Study for standardization of the lighting system in fruit sorting

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Abstract. Sorting is a very important step in the fruit processing. The attributes definition and characterization are important for both marketing and end user, making it necessary to establish regulations for classification and standardization in order to unify the language of the market and enabling a more efficient market and also increase consumer awareness. For this end, it is necessary to standardize the technical criteria that can change the perception of the product. Studies have been developed in order to standardize a methodology to determine the subclass of fruit ripening, evaluating the influence of different light sources in the subclass evaluation.

1. Introduction

Brazil, following the changes in the global economy, improves its processes to ensure quality of various products and to meet international requirements, and to position itself consistently in the global market. Brazil’s agricultural sector is the one that has shown greater international success, occupying the 3rd place in the world in fruit production.

However, some production problems still hinder the sector’s growth according to its capacity. It can be inferred from the displayed volume production a loss reaching 40 % domestically. Misuse of soil management techniques and planting, lack of storage infrastructure and logistics, inadequate packaging and misinformation of the producer are all factors that contribute to increasing losses in fruit production [1].

Parameters such as appearance, taste and typical fruit color, as well as uniformity of size and shape, are just some of the demands from international consumers. To meet all requirements and to deal with the high levels of perishability and fragility that are intrinsic, the fruit production requires a complex system of planting, harvesting, post-harvest treatment, storage, transport and display in retail outlets.

To meet international requirements, especially from Europe, Brazil created regulations and standards that would guarantee quality and standardization in fruit production. The main purpose of
this classification is to separate fruit into uniform lots, characterizing fruits by group (genome classification), class (size), subclass (ripening stage), presentation and category (quality).

Among the parameters to be evaluated, the one showing most complexity is the determination of the subclass, which evaluates fruit ripening. This evaluation is performed visually, according to the fruit coloration. However, there is no technical definition regarding different colors because the classification is tied to only a fixed number of categories. The banana, for example, has ripening subclasses defined from C1 to C7, corresponding to the following stages: completely green; green with yellow traces; greener than yellow; more yellow than green; yellow with green tip; yellow; and yellow with brown spots [2].

This comparative method is very subjective, since the visual analysis of color depends on several factors, such as room light, observer, viewing angle, etc., thus undermining the classification process’ reliability.

This paper presents a study to define a scientific methodology to standardize the classification of fruit based on colorimetry and photometry techniques. The ripening scale was associated with the peel’s spectral distribution, with the study of the influence of illumination on the characterization of the ripening stages.

This research was conducted in the Division of Optical Metrology (Diopt) of the National Institute of Metrology, Quality and Technology (Inmetro) in collaboration with the Dimensional and Computational Metrology Laboratory of Universidade Federal Fluminense (UFF), Rio de Janeiro, Brazil.

2. Methodology
A fruit’s ripening and quality can be indicated well enough by the color of its peel. Each fruit has different types and concentrations of pigments which absorb and reflect electromagnetic radiation in the visible wavelength and, for each fruit, color difference may be determined on the basis of the reflected radiation on the surface. As a study to define the methodology for characterization of color in fruits, the spectrocolorimetric system from Inmetro’s Optical Metrology Division (Diopt) was used to analyse the spectral feature of some fruits bought in common market. The fruits analysed were: banana, guava, orange, lemon, apple, papaya, mango and passion fruit.

2.1. Materials and methods
Diopt’s spectrocolorimetric system is basically composed by a spectrocolorimeter, an electrical current source, a lamp holder and a sample holder. Measurements of the peel’s spectral radiance were performed by frontally illuminating it, and acquiring its reflection at 45°, by the spectrocolorimeter - is the so called 0°: 45° geometry. Nine commercial lamps were used to illuminate the fruit and check for differences in spectral distribution and final color perception [3].

Using the light spectra reflected by the fruit’s peel both the radiance factor and the tristimulus values XYZ were calculated according to CIE recommendation [4]. From this result, the chromaticity coordinates were calculated in CIE xy and CIE L*a*b* systems as well as the color difference ΔE* for the different lighting systems. The lamps used were characterized by their correlated color temperature (CCT) and color rendering index (CRI) [4].

3. Results and Discussion
An example of the lighting influence in the color perception of two ripening stages of the Papaya can be seen in Table 1.

In figures 1 to 3 it’s shown the spectral distribution in two ripening stages of the analyzed fruits. For each fruit, distinct features and change in visual perception are represented in the spectrum change. To analyse the influence of lighting in the characterization of peel color and of each ripening subclass, the banana was chosen because of its importance in Brazilian production [1]. From the radiance factor the CIE L*a*b* was calculated for each ripening stage. The value of a* increases with ripening to C7 class, with no overlap between classes of values, which is in accordance with the
visually perceived. This behaviour does not occur with other parameters, and the value of C7 class coincides with those of other classes. Thus, the value of a* proves to be a good indicator for ripening [2].

**Table 1.** Papaya perception using four different lighting systems [1].

| Source                  | Green papaya | Ripe papaya |
|-------------------------|--------------|-------------|
| Dichroic                | ![Image](image1.jpg) | ![Image](image2.jpg) |
| LED                     | ![Image](image3.jpg) | ![Image](image4.jpg) |
| Metal halide            | ![Image](image5.jpg) | ![Image](image6.jpg) |
| High Pressure sodium    | ![Image](image7.jpg) | ![Image](image8.jpg) |

**Figure 1.** Measurements of two ripening subclasses: apple, guava and banana.
Figure 2. Measurements of two ripening subclasses: mango and lemon.

Figure 3. Measurements of two ripening subclasses: passion, papaya and orange.

Nine commercial lamps (F01 to F09) were used to analyze the influence of illumination on the peel color, with their CCT and CRI values shown in table 2. The banana peel’s colors were measured in each ripening under each subclass for the nine types of lighting (F01 to F09) [3].
Table 2. Sources used in the characterization of maturation steps [3].

| Source  | CCT (K) | CRI  |
|---------|---------|------|
| F01     | 400 W, tubular high pressure metal halide | 3834 | 49.5 |
| F02     | 250 W, tubular high pressure sodium | 2059 | 22.5 |
| F03     | 400 W, ellipsoidal high pressure metal halide, daylight | 5680 | 77.0 |
| F04     | 1000 W, tubular double envelope incandescent halogen | 2991 | 99.6 |
| F05     | 150 W, tubular high pressure metal halide | 3545 | 97.1 |
| F06     | 42 W, compact fluorescent Dulux | 3864 | 78.8 |
| F07     | 54 W, fluorescent T5 Lumilux | 4085 | 78.2 |
| F08     | 73 W, luminaire with 49 LED | 4284 | 67.3 |
| F09     | 32 W, fluorescent T8 | 4010 | 83.3 |

Analysing the ΔE* color difference calculated from CIEL*a*b* for each source (F01 to F09) using source F04 (incandescent) as a reference, high levels of ΔE* are shown for all sources, with the exception of F05. The ΔE* values of sources F01 to F08 increase as the banana ripens, i.e. the color difference is smaller in the evaluation of the green banana, than for the yellow. The color difference is large (ΔE* > 8.0) for lamps F06, F07 and F09, regardless of the assessed subclass.

4. Conclusions
This paper presents a methodology for analysis of a fruit’s appearance, with the objective of standardize the characterization stage of ripening classes. The influence of lighting in this classification is evaluated by comparing nine different commercial lamps. During the analysis it was found that the chromaticity coordinate a*, of the CIEL*a*b* system, proved to be a good indicator of ripening and was strongly influenced by the different sources in the lighting system. A greenish appearance was perceived with the use of lamps with higher TCC and a yellowish appearance was noticed with lamps with smaller CCT thereby influencing the classification during the packaging process. It is necessary to establish the type of lighting to be used mainly in automated fruit sorting systems. This work highlights the importance of standardization of the fruit ripening scale, due to the diversity undertaken among the different exporting countries in this sector, in order to guarantee the quality of the final product.

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