Received: 6 February 2017 | Revised: 5 June 2017 | Accepted: 6 June 2017

DOI: 10.1111/joss.12278

ORIGINAL ARTICLE

WILEY Journal of Sensory Studies

Consumer's expectation of changes in fruit based on their sensory properties at purchase. The case of banana (*Musa Cavendish)* appearance evaluated on two occasions: Purchase and home consumption

Eliana S. Elizagoyen[1,2] | Guillermo Hough[1,2] | Lorena Garitta[1,3] | Susana Fiszman[4] | Juan Eduardo Bravo Vasquez[5]

[1]Departamento de Evaluación Sensorial de Alimentos, Instituto Superior Experimental de Tecnología Alimentaria, H. Irigoyen 931, Nueve de Julio, Buenos Aires, Argentina

[2]Comisión de Investigaciones Científicas de la Provincia de Buenos aires, Nueve de Julio, Argentina

[3]Consejo Nacional de Investigaciones Científicas y Técnicas, Nueve de Julio, Argentina

[4]Instituto de Agroquímica y Tecnología de Alimentos (CSIC), Catedrático Agustín Escardino 7, Paterna, Valencia, 46980, Spain

[5]Universidad Tecnológica Equinoccial, Bourgeois N34-102, Quito, Ecuador

Correspondence
Eliana Soledad Elizagoyen, Departamento de Evaluación Sensorial de Alimentos. Instituto Superior Experimental de Tecnología Alimentaria, H. Irigoyen 931, Nueve de Julio, Buenos Aires, Argentina.
Email: eliana@desa.edu.ar

Abstract

The objective of this work was to estimate the expectation of change in sensory properties of fruits by analyzing the different choice criteria at purchase and consumption occasions. Bananas were taken as a case study, evaluated with consumers from Argentina, Ecuador, and Spain. A set of 10 digital images of bananas ranging from totally green to overly ripe were first submitted to a trained panel to ensure there were significant differences between them on a ripening scale. These images were then presented to 300 consumers in total from Argentina, Ecuador, and Spain. Consumers assessed each image choosing between under-ripe, ok, or over-ripe; considering two different occasions: when purchasing the bananas and when consuming the bananas in their homes. Based on hue-angle measurements, survival analysis statistics were applied to estimate the optimum ripening indexes (ORI). ORI for purchase occasions were lower than for home consumption occasions, that is, bananas are bought greener, with the expectation that they would ripen to the adequate stage in the period between purchase and consumption. There were also differences between the ORI estimated over the three countries. On average, Argentine consumers preferred riper bananas than Ecuador or Spanish consumers.

Practical applications

For certain fruits, such as bananas shown in this study, consumers consciously choose or ask for a not totally ripe product with the expectation that it will reach optimum ripeness on the consumption occasion. Retail stores should consider this fact in marketing their products providing recommendations for consumers, such as "keep at room temperature and consume after 2 or 3 days"; or "we recommend you consume this melon today." For the particular case of bananas, the current commercial chart used to estimate banana maturity based on sensory appearance would not always be adequate. This work provides a range of maturation based on consumer input, both for purchase and home-consumption situations. These ranges could serve as a guide for retail stores that sell bananas in different countries.

1 | INTRODUCTION

Consumer preferences within a single fruit-type and/or cultivar are often defined by the stage of ripeness (Harper, Gunson, & Jaeger, 2003). The stages of ripeness are basically three: under-ripe, ok, and over-ripe. Jaeger, Lund, Lau, and Harper (2003) in a preference study of pears found consumer segments with different acceptability scores for ripe and not-ripe samples. Crisosto and Crisosto (2001) found that kiwifruit with a given degree of ripeness was liked by some consumers and disliked by others. Crisosto, Crisosto, and Metheney (2003) reported that 78% of consumers over 60 years old were willing to buy full dark red "Brooks" cherries, while only 42% of consumers under 18

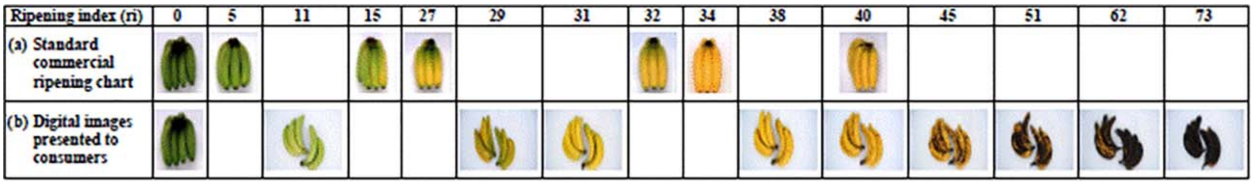

FIGURE 1 Ripening index = hue of the greenest bananas − hue of the corresponding sample, corresponding to: (a) commercial banana color chart, (b) digital images used in this study

were willing to buy cherries with the same degree of ripeness. Thus, there is evidence over different types of fruit that if a single degree of ripeness is chosen there will be consumers who will accept it, others who can find it under-ripe and still others who may find it over-ripe (Garitta, Hough, & Hulshof, 2008). In all these studies, consumers' evaluated the fruits regarding consumption, and not at point of purchase.

Traditionally, consumers have been asked whether they would consume the product or not (Garitta, Serrat, Hough, & Curia, 2006; Hough, Garitta, & Gomez, 2006; Hough, Langohr, Gómez, & Curia, 2003). During their decision-making process, consumers rely on different attributes before deciding whether to buy or consume a certain food product (Ragaert, Verbeke, Devlieghere, & Debevere, 2004). Evaluative criteria may change depending if it is at purchase or consumption stage (Gardial, Clemons, Woodruff, Schumann, & Burns, 1994). This suggests that consumers might give different importance to a certain attribute when deciding to purchase or to consume a product. For this reason, estimated shelf life or sensory limits may vary if consumers are asked whether they would buy a product; or if asked whether they would consume it at their homes. This might be particularly important for food products in which consumers can evaluate ripeness when observing, touching, smelling, or even hearing the product at purchase (Sun, Huang, Xu, & Ying, 2010). In our local fruit shop in Argentina, when buying a melon the saleslady will ask when it is intended to be eaten. If *today* then a really ripe melon will be chosen; but if the *in 3–4 days*, she will choose a less ripe melon with the expectation that it will be just right in 3–4 days. The criterion for evaluating melon's ripeness goes from softly touching the skin surface to evaluating the aroma. Pears are sometimes green and hard and sold at a reduced price, with the claim by the saleslady that if left a few days out of the refrigerator they will ripen and be delicious. Watermelon ripeness is often evaluated by vendors and consumers by listening when the fruit is tapped with their knuckles. Bananas, our case study, and detailed below, are evaluated at purchase and consumption by their appearance. Although this difference in criteria between purchase and consumption regarding what consumers consider important in one situation and the other are part of consumers' every day experience, there have been no studies that have proposed a methodology to research and quantify the difference in criteria.

Bananas are one of the most popular fruits worldwide. They are usually harvested green and they remain without significant changes in peel color, texture, or composition until ripening is initiated with ethylene treatment (Dadzie & Orchard, 1997). Once this occurs the process is irreversible and involves nonhomogeneous peel color changes and the appearance of brown spots over the yellow background. Peel color is considered the primary quality parameter evaluated by consumers and it is associated with specific tastes or uses that can thus determine acceptance or rejection. Peel color correlates well with physical–chemical parameters that take place during the ripening of bananas, including pulp color, pH, conversion of starch into sugars, and development of flavor (Ramáswamy & Tung, 1989).

Banana ripening is evaluated commercially by instrumental techniques (Wainwright & Hughes, 1990), and also by visual comparison of the banana's color with the standardized color chart shown in Figure 1a (Li, Slaughter, & Thompson, 1997; Von Loesecke, 1950).

Bagnato, Klieber, Barrett, and Sedgley (2002) considered that the visual inspection generated reliable and reproducible results. They defined banana's shelf life as the number of days it took for bananas to ripen from stage 4 (more yellow than green) to stage 7 (full yellow with light brown flecks). They considered that consumers would reject bananas below stage 4 as green and those above stage 7 as overripe. There is no reference to an experimental study with consumers that confirmed these limits. Also, it is not clear if these limits refer to purchase or consumption occasions.

Consumer studies are an appropriate tool for determining a food product's sensory shelf life (Hough et al., 2003). Survival analysis has been used to determine how long a certain product could be stored before a consumer rejects the product. This methodology focuses on the risk of the consumer's rejection of the product, estimating the shelf life as the time necessary to reach a fixed percentage of consumer rejection (Hough et al., 2003). Survival analysis methodology applied to the banana ripening chart (Figure 1a) would show that there will be consumers who find stage 3 as appropriate and stage 6 as over-ripe. It would be of interest to analyze the dispersion in consumer acceptability of bananas corresponding to the suggested limits of 4 and 7 on the standard ripening chart (Figure 1a). And, as discussed above, their criteria might change depending if they are buying bananas or whether they are about to consume one. Thus, bananas, or other fruits, do not have inherent ripeness limits, rather these will depend on the interaction of the fruit with the consumer, and this interaction will be influenced by whether they are at a purchase or consumption occasion.

There are many other factors which could be taken into account when estimating the food product's sensory shelf life and could change the criterion of consumer's evaluation; an example of these is the consumer's home country. Consumers in different countries might relate differently with products based on whether they are produced locally and/or if it is highly consumed. López Osornio et al. (2008) investigated the optimum cooking temperatures of beef based on acceptance or rejection data obtained from consumers from different countries and age groups and stated preference for degree of doneness. Country of residence and age group had little influence on optimum cooking temperatures. Conversely, Giménez et al. (2007) studied shelf life of different brown bread formulations finding differences between Uruguay and Spain inhabitants. For such a worldwide popular fruit such as bananas, there have been no studies which have analyzed differences in appearance acceptability criteria of consumers from different countries; or whether differences regarding purchase or consumption occasions are similar across countries.

Goncalves et al. (2007) showed that chromatic functions of chroma and hue correlated closely with the evolution of color and anthocyanins levels during storage of sweet cherries. Hung, Morita, Shewfelt, Resurreccion, and Prussia (1995) determined if sensory assessors perceived changes of golden apple color in green and yellow hues separately or on a hue continuum from green to yellow. They showed that assessors could detect decreasing greenness, increasing yellowness, and color changes from green to yellow in an equal fashion. Of all the instrumental color measurements (L^*, a^*, b^*, hue), hue provided the best correlations with the sensory measurements. Hue (h_{ab}*) is the attribute according to which colors have been traditionally defined as reddish, greenish, yellowish, etc. (Arocas et al., 2013). Thus hue would seem the most adequate choice for expressing instrumental color changes of bananas during storage.

The objective of this work was to contrast the behavior of consumers when evaluating optimal ripening of fruits considering two different occasions: purchase and home consumption; considering bananas as a case study. We also considered consumers from three different countries where bananas are popular but with different production and import characteristics: (a) Argentina, which is a net importer (mainly from Ecuador); (b) Ecuador which is a net producer; and (c) Spain which both produces (Canary Island bananas) and imports. Bananas were chosen for this study due to:

- their worldwide popularity;
- their appearance, linked to ripeness, is easily evaluated by consumers; and
- as appearance is their critical ripeness index, it facilitated comparison between countries by using digital photographs.

2 | MATERIALS AND METHODS

2.1 | Samples

Bananas (*Musa Cavendish*) imported from Ecuador were bought at a local market in the city of 9 de Julio, Buenos Aires, Argentina. Two hands with nine units in total were selected to be as close as possible to stage 1 of the standard banana color chart (Figure 1a). They were bought in the month of April (Southern hemisphere) and the ethylene ripening treatment had begun.

The nine green bananas (second photograph of Figure 1b) were stored at room temperature (22 ± 2°C) to thus simulate market/home conditions.

Garitta, Hough, and Chaves (2013) showed that sensory evaluation of digital images of broccoli was equivalent to the sensory evaluation of the real product; adding to this is the fact that images are widely used to define maturity stage of bananas. Thus digital images of bananas in nine different maturity stages were used to evaluate maturity. The digital images and their calibration were done as described by Garitta et al. (2013). The completely green banana color was taken from the stage 1 of Figure 1a. Thus a total of 10 digital images were used: nine corresponding to different storage times and one (the greenest) taken from the commercial chart shown in Figure 1a. A three-digit code was added to each image. The 10 images were chosen so as to cover the span of the commercial chart plus images with more intense ripening to account for consumers who like really ripe bananas and also to ensure a sufficiently high proportion of consumers rejecting the ripest sample of all. This high proportion of consumers rejecting the sample with the longest storage time is recommended to avoid a high number right-censored data which increases estimation uncertainty (Hough, 2010). The images within the range of the commercial chart did not match these exactly as experimentally this exact matching is difficult.

2.2 | Instrumental color measurement

Adobe Photoshop (Adobe Systems Inc., San José, California) was used to measure CIELAB parameters of each image. All bananas in the bunch, that is, a total of nine as mentioned in the previous section, were measured, excluding the voids between bananas. Parameters a^* and b^* were calculated Spyridon, Siti, Kamdem, and Yam (2000). Hue angles were calculated as follows (Lemoine, Civello, Chaves, & Martínez, 2009):

$$h_{ab} = \arctan\ (a*/b*) \rightarrow \text{when } a*>0 \text{ and } b*>0$$

$$h_{ab} = 180^\circ + \arctan(a*/b*) \rightarrow \text{ when } a*<0 \text{ and } b*>0$$

In this study, the greenest banana had a h_{ab}= 116° and the totally over-ripe banana had a h_{ab}= 43°, that is, the hue value for the green banana was greater than the hue value for a ripe banana. To avoid this numerically inverse relationship with storage time, we considered that the following ripening index (ri) which increases with ripeness, was easier to follow and interpret:

$$ri_{sample} = hue_{greenest} - hue_{sample}$$

Where:

$hue_{greenest}$: hue of the greenest sample, and

hue_{sample}: hue of a given sample.

Images in Figure 1b had ri indices of: 0, 11, 29, 31, 38, 40, 45, 51, 62, 73 (from left to right).

2.3 | Trained panel evaluation

Before presenting samples to consumers for ripeness evaluation, one should be sure that samples could be perceived as different. Thus to confirm that the digital images corresponded to visible changes during banana ripening, a panel of 10 assessors screened and trained following the ISO 8586 (2012), measured the appearance of the images. Measurements were in individual booths with the middle of the monitor screens leveled for assessors' eyes. Illumination was with daylight type fluorescent light.

Two training sessions were held where assessors were familiarized with the images and discussed how they would place them on a ripeness scale: 0 = completely unripe to 10 = very ripe. Following this, assessors received the 10 images on their computer screen in randomized order and measured the degree of ripeness on the 0–10 scale. Measurements were done by duplicate.

2.4 | Consumer panels

As explained in the introduction section, consumers from three different countries were chosen: Argentina, Ecuador, and Spain. In Argentina, consumers were from the city of 9 de Julio, with 40,000 inhabitants, it is located 250 km to the West of Buenos Aires. The ethnic origin of the population (majority white Caucassian), the products in markets and exposure to nationwide media is similar to the rest of Argentina. In Spain, consumers were from Valencia, a major cosmopolitan city and in Ecuador they were from the capital city Quito. In all three cities consumers were recruited from consumer databases, and they were chosen among those who named bananas in first or second place among fruits consumed weekly. Ages were between 18 and 60 years, and there were approximately half female.

Hough, Calle, Serrat, and Curia (2007) presented graphs which allow estimation of the number of consumers necessary for shelf-life estimations based on survival analysis statistics. They presented the case of choosing an average σ (see Equation 1a below), an alpha value (Type I error) of 5%, a beta value (Type II error) of 20%, the shelf life to be in the middle of the studied time range, and a difference between the true shelf life and the estimated shelf life of 0.5 on a 0–6 time scale; with these parameters the estimated number of consumers would be 120. The limitations of our project led us to take 100 consumers per country, thus a total of 300. Considering 100 instead of 120 means a slight shift in the chosen parameters, for example, a difference of 0.55 instead of 0.5; or an average σ of 0.40 instead of 0.44.

Consumer testing was in sensory laboratories with individual booths provided with computer screens. These were calibrated for all consumers to receive similar images and positioned for the eye of the consumer to be directed to approximately the middle of the screen. The 10 images (Figure 1b) were presented individually with three-digit codes in a balanced order. For each image, the consumer first responded if he/she found the bananas under-ripe, ok, or over-ripe to buy, and then if they found the bananas under-ripe, ok, or over-ripe to consume in their homes.

2.5 | Statistical analysis

2.5.1 | Trained panels

Trained panel data were submitted to analysis of variance (ANOVA) considering assessor as a random effect and samples (digital images of Figure 1b) as fixed effects. This ANOVA was performed using Genstat 16th edition (VSN International, Hemel Hemstead, UK).

2.5.2 | Consumer panels

In fruit ripening, there are two events of interest: the fruit goes from under-ripe to being ok and from being ok to being over-ripe. The model used to estimate optimum ripening index (ORI) based on survival analysis statistics was presented by Hough (2010).

ORI is the random variable representing ORI which follows the cumulative distribution function F. For each ripening index (ri) there will be two rejection functions:

$R_{ur}(\mathrm{ri})$ = probability of a consumer (or proportion of consumers) rejecting a banana with a ripening index > ri because it is under-ripe, that is, $R_{ur}(\mathrm{ri}) = P(\mathrm{ORI} > \mathrm{ri}) = 1 - F(\mathrm{ri})$

$R_{or}(\mathrm{ri})$ = probability of a consumer (or proportion of consumers) rejecting a banana with a ripening index < ri because it is over-ripe, that is, $R_{or}(\mathrm{ri}) = P(\mathrm{ORI} < \mathrm{ri}) = F(\mathrm{ri})$

Usually, survival times, or as in this case, ri's are not normally distributed; instead their distribution is often right skewed. A log-linear model was used:

$$Y = \ln(\mathrm{ORI}) = \mu + \sigma W$$

where W is the error term distribution. That is, instead of the ORI, its logarithmic transformation is modeled. Hough (2010) discussed the use of different distributions, for example, the log-normal or the Weibull distributions. Choosing the log-normal distribution, the functions associated with the rejection are:

$$R_{ur}(\mathrm{ri}) = 1 - \Phi\left(\frac{\ln(\mathrm{ri} - \mu_{ur})}{\sigma_{ur}}\right) \tag{1a}$$

$$R_{or}(\mathrm{ri}) = \Phi\left(\frac{\ln(\mathrm{ri} - \mu_{or})}{\sigma_{or}}\right) \tag{1b}$$

Where, for both events, $\Phi(.)$ is the cumulative normal distribution function and μ_{ur}, μ_{or}, σ_{ur}, and σ_{or} are the model's parameters.

To analyze if purchase or home consumption occasions and country of origin influenced ORI, regression models with inclusion of covariates were applied (Klein & Moescheberger, 1997; Meeker & Escobar, 1998). The complete models for each event are as follows:

Model for rejection due to under-ripe:

$$Y = \ln(\mathrm{ri}_{ur}) = \mu_{ur} + \sigma_{ur} W = \beta_0 + \beta_1 Z_{ph} + \beta_2 Z_{ec} + \beta_3 Z_{sp} + \beta_4 (Z_{ph} Z_{ec}) + \beta_5 (Z_{ph} Z_{sp}) + \sigma_{ur} W \tag{2a}$$

Where:

ri_{ur} = ripening index at which a consumer rejects a sample because it is under-ripe;

β_{0-5} = regression coefficients;

Z_{ph} = 0 if purchase occasion, 1 if home consumption occasion;

Z_{ec} = 0 if the consumer is from Argentina or Spain, 1 if consumer is from Ecuador;

$Z_{sp} = 0$ if the consumer is from Argentina or Ecuador, 1 if consumer is from Spain;

σ_{ur} = the shape parameter, which does not depend on the covariates; and

W = error distribution.

Model for rejection due to over-ripe:

$$Y = \ln(ri_{or}) = \mu_{or} + \sigma_{or} W = \beta_0 + \beta_1 Z_{ph} + \beta_2 Z_{ec} + \beta_3 Z_{sp} + \beta_4 (Z_{ph} Z_{ec}) + \beta_5 (Z_{ph} Z_{sp}) + \sigma_{or} W \quad (2b)$$

Where:

ri_{or} = ripening index at which a consumer rejects a sample because it is over-ripe;

β_{0-5} = regression coefficients;

$Z_{ph} = 0$ if purchase occasion, 1 if home consumption occasion;

$Z_{ec} = 0$ if the consumer is from Argentina or Spain, 1 if consumer is from Ecuador;

$Z_{sp} = 0$ if the consumer is from Argentina or Ecuador, 1 if consumer is from Spain;

σ_{or} = the shape parameter, which does not depend on the covariates; and

W = error distribution.

Optimum ripening indices were obtained from the minimum of the curve that resulted in adding the curve of rejection due to under-ripe and the curve of rejection due to over-ripe (Hough, 2010). The formula for calculating ORI's confidence intervals has been published previously (Garitta et al., 2006).

To define the distribution models that best adjusted the experimental data (normal, log-normal or Weibull distributions) the log-likelihood criterion was used (Hough, 2010).

Survival analysis calculations were performed with the TIBCO Spotfire S+ software (TIBCO, Inc., Seattle, WA).

3 | RESULTS

3.1 | Trained panel

The trained sensory panel measured ripeness on a scale that went from 0 = completely unripe to 10 = very ripe. ANOVA showed significant differences between samples, and Fisher's least significant difference (LSD) indicated that all samples (images) differed from each other. Mean values and the LSD are in Table 1. These results confirmed that the 10 images to be presented to consumers (Figure 1b) were all different from each other on an increasing ripeness scale.

TABLE 1 Mean sensory ripeness values measured on 0 (completely unripe) to 10 (very ripe) scale, and Fisher's 5% least significant value (LSD); corresponding to images shown in Figure 1b

Image	Sensory ripeness
1	0.0
2	1.8
3	2.7
4	3.6
5	5.1
6	6.1
7	7.0
8	8.1
9	9.0
10	10.0
LSD	0.23

3.2 | Optimum ripening index

The consumer data from the three countries for the event "under-ripe to ok" was best adjusted by the normal distribution for both the purchase and home consumption occasions. For the "ok to over-ripe" event the best-fitting distribution was the log-normal both for the purchase and home consumption occasions.

When the covariate models, which included occasion (purchase and home consumption) and consumer's country of origin (Argentina, Ecuador, and Spain), were tested following Equations 2a and 2b, main effects and two-way interactions were significant. That is, both occasion and country of origin were significant. Thus, the full model was adopted.

Under-ripe model (Equation 2a):

$$\mu_{ur} = 2.41 + 5.15 Z_{ph} + (-0.32) Z_{ec} + (-4.49) Z_{sp} + 0.86 (Z_{ph} Z_{ec}) + 4.74 (Z_{ph} Z_{sp})$$

$$\sigma = 8.84$$

Over-ripe model (Equation 2b):

$$\mu_{or} = 3.83 + 0.15 Z_{ph} + (-0.07) Z_{ec} + (-0.13) Z_{sp} + (-0.03)(Z_{ph} Z_{ec}) + 0.02 (Z_{ph} Z_{sp})$$

$$\sigma = 0.13$$

As the occasion X country of origin effects were significant, both for the under-ripe (Equation 2a) and over-ripe (Equation 2b) events, this meant that there were a total of two occasions X 3 countries X 2 events = 12 rejection curves. These are presented in Figure 2. For each occasion and each country, percent rejection from both events was added and the minimum of this resulting curve was the estimated ORI corresponding to the chosen occasion and country. The curves resulting from the sum of under-ripe and over-ripe curves are also presented in Figure 2. The estimated ORI's and their confidence intervals are showed in Table 2.

4 | DISCUSSION

The trained sensory panel were able discriminate among samples using a single ripening scale. To use this scale trained assessors had to

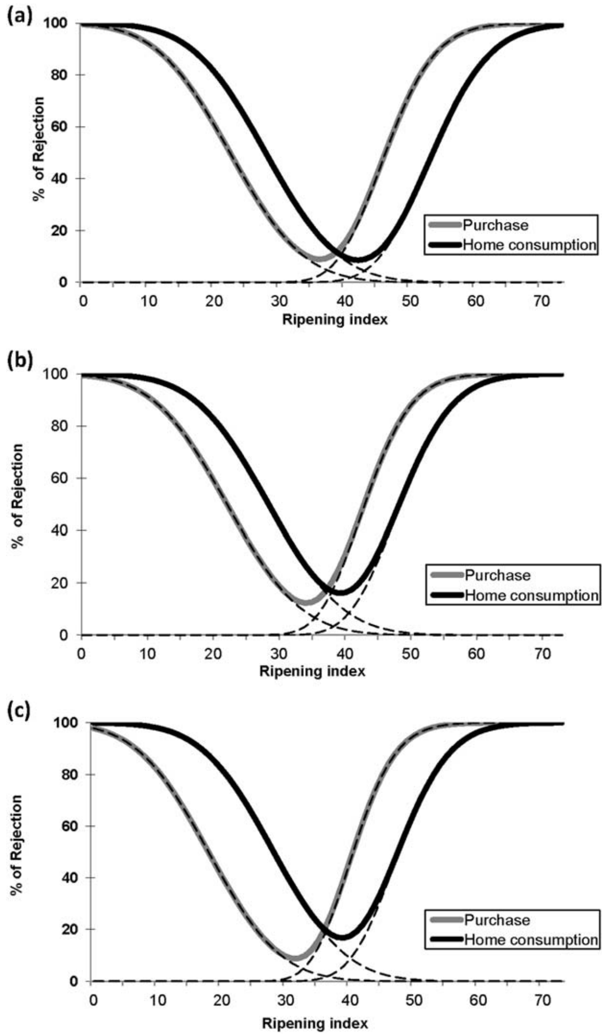

FIGURE 2 Percent rejection versus ripening index for purchase and home consumption occasions for consumers from each of the three countries: (a) Argentina, (b) Ecuador and (c) Spain. Dashed lines represent individual rejection curves for under and over ripe.

combine a number of visual cues into a single score. The cues (Figure 1) comprised skin color from green to yellow, spots changing in color and size, and visual firmness of the banana skin. This type of sensory scale, where assessors have to combine a number of descriptors into a single score has been used successfully for other heterogeneous food products such as broccoli (Garitta et al., 2013) and fish (Hyldig & Green-Petersen, 2004).

As stated in the Introduction, a number of publications (Arocas et al., 2013; Goncalves et al., 2007; Hung et al., 1995) have shown that hue is an adequate index to follow appearance changes during fruit ripening. Thus hue was chosen as the most adequate parameter for expressing instrumental color changes of bananas during storage. The difficulty of interpretation, in the sense that the greenest banana had the highest hue and the ripest banana the lowest, was overcome by introducing a ripening index obtained by subtracting a sample's hue from the hue of the greenest banana.

The estimated ORI depended on the occasion consumers chose bananas. When buying bananas ORI was lower than when consuming bananas. This was to be expected as bananas are not usually bought daily, rather a bunch of bananas is bought to be consumed in the following days. If bananas at point of purchase were bought with ripening indices corresponding to home consumption, these would be ok for the purchase date, but would soon be over-ripe. To avoid having to dispose of over-ripe bananas, consumers consciously choose them slightly green. Does this mean that if a consumer wants to eat a banana on purchase date he/she will eat it greener than they really like it? Not necessarily as an organized consumer will have a few bananas from the previous purchase to consume till the new batch are ok. Banana ripeness is easily evaluated by consumers by appearance. But this decision of consciously buying an unripe fruit can occur with the help of fruit-shop attendants for other fruits such as melons. In local shops the client is asked when he/she is going to eat the melon; based on the answer, a really ripe melon is chosen or one needing a few days storage.

Ares, Giménez, and Gámbaro (2008) also considered purchase and consumption occasions in shelf-life estimation of lettuce. They found that shelf life considering purchase occasion was lower than shelf life in home consumption occasion. However, for lettuce the consumer reasoning was different to bananas. When buying lettuce, consumers look out for the optimal product, with no wilting or signs of decay. However, if they bought lettuce a few days ago, and he/she finds the plant slightly past the shelf life, he/she will probably consume it anyway discarding outer leaves or spoilt spots. In the case of bananas consumers consciously choose a green banana with the expectation that it will change to optimum ripeness in the next few days.

TABLE 2 Optimum ripening indices (ORI) ± 95% confidence intervals for consumers from Argentina, Ecuador, and Spain, both for purchase and home consumption occasions

Country	Occasion	ORI ± 95% confidence intervals	Total % rejection at ORI	% Rejection due to under-ripe at ORI	% Rejection due to over-ripe at ORI
Argentina	Purchase	36 ± 1.2	8.8	6.2	2.6
	Home	42 ± 1.3	8.5	5.5	3.0
Ecuador	Purchase	34 ± 1.2	12.2	8.9	3.3
	Home	39 ± 1.2	16.1	11.5	4.5
Spain	Purchase	31 ± 1.2	8.8	6.9	1.9
	Home	39 ± 1.2	16.7	10.4	5.8

There were also differences in ORI between countries both for purchase and home consumption occasions. For the purchase occasion, Argentine consumers had an estimated ORI of 36. Figure 1a shows that this corresponds to a totally yellow banana with a ripening index close to position 6 of the commercial color index chart. ORI for Ecuador consumers was 34, slightly lower than for Argentina and coinciding with position 6 of the commercial color index chart. For both these countries ORI's for purchase occasion were close to the higher limits of the commercial chart. For Spanish consumers, the ORI was 31, which corresponds to an intermediate between positions 4 and 5 of the commercial chart.

For home consumption occasion consumers from Ecuador and Spain had the same ORI= 39, close to the position 7 of the commercial chart. Argentina had a higher ORI= 42, which was beyond the higher limit of the commercial chart (Table 2 and Figure 1b). Depending on the consumer segment the commercial chart would not always be adequate when estimating appropriate ripeness for home consumption occasion.

Both for purchase and home consumption occasions ORI varied across countries, thus a universal color chart would not be valid.

Figure 2 shows that for the purchase occasion a range of ripening index of 30–36 would produce an estimated rejection $\leq$20% for all three countries. This range could serve as a guide to retail stores selling bananas in different countries and/or to consumers from different backgrounds. If the range in a particular country is not known, this ripening index range for purchase occasion of 30–36 estimated over three countries with different characteristics could be used as an initial estimation till proper data for the particular country is produced.

Figure 2 also shows that within a ripening index range of 36–42 home consumption rejection was $\leq$20% for all three countries. This range could be of value for shops catering for consumers who pick up a banana as a snack to eat on their way.

Bagnato et al. (2002) defined banana's shelf life as the number of days it took for bananas to ripen from stage 4 (ri= 27) to stage 7 (ri= 40) of the commercial chart shown in Figure 1a. Comparing stage 4 with ORI values shown in Table 2, it is suggested that the criteria of considering this image as the initial stage of a banana's shelf life should be revised as its ri = 27 is significantly lower than purchase occasion ORI's for all three countries. This study shows that stage 7 of the commercial chart is an adequate image corresponding to home consumption occasion, with a ri = 40 it is close to ORI's of the three countries.

5 | CONCLUSIONS

The main conclusions from this work were:

1. An appearance ripening index based on hue angle was defined which helps interpretation of appearance changes as this index increases with increasing banana ripeness.
2. ORI for purchase occasions were lower than for home consumption occasions, that is, bananas are bought greener, with the expectation that they would ripen to the adequate stage in the period between purchase and consumption.
3. There were differences between the ORI estimated over the three countries. On average Argentine consumers preferred riper bananas than Ecuador or Spanish consumers. Ranges of ripening index values were suggested for both purchase and home consumption occasions.
4. It is suggested that the criteria of considering stage 4 of the commercial chart as the initial stage of a banana's shelf life should be revised as its ri = 27 is significantly lower than purchase occasion ORI's for all three countries.

REFERENCES

Ares, G., Giménez, A., & Gámbaro, A. (2008). Sensory shelf life estimation of minimally processed lettuce considering two stages of consumers' decision-making process. *Appetite*, *50*, 529–535.

Arocas, A., Varela, P., González-Miret, M. L., Salvador, A., Heredia, F. J., & Fiszman, S. M. (2013). Differences in colour gamut obtained with three synthetic red food colourants compared with three natural ones: pH and heat stability. *International Journal of Food Properties*, *16*, 766–777.

Bagnato, N., Klieber, A., Barrett, R., & Sedgley, M. (2002). Optimizing ripening temperatures of *Cavendish* bananas var. "Williams" harvested throughout the year in Queensland, Australia. *Australian Journal of Experimental Agriculture*, *42*, 1017–1022.

Crisosto, C. H., & Crisosto, G. M. (2001). Understanding consumer acceptance of early harvested "Hayward" kiwifruit. *Postharvest Biology and Technology*, *22*, 205–213.

Crisosto, C. H., Crisosto, G. M., & Metheney, P. (2003). Consumer acceptance of "Brooks" and "Bing" cherries is mainly dependent on fruit SSC and visual skin color. *Postharvest Biology and Technology*, *28*, 150–167.

Dadzie, B. K., & Orchard, J. E. (1997). Routine post-harvest screening of banana/plantain hybrids: Criteria and methods. In *INIBAP technical guidelines 2* (pp. 5–30). Rome: IPGRI.

Gardial, S. F., Clemons, D. S., Woodruff, R. B., Schumann, D. W., & Burns, M. J. (1994). Comparing consumer's recall of prepurchase and postpurchase product evaluation experiences. *Journal of Consumer Research*, *20*, 548–560.

Garitta, L., Hough, G., & Chaves, A. (2013). Sensory analysis of broccoli over time: Consumer defined critical attributes and evaluation of digital photographs in comparison to real product appearance. *Food Quality and Preference*, *29*, 48–52.

Garitta, L., Hough, G., & Hulshof, E. (2008). Determining optimum ripening time of fruit by applying survival analysis statistics to consumer data. *Food Quality and Preference*, *19*, 747–752.

Garitta, L., Serrat, C., Hough, G., & Curia, A. (2006). Determination of optimum concentrations of a food ingredient using survival analysis statistics. *Journal of Food Science*, *71*, 526–532.

Giménez, A., Varela, P., Salvador, A., Ares, G., Fiszman, S., & Garitta, L. (2007). Shelf life estimation of brown pan bread: A consumer approach. *Food Quality and Preference*, *18*, 196–204

Goncalves, B., Silva, A. P., Moutinho-Pereira, J., Bacelar, E., Rosa, E., & Meyer, A. S. (2007). Effect of ripeness and postharvest storage on the evolution of colour and anthocyanins in cherries *Prunus avium* L. *Food Chemistry*, *103*, 976–984.

Harper, R., Gunson, A., & Jaeger, S. (2003). The case of fruit quality: An interpretive review of consumer attitudes, and preferences for apples. *Postharvest Biology and Technology*, *28*, 333–347.

Hough, G. (2010). *Sensory shelf life estimation of food products*. Boca Raton, FL: Taylor and Francis Group.

Hough, G., Calle, M. L., Serrat, C., & Curia, A. (2007). Number of consumers necessary for shelf life estimations based on survival analysis statistics. *Food Quality and Preference*, *18*, 771–775.

Hough, G., Garitta, L., & Gomez, G. (2006). Sensory shelf-life predictions by survival analysis accelerated storage models. *Food Quality and Preference*, *17*, 468–473.

Hough, G., Langohr, K., Gómez, G., & Curia, A. (2003). Survival analysis applied to sensory shelf life of foods. *Journal of Food Science*, *68*(1), 359–362.

Hung, Y. C., Morita, K., Shewfelt, R., Resurreccion, A. V. A., & Prussia, S. (1995). Sensory and instrumental evaluation of apple color. *Journal of Sensory Studies*, *10*, 15–23.

Hyldig, G., & Green-Petersen, D. M. B. (2004). Quality index method—An objective tool for determination of sensory quality. *Journal of Aquatic Food Product Technology*, *13*, 71–80.

ISO 8586. (2012). Sensory analysis - General guidelines for the selection, training and monitoring of selected assessors and expert sensory assessors. Geneva, Switzerland: International Organization or Standardization.

Jaeger, S. R., Lund, C. M., Lau, K., & Harper, F. R. (2003). In search of the “ideal” pear Pyrus spp.: Results of a multidisciplinary exploration. *Journal of Food Science*, *68*(3), 1108–1117.

Klein, J. P., & Moescheberger, M. L. (1997). *Survival analysis, techniques for censored and truncated data*. New York: Springer.

Lemoine, L., Civello, P., Chaves, A., & Martínez, G. (2009). Hot air treatment delays senescence and maintains quality of fresh-cut broccoli florets during refrigerated storage. *LWT - Food Science and Technology*, *42*, 1076–1081.

Li, M., Slaughter, D. C., & Thompson, J. E. (1997). Optical chlorophyll sensing system for banana ripening. *Postharvest Biology and Technology*, *12*(3), 273–283.

López Osornio, M. M., Hough, G., Salvador, A., Chambers, E. IV, Mcgraw, S., & Fiszman, S. (2008). Beef's optimum internal cooking temperature as seen by consumers from different countries using survival analysis statistics. *Food Quality and Preference*, *19*, 12–20.

Meeker, W. Q., & Escobar, L. A. (1998). *Statistical methods for reliability data*. New York: Wiley.

Ragaert, P., Verbeke, W., Devlieghere, F., & Debevere, J. (2004). Consumer perception and choice of minimally processed vegetables and packaged fruits. *Food Quality and Preference*, *15*, 259–270.

Ramáswamy, H. S., & Tung, M. A. (1989). Technical note: Textural changes as related to color of ripening bananas. *International Journal Food Science Technology*, *24*, 217–221.

Spyridon, E. P., Siti, A. M., Kamdem, R. E., & Yam, K. L. (2000). A versatile and inexpensive technique for measuring color of foods. *Food Technology*, *54*(12), 48–51.

Sun, T., Huang, K., Xu, H., & Ying, Y. (2010). Research advances in nondestructive determination of internal quality in watermelon/melon: A review. *Journal of Food Engineering*, *100*, 569–577.

Von Loesecke, H. W. (1950). *Bananas: Chemistry*, *physiology*, *technology* (pp. 108–109). New York: Interscience.

Wainwright, H., & Hughes, P. (1990). Changes in banana pulp color during ripening. *Fruits*, *451*, 25–28.

How to cite this article: Elizagoyen ES, Hough G, Garitta L, Fiszman S, Bravo Vasquez JE. Consumer's expectation of changes in fruit based on their sensory properties at purchase. The case of banana (*Musa Cavendish)* appearance evaluated on two occasions: Purchase and home consumption. *J Sens Stud*. 2017;32:e12278. https://doi.org/10.1111/joss.12278