Barth, Perry, Schmidt, and Klein, 1992). However, together with changes in appearance there can be aroma or flavor changes which could be judged negatively by consumers. For broccoli there have been no studies confirming that appearance is effectively the critical attribute from a consumers' perspective.

The definition of quality is very complex within the food industry. In the literature it is very common to find a mixture of the quality, the concept, with quality, the measurement of attribute (Bremner, 2002). The quality scoring method (QSM) is a common method for quality control often developed for the company's specific products such as milk and fish. In this method, the trained assessors evaluate the effect of the changing attributes on the end quality of the product by scoring, grading or ratings (Rogers, 2010).

Siomos, Gerasopoulos, and Tsouvaltzis (2005) used QSM to assess white asparagus spears treated with hot water and Baur, Klaibera, Weib, Hammesb, and Carle (2005) used this method to evaluate the effect of temperature and chlorination on shelf-life and physiological properties of ready-to-use iceberg lettuce. Ku and Wills (1999) applied this methodology to broccoli treated with 1-methylcyclepropene; however they showed limited information in their score sheet on the sensory characteristics corresponding to each score.

Some vegetables such as broccoli have a heterogeneous appearance difficult to assess by a trained sensory panel. Broccoli has a heterogeneous appearance throughout storage. When it is freshly harvested there are heterogenous shades of green and blue, and during storage the heterogeneity turns to different shades and levels of green, yellow and brown. Due to this heterogeneous appearance of broccoli, quality scoring method (QSM), where assessors evaluate the product more broadly providing a final score which includes several aspects of an attribute, would be more appropriate than the descriptive analysis methodologies such as quantitative descriptive analysis (QDA, Stone, Bleibaum, and Thomas, 2012) and the Spectrum™ descriptive analysis method (Meilgaard, Civille, and Carr, 2007) where the assessors focus on a number of sensory descriptors, scoring each one separately.

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Sensory evaluation trials, most of the time, involve the use of a large amount of sample. When conducting consumer studies, these samples have to be moved to different sites, which implies a significant logistic cost. Also samples have to be stored under controlled conditions to ensure limited sensory changes, and thus cold storage and atmosphere control have to be accounted for.

Recently computerized image analysis techniques (also known as computer vision systems), which purport to overcome the deficiencies of visual and other instrumental techniques have been proposed (Chen, Chao, and Kim, 2002). Most recent applications include classification and quality evaluation of various foods such as apples (Leemans, Magein, and Destain, 2002) chicory (Zhang, De Baerdemaeher, and Schrevens, 2003), and meats (O'Sullivan et al., 2003). Balaban, Aparicio, Zotarelli, and Sims (2008) correlated a computer vision system versus the sensory evaluation of digital photographs. They obtained good correlations between both measuring methods and chose computer vision to eliminate what they called the panel's subjectivity. However, their panel did not evaluate the real product so they would not know if the image represented the sensory evaluation of the real product. Mendoza and Aguilera (2004) implemented a computer vision system to identify the ripening stages of banana based on color, development of brown spots, and image texture information from a quality control perspective. However there was not a direct comparison between the sensory evaluation of the real banana in relation to the sensory evaluation of the digital photograph of the banana. Although these instrumental measures are valuable, they will not suffice to define color quality without extensive consumer calibration (Francis, 1995).

Verifying if the sensory evaluation of a digital photograph is equivalent to the sensory evaluation of the real product would be advantageous. The visual assessment of images eliminates the temporal and geographic restrictions imposed when evaluating perishable foods. Images last longer than a meal or food product and they can be shared electronically. This allows greater flexibility in the analysis of visual attributes.

The objectives of the present work were: (a) define the critical attribute of broccoli from a consumers' perspective and (b) for broccoli compare the trained panel sensory evaluation of real products versus the sensory evaluation of the corresponding digital photographs. These objectives will be pursued in two different experiments.

2. Plant material

Broccoli (*Brassica oleracea* L. var. Italica, cv De Cicco) which had been harvested that same day was acquired from a local farm and transported to our Institute in wooden boxes within 5 h. Harvesting was between the months of May and August (Southern Hemisphere). The following day, that is 24 h after harvesting, the broccoli was treated differently for Experiment 1 and 2 as explained below.

3. Experiment 1: Defining the critical attribute

Appearance of broccoli is evaluated at point of purchase, very often defining the consumer's willingness to buy the product. It can also be evaluated in the home after storage and prior to the cooking of the product. Be it in the point of purchase or at home, appearance is evaluated by the consumer on raw broccoli. Aroma and flavor however are evaluated on the cooked product as broccoli is rarely consumed raw. Thus in the present experiment, designed to determine the critical attribute from a consumer's perspective, appearance was evaluated on raw broccoli and aroma and flavor on cooked broccoli.

3.1. Materials and methods

3.1.1. Sample preparation

Broccoli heads were stored at room temperature (18–22 °C) for 24, 96, and 192 h after harvesting. These times were chosen to have fresh, intermediate and deteriorated samples. While quite often broccoli is stored under refrigerated conditions, in this experiment, which was to define the critical attribute, broccoli heads were stored at room temperature to accelerate the process of sensory deterioration. Having reached their storage time, the samples were stored in polyethylene bags in a freezer at −18 °C till evaluation.

For appearance evaluation, samples were removed from the freezer 3 h before evaluation and left with no further processing to thus represent realistic consumer evaluation conditions in the market place.

For aroma and flavor evaluation, samples were removed from the freezer 3 h before evaluation. The present work was part of a wider project on minimally processed broccoli, thus following general standards for this type of product, broccoli was cut in florets with 3 cm stalks and surface-sterilized by washing at 15 °C with 150 ppm of chlorine for 10 min. In Argentina broccoli is consumed cooked by boiling. There are no standards on broccoli: water relationships nor cooking times. To ensure abundant water to thus avoid a sharp drop in water temperature when broccoli was added to the boiling water, 1 kg of broccoli per 8 L of water was used. The cooking time was standardized to 10 min after placing the broccoli in the pot. After boiling they were drained and placed in cold water to stop the cooking.

3.1.2. Consumer evaluation

Sixty people who had consumed broccoli in the last 2 weeks were recruited. They were from the town of Nueve de Julio, a city with 40,000 inhabitants located 250 km to the west of Buenos Aires. In Nueve de Julio the ethnic origin (majority white Caucasian), the products in market places and exposure to nationwide media is similar as to the rest of Argentina.

To evaluate appearance the 3 samples corresponding to the 3 storage times were placed on individual tables in a room. Consumers entered the room with their score sheets clipped together in a balanced order and evaluated the appearance of the samples following this order. For each sample they used a scale with 9 boxes anchored at the left end with "dislike very much", in the middle with "indifferent" and at the right end with "like very much".

For aroma and flavor approximately 30 g of cooked broccoli were placed in 100 cm^3 covered glasses wrapped with brown paper and identified by a random three-digit code. Samples were evaluated in a sensory laboratory with artificial lighting which consisted of red bulbs wrapped in wafer thin brown paper. This illumination and the covered glasses ensured consumers could not judge the appearance of the product while evaluating aroma and flavor. Order of presentation was balanced over consumers.

3.1.3. Statistical analysis

For each one of the sensory acceptability attributes (appearance, aroma and flavor), an analysis of variance (ANOVA) was performed considering consumer as a random factor and storage time as a fixed factor.

3.2. Results and discussion

Fig. 1 shows consumer sensory acceptability versus storage time. For the appearance attribute there were significant differences between storage times, consumers gave highest scores to broccoli with 24 h storage and lowest scores to the sample with 192 h storage. For both aroma and flavor attributes, there were

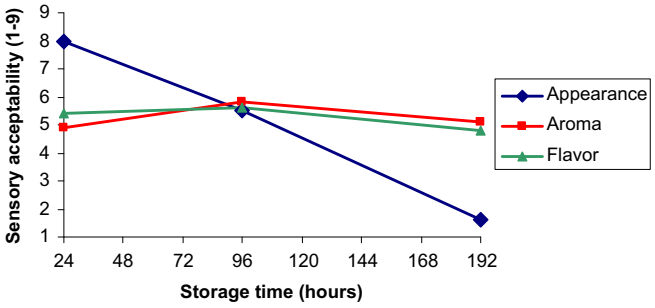

Fig. 1. Consumer sensory acceptability versus storage time.

no significant differences in terms of storage time, consumers gave similar scores to the three broccoli samples.

Fig. 1 shows mean results over the 60 consumers. Looking at each individual consumers' data individually showed that only 2 out of the 60 consumers did not follow the trend shown in Fig. 1. For aroma and flavor the majority of consumers followed the pattern shown in Fig. 1, but there were some that showed decreasing sensory acceptability with storage time, and others increasing sensory acceptability. Thus, even for these consumers, appearance would still be the critical attribute.

Aked (2000) indicated that for fruits and vegetables appearance is a key quality factor. They also mentioned that flavor can rarely be assessed by the consumer prior to purchase but it is critical in the repeat purchase of a particular product cultivar. However, we have shown that for broccoli, aroma and flavor acceptability did not change with storage time while appearance acceptability for the same samples changed significantly as shown in Fig. 1. The fact that aroma and flavor acceptability did not change does not necessarily mean that the aroma and flavor were the same for the different storage times. However, we have shown that if this aroma and flavor differences did exist they did not influence sensory acceptability of these attributes as measured by consumers. The appearance of the raw broccoli definitely did change and these changes significantly affected sensory acceptability, thus we can conclude that appearance was the critical attribute as evaluated by consumers.

As mentioned in Section 3.1.2, consumers' were of similar characteristics to the majority of Argentina broccoli consumers, thus results can be considered representative of the country. In some countries broccoli is consumed with relatively low cooking times in relation to Argentina, this may have an influence on appearance and flavor sensory acceptability; thus the present results would have to be confirmed where broccoli is consumed with low cooking times.

4. Experiment 2: Use of digital photographs

4.1. Materials and methods

4.1.1. Sample preparation

4.1.1.1. Real broccoli. The plant material described above was cut in florets with 3 cm stalks and placed in water at 15 °C with 150 ppm of chlorine for 10 min. Approximately 300 g of these florets were placed in a Styrofoam tray and wrapped in a 15 μm thick PVC film. These trays were stored for 1, 5, 7, 12, and 27 days at 8 °C. After this storage the broccoli samples were placed at −18 °C till their evaluation. Storage times were different to those used in Experiment 1, because the temperature used in this experiment was lower, therefore the deterioration was slower than at 20 °C.

4.1.1.2. Digital photographs. Broccoli stored 1, 5, 7, 12, and 27 days at 8 °C were photographed with a Sony DSC-W55, 7.5 pixels digital camera. The photographs were taken over a white surface illuminated by two daylight-type fluorescent lights. The camera was placed above the samples at 40 cm distance, using the automatic adjustment camera setting with no flash.

4.1.1.2.1. Monitor calibration. To evaluate the photographs a Philips 17" LSD monitor was used. First the auto-calibration button of the monitor was pressed. Then 3 different colored objects were used for further calibration. These objects were photographed with the digital camera under the same conditions as described above. The photographs were viewed using Microsoft office Picture Manager (Microsoft Office 2007). The photograph on the PC monitor was visually compared with the real object. This comparison was carried out by 4 trained sensory assessors. The photographs were calibrated using the "PUBLISHING IMAGE – COLOUR: IMPROVING COLOUR" tool of the picture manager. For viewing, the position of the monitor was such that eye level was at a right angle and at the same height as the center of the monitor. Once this procedure had been performed, the computer CPU and monitor were the same throughout the experiment.

4.1.2. Real broccoli

A panel of 8 assessors was screened following the guidelines of the ISO 8586–1 Standard (1993) and trained in QSM.

As shown in Experiment 1 appearance was the critical shelf life and quality descriptor, thus the QSM was focused on this attribute.

As a first step the panel leader prepared a score sheet considering the sensory properties of the broccoli samples and following the format published for other food products (Hernández-Herrero, Roig-Sagues, Lopez-Sabater, Rodríguez-Jerez, and Mora-Ventura, 2002; Hyldig and Green-Petersen, 2004). This original score sheet was presented together with broccoli samples stored at room temperature (18–22 °C) for 24, 96, and 192 h after harvesting. These times were chosen to have fresh, intermediate and deteriorated samples. The panel discussed the score sheet reaching consensus after three sessions. The final score sheet is in Table 1. Once this score sheet was obtained, there were an additional three training sessions. During these the panel agreed on the scores of samples stored at 8 °C with different degrees of deterioration. Overall the methodology to obtain the QSM score sheet is similar to that used to obtain attributes and descriptors in other descriptive methods such as QDA.

Samples in the Styrofoam trays were evaluated over a white surface illuminated by two daylight-type fluorescent lights, the same conditions as those used for the photographs. For measurement, samples were coded with 3-digit numbers and presented to assessors in a randomized order. Measurements were by duplicate.

4.1.3. Digital photographs

The panel was the same as the one that worked with the real broccoli. Three weeks after having measured the real broccoli using the QSM methodology, the panel evaluated the appearance quality of the digital photographs on the PC monitor, using the same QSM score sheet (see Table 1). It was considered that 3 weeks was sufficient for assessors to forget their previous scores on the real product. The QSM method was well-known by assessors, thus only 2 re-training sessions were conducted.

Digital photographs were coded with 3-digit numbers and presented to assessors in a randomized order for their measurement. These were by duplicate.

4.1.4. Statistical analysis

Analysis of variance was applied to the data considering assessor as a random effect and storage time∗methodology (digital photograph and real broccoli) as fixed effects. This ANOVA was

Table 1
Score sheet for broccoli' sensory evaluation applying QSM.

Attribute	QSM					
	6	5	4	3	2	1
Appearance	Predominantly darkgreen Small lighter green spots	Predominantly dark green and lighter green Small yellow/brown spots	Predominantly dark green and lighter green Yellow/brown spots	Dark green and lighter green color background Yellow/brown color patches	Predominantly yellow and brown color Dark green and lighter green spots and patches	Completely brown

Table 2
Means quality scores for both the real broccoli and digital photograph methodologies (p and Fisher-LSD values at 5% level).

Storage time (days)	Methodology	
	Real broccoli	Digital photograph
1	6.0	6.0
5	4.6	4.8
7	3.2	3.5
12	2.4	2.3
27	1.4	1.5

[a]There were no significant differences between methods.
[b]Methodology, storage time and their interaction Fisher-LSD-values were, respectively: 0.141, 0.223, and 0.315.
[c]Methodology, storage time and their interaction p values were, respectively: 0.201,<0.001, and 0.392.

performed using Genstat 13th edition (VSN International, Hemel Hemstead, UK).

4.2. Results and discussion

Analysis of variance showed that there were no significant differences between evaluations of the real broccoli and the corresponding photograph, and the method × storage time interaction was not significant either. As expected, there were significant differences between storage times, where the decrease with storage time was consistent. Also all assessors evaluated in a similar way the real broccoli and the corresponding photograph. Table 2 shows the average QSM scores given by the panel for the real broccoli and the digital photographs.

In the present Experiment it was found that when using this method the evaluation of the digital photographs was equivalent to the evaluation of the real product. As mentioned in the introduction evaluation of photographs has the practical application of not having to rely on fresh produce for quality control standards. These photographs can also serve the purpose of standardizing quality in different geographical locations, where all interested parties would be using the same digital standard. Using photographs, producers and retailers could agree on a standard commercial quality to guarantee consumer satisfaction. Similarly, in the import–export trade, digital photographs could help both parties in establishing a standard quality. Also in research projects on post-harvest broccoli treatments, the logistics of the sensory evaluation of broccoli appearance is simplified by the use of digital photographs. This is valid both for trained panel and for consumer acceptability studies.

5. Conclusions

The two experiments presented in this work have shown that (a) appearance was the critical attribute of broccoli shelf life deterioration and (b) the evaluation of digital photographs was equivalent to the evaluation of the real product.

These conclusions are of immediate value for sensory evaluation of broccoli during storage. Appearance is a critical attribute in the deterioration of other vegetables and fruits such as lettuce, spinach, bananas and peaches. In some of these, for example lettuce, there is a combination of appearance defects like wilting, yellow spots and loss of intensity in green color. The QSM method would very likely be an appropriate method to quantify these changes. In broccoli we have shown that the digital photograph can be used to evaluate appearance. In leaf vegetables, where wilting is a critical defect, the equivalence between photographs and the real product should be studied.

Further research to this work would be to investigate the possibility of automating the digital photograph evaluation by counting pixels of particular colors.

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