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Modelling RGB colour aspects and translucency of fresh-cut tomatoes

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Abstract

Translucency is one of the major problems in fresh-cut fruit. This phenomenon seriously limits the use of fruit by the fresh-cut industries. Techniques for measuring translucency in this kind of product are not readily available. As a consequence, the processes that are important in the development of translucency are little understood, let alone described in detail.

Based on techniques used in the industry of paint, paper and textiles, a measuring technique using video image analysis (VIA) involving light reflected from a sample placed in a double white and black background was used to assess the development of translucency and its interference with colour measurement in fresh-cut tomatoes. The effects of stage of maturity at the time of processing as well as the effect of storage temperature were studied in two separate experiments. The data were expressed as the average intensities per pixel of red (R), green (G) and blue (B) for the white and for the black background separately. A model was developed and presented that describes the change in the RGB values of tomatoes after cutting and during storage. In the model, the observed effects were considered to be the result of two processes namely changes in colour due to the production or degradation of pigments and development of translucency (i.e. physical water-soaking). Both processes resulted in changes in each one of the colour aspects R, G and B. Each colour aspect was considered to be built up by a variable part that changes according to a first order reaction mechanism and a fixed part that is invariable under the circumstances under study. The data obtained on both experiments were used to estimate the model parameters by multiple non-linear regression analysis using R, G and B as response variables and time, temperature, stage of maturity and background simultaneously as explaining variables.

The change from opacity to translucency in the pericarp was the main change in appearance of tomato slices during refrigerated storage, for all stages of maturity and storage temperatures. Changes in colour were much less pronounced and related to a small increase in redness for all stages. The susceptibility to develop translucency was very much dependent on the maturity stage of the fruit at harvest and rather independent of temperature.

Keywords: *Lycopersicum esculentum*; Water-soaking; Video image analysis; Minimally processed

1. Introduction

The appearance of fresh-cut products changes with time due to the production and/or degradation of pigments (Artes et al., 1999; Rocha and Morais, 2003) and due to physical changes such as loss of water (Barry Ryan and O'Beirne, 1998) and water-soaking (Jeong et al., 2004). For fresh-cut tomato, two different processes, maturation (Artes et al., 1999) and the development of translucency (Aguayo et al., 2004; Jeong et al., 2004), result in changes in appearance after processing.

The colour and other optical properties that contribute to the appearance of food products can be assessed using video image analysis (VIA). The images are captured with a CCD camera and saved in the RGB (red, green, blue) format (Du and Sun, 2004).

The changes in the overall appearance of tomato slices during refrigerated storage were assessed using VIA by Lana et al. (2004). Changes in appearance, attributed at that time mainly to alterations in colour, were parallel to a decrease in the RGB values. All three colour aspects R, G and B

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Nomenclature

k_c	rate constant of change of colour aspect due to pigments (day^{-1})
k_t	rate constant of change of colour aspect due to translucency (day^{-1})
R	universal gas constant (8.314 J/mol/K)
t	Time (day)
T	Temperature (K (°C))

Subscripts

0	initial
bb	black background
fin	invariable part at infinite time
I	of stage I
II	of stage II
III	of stage III
ref	at reference temperature (=10 °C)
wb	white background

changed according to a simple first order mechanism, which incorporated the maturity stage of the fruit at harvest and both temperature and storage time. Each colour aspect was considered to be build up by a variable part that changed according to a first order mechanism (simple exponential decay) and a fixed part invariable under the circumstances studied. Pooling data in an integral analysis revealed that all three aspects shared a common rate constant and a common temperature dependence. This approach proved to be powerful in combining all available information and improving the understanding on how the process of colour change in cut tomato depends on all the considered factors simultaneously (temperature, maturity stage and storage time).

In the above mentioned experiment, the tomato slices became translucent after 2–4 days of storage. Occurrence of translucency will interfere in colour measurements. The problems associated with the colour measurement of translucent samples were discussed in detail by Hutchings (1994) and by MacDougall (2002). Translucency is probably the most important source of structural error during colour measurement. It can lead to severe confusion in both visual assessment and instrumental measurement. The colour measurement of translucent samples are sensitive to ambient light, path length changes, background changes, and small differences in the optical configuration of the instrument.

To assess the contribution of ripening and translucency to the final appearance of the tomato slices, experiments were performed with samples placed over a half white and half black background. This approach was based on techniques previously used to measure the hiding power of a colorant layer, which has an inverse relation with the translucency of that layer. The hiding power can be calculated as the reciprocal of the ratio between the reflectance of a sample over a white background and over a black background (Judd and Wyszecki, 1975). In the present work, it was expected that the difference in colour aspects (RGB) between both backgrounds would be closely related with the intensity of translucency and eventually could be used to quantify the translucency development. However, previous statistical analysis, described in detail in Lana et al. (2005b), showed that the translucency was better expressed as a decrease in the RGB colour aspects themselves (RGB), when the measurement was done placing the sample on a black background, than in differences between both backgrounds.

In order to better understand how changes in optical properties are expressed in terms of RGB values the model previously reported (Lana et al., 2004, 2005a) was expanded in order to include both the changes in colour and translucency that happens in fresh-cut tomato during storage. Doing so, it is expected that it will be possible to describe how both processes happen after cutting and how they depend on storage time, storage temperature and maturity stage of the fruit.

2. Material and methods

2.1. Harvesting and processing

2.1.1. Experiment 1: effect of stage of maturity

Tomato fruit *Lycopersicon esculentum* (cv Belissimo) were harvested in September 2004 in a commercial greenhouse in Made, The Netherlands. The fruit were harvested on a single day, when at three stages of maturity 3, 6 and 9 (named here as I, II and III) following the tomato colour chart from The Greenery (Barendrecht, The Netherlands). The fruit were transported immediately after harvesting and selection to Wageningen (The Netherlands). The same day, the fruit were washed in cold tap water in a sanitised room and stored overnight at room temperature.

The next day, fruit similar in colour, shape and size were paired and numbered. One fruit was stored intact while the other was sliced in 7-mm thick transversal slices. The first and last slices were discarded and the central four were stacked in the same relative position they had in the fruit. Intact and sliced fruit were placed in a white polystyrene tray (138 mm × 138 mm × 25 mm) and covered with a plastic film highly permeable (appropriate for microwave cooking) and stored at 5 ± 0.5 °C. For each combination of maturity stage × processing (intact or sliced) × storage time, six replicates, corresponding to a tray with one fruit, were analysed. Only the second slice from the bottom of the stack was used. This set-up ensured that slices from the same position in the fruit were taken in successive measurements. It also avoided the confounding effect of possible whitening of the cut surface of the slice at the top of the stack and the influence of leakage in the bottom of the tray on the intensity of water-soaking. In this way, changes in optical properties could be ascribed solely to the effect of treatment.