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Evaluating the effect of storage conditions on the shelf life of cape gooseberry (*Physalis peruviana* L.)

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ABSTRACT

Cape gooseberry is the fruit of the plant *Physalis peruviana* L. and has gained commercial and scientific interest for its contents of health-promoting compounds. An integral approach to estimate shelf life of cape gooseberry was conducted taking into account physicochemical, microbiological and nutritional changes and consumer acceptance. The experiments were performed for 5 independent harvest times during two years (2014–2015). The conditions of storage were temperatures of 4, 8 and 12 °C and a relative humidity of 80%. Fruit with (Y) and without calyx (N) were packed into polyethylene terephthalate (PET) trays and polypropylene (PP) baskets, respectively. The experiment was conducted for a total of 76 d or shorter when the fruit was spoilt earlier. Fruit with the calyx showed a longer shelf life, while 8 °C was the temperature that gave longer shelf lives irrespective of the calyx presence. The critical quality attribute of shelf life without calyx was fungal growth, which determined consumer acceptance; weight loss was the most critical quality attribute for the fruit with calyx. Studying various quality attributes in an integral way appeared to give a better understanding of the shelf life.

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1. Introduction

Shelf life is defined as the time during which a food product remains safe, retains desired sensory, chemical, physical and microbiological characteristics and complies with any label declaration of nutritional data when stored under recommended conditions (IFST, 1993). This time also implies that the food remains of an acceptable quality to the consumer. Thus, all the above parameters should be taken into account when assessing the shelf life of a food product (Hough & Garitta, 2012). Shelf life estimation of a fresh food can be evaluated from a product and/or a consumer perspective; a product view is related to changes occurring in the fruit, such as microbiological, physical, chemical, biochemical changes, and the consumer point of view is based on sensory evaluation (Van Boekel, 2009). Food safety aspects have the priority when setting shelf life times. Nevertheless, according to the nature of the food product, sometimes food safety hazards do not occur before other changes in the food, altering the quality and causing rejection by the consumer. Between the available techniques for consumer acceptance, survival analysis has emerged as a relatively simple methodology to determine shelf life of foods (Hough & Garitta, 2012; Hough, Luz Calle, Serrat, & Curia, 2007). Survival analysis has been used before in fresh foods like lettuce and broccoli, conducting the current data methodology, where a consumer evaluates a single sample (Araneda, Hough, & De Penna, 2008; Garitta, Hough, & Chaves, 2013; Libertino, Osornio, & Hough, 2011). The combination of both perspectives (product and consumer) avoids the bias caused by the 'arbitrary' choices when deciding about shelf life based only on the product point of view; ultimately, it is the consumer who decides what is tolerated for consumption or not (Guerra, Lagazio, Manzocco, Barnabà, & Cappuccio, 2008; Hough & Garitta, 2012). An integral approach to study shelf life of foods based on combination of perspectives complies better with the quality definition of satisfying consumer needs (Luning & Marcelis, 2009).

Cape gooseberry is the fruit of the plant *Physalis peruviana* L. that belongs to the *Solanaceae* plant family and the genus *Physalis*. This fruit has a diameter of approximately 1.25–2.50 cm, 4–10 g of weight, orange yellow skin and a juicy pulp containing numerous

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small seeds. The berry is contained in a bladder-like calyx (Fischer, 1995). Cape gooseberry contains health-promoting compounds, especially ascorbic acid and β-carotene (Olivares-Tenorio, Dekker, Verkerk, & van Boekel, 2016). Few studies on postharvest behaviour of cape gooseberry have been reported (Alvarado, Berdugo, & Fischer, 2004; Lanchero, Velandia, Fischer, & Varela, 2007), nevertheless, shelf life estimations have not been conducted so far.

The present study aims to evaluate the effect of storage conditions such as temperature (4, 8 and 12 °C) and presence (Y) or absence (N) of calyx on the shelf life of cape gooseberry under 80% RH. This study brings an integrated approach that involves not only physicochemical and microbiological changes of the fruit as has been worked traditionally, but also incorporates the evaluation of health-promoting compounds (ascorbic acid and β-carotene) and consumer acceptance assessed by a survival analysis. This approach is an attempt to give a more holistic view of the quality attributes changes that affect the shelf life of foods and allows making more accurate estimations based on product and consumer perspectives.

2. Materials and methods

2.1. Fruit material

Cape gooseberry (*Physalis peruviana* L. Ecotype Colombia) fruit grown in Pasca, Cundinamarca, Colombia (2180 m.a.s.l.) were harvested from February to March 2014 and from March to April 2015 according to Table 1. After harvesting, fruit were selected, choosing category I and extra with ripeness state No. 4 (for all experiments) according to the Colombian standard for cape gooseberry NTC 4580 (ICONTEC, 1999), see appendix 1. Fruit subjected to be studied with calyx were immediately placed into a dry chamber to reduce the humidity of the calix (36 h at 18 °C) and stored according to the experimental conditions described below. Fruit subjected to be studied without calyx were pealed after selection and packed in trays with approximately 300 g of berries each and immediately stored according to the experimental conditions described below.

2.2. Experimental design and storage conditions

A full 2 × 3 factorial design was used. Factors: calyx (presence: Y and absence: N) and temperatures (4, 8, and 12 °C). Relative humidity (RH) was set at 80%. Two different package conditions were used, one for each presentation of fruit as explained in appendix 2. The set of experiments is depicted in Table 1. Samples were taken for physicochemical, phytochemical and fungal growth analyses every 12 d until the fruit was visually spoilt. Samples subjected to HPLC analyses were treated according to the procedure in appendix 2. All five experiments were independent. For consumer evaluation, samples were taken weekly until reaching approximately 95% of consumer rejection. One survival study was done for each year.

2.3. Physicochemical analyses

Blended and filtered fruit was used to measure titratable acidity against 0.1 mol L^{-1} NaOH. The same juice was used to measure pH (HANNA instruments, inc, USA) and total soluble solids TSS with a refractometer (Brixco, 0–32) at 20 °C. Different extraction methods were performed separately for organic acids content and sugars content, and both analyses were conducted by HPLC (Dionex Ultimate 3000 RS diode array detector). Maturity index corresponds to the ratio of TSS/titratable acidity, according to NTC 4580 (ICONTEC, 1999), see appendix 1. Weight loss was assessed with gravimetric analysis, taking as reference day 0 weight. Colour and firmness of the berries were analysed directly with a colorimeter (Konica Minolta Chroma Meter Chroma Meters CR-400) and texture analyser (Brookfield Engineering Laboratories, Inc, USA). Detailed methods are given in appendix 2. All measurements were performed in duplicate or triplicate of samples.

2.4. Fungal growth

Two methods were used to assess fungal growth. Mould count and level of mycelium growth according to methods described in appendix 2.

2.5. Ascorbic acid and β-carotene

Ascorbic acid content was determined according to the procedure described by Hernández, Lobo, and González (2006) with modifications, see appendix 2 (Hernández et al., 2006). The β-carotene content in cape gooseberry fruit was determined following the procedure described by Bushway (1986) with modifications, see appendix 2 (Bushway, 1986). Measurements were performed in duplicate of fruit and extracts and results were expressed in g kg^{-1} of ascorbic acid or β-carotene on fresh weight basis.

2.6. Consumer evaluation: survival analysis

A preliminary study was conducted to set the conditions of the survival analysis, see appendix 3. The consumer study based on survival analysis was conducted for samples of cape gooseberry without calyx placed in PET trays. The consumers recruited were located in different places of the northern part of Bogotá, Colombia. For 2014, fruit stored at 8 and 12 °C were evaluated by 798 consumers (from 20 to 60 years old with gender equality 50%/50%) over 8 weeks (56 d). The whole consumer study was repeated in 2015. In this year the PET trays were stored at 4, 8 and 12 °C and samples from two independent fruit batches were evaluated at 4 °C (See Table 1). The same locations as in the 2014 study were selected and 914 consumers participated in the study (from 20 to 60 years old with 52%/48% male/female) over 9 weeks (63 d). Every week, the same trays (one for each temperature/experiment) were evaluated visually by different consumers in the two studies. Consumers were asked the question 'are you willing to consume this fruit?' for every sample. Each consumer had to evaluate two (in 2014) and four samples (in 2015) and simply respond 'yes' or 'no' for every sample, according to their willingness to consume, based only on the general appearance (Libertino et al., 2011). The number of weekly respondents was changed deliberately in order to increase the

Table 1
Set of experiments conducted for shelf life evaluation of cape gooseberry.

Year	Harvest time	Storage temperature (°C)	Physicochemical	Phytochemical	Microbiological	Consumer Study
2014	March	8,12	x	x	x	One survival analysis study for 2014 (8 and 12 °C)
2014	April	8,12	x	x	–	
2014	May	8,12	x	x	–	
2015	March	4,8,12	x	x	x	One survival analysis for 2015 (4, 8 and 12 °C)
2015	April	4	x	x	x	

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