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.

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 cm³ 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