Appetite 54 (2010) 363–368

Contents lists available at ScienceDirect

Appetite

journal homepage: www.elsevier.com/locate/appet

Research report

Influence of luminance distribution on the appetizingly fresh appearance of cabbage

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ARTICLE INFO

Article history:
Received 28 April 2009
Received in revised form 28 December 2009
Accepted 5 January 2010

Keywords:
Visual freshness perception
Histogram matching technique
Image statistics
Cabbage

ABSTRACT

We investigated the effect that the parameters of luminance distribution in fresh food have on our visual perception of its freshness. We took pictures of the degradation over 32 h in freshness of a cabbage. We used original images, which were patches of the pictures taken at different sampling hours, and artificially generated pictures, called "matched images," created by fitting the luminance histogram shape of the original image (taken at the 1st hour) to those at various freshness stages using a luminance histogram-matching algorithm. Nine participants rated the perceived freshness of the original and the matched images on a scale of degradation. As a result, we found that the participants could quantitatively estimate the degradation in freshness of the cabbage simply by looking at the presented images. Some parameters of the luminance histograms monotonically change with decreasing freshness, indicating that the freshness of cabbage can be estimated using these parameters. However, the freshness ratings for the matched images after the 8th hour of degradation had lower modification than those for the respective original images. These results suggest that the luminance distribution in the vegetable texture partly contributes to visual freshness perception but other variables, such as spatial patterns, might also be important for estimating visual freshness.

Introduction

In daily shopping, we quickly choose the vegetables that look fresh and appetizing without touching or tasting them. This fact suggests that humans can estimate the quality of food, such as the deterioration or the freshness of vegetables, using optical cues. However, it remains unknown how humans perform this quality assessment.

In general, one of the most plausible cues for the estimation of visual freshness might be colour perception since the tri-chromatic colour vision in primates is traditionally believed to have evolved to detect ripe fruit on a dappled background of leaves (Mollon, 1989; Osorio & Vorobyev, 1996; Regan et al., 2001). However, some researchers have reported that, compared to other factors, colour appearance contributes to a lesser extent to freshness perception in some fruits and vegetables (Péneau, Brockhoff, Escher, & Nuessli, 2007). For example, Péneau et al. (2007) investigated the sensory attributes influencing consumer perception of the freshness of strawberries and carrots. The sensory characters of products, which include not only taste and odor, but also visual parameters such as shininess (or glossiness) and colour, were evaluated by trained panels, indicating that subjective visual parameters such as bruising and shininess are the best predictors of consumer perception of freshness, while colour does not strongly contribute to freshness perception. In this study, the relationship between subjective sensory attributes and freshness was examined. However, the relationship between freshness and sensory attributes such as shininess is just beginning to be understood, and the optical or physical cues relating to freshness perception are still relatively unknown. In order to examine the relationship between some physical parameters and freshness perception, experimental approaches using psychophysical techniques are necessary.

Recently, a physical property that might serve as a visual freshness cue was reported in visual science: Motoyoshi, Nishida, Sharan, and Adelson (2007) showed that image statistic values, such as the distribution characteristics of luminance, are highly correlated with the perceived glossiness and lightness of the visual texture. They demonstrated that as the luminance distribution in

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doi:10.1016/j.appet.2010.01.002

the observed image became positively skewed, perceived glossiness of the image increased. Moreover, they found that observers' visual adaptation to a positively skewed image made subsequent images look less glossy, and concluded that the human visual system can extract the luminance distribution skewness to be able to perceive the quality of a surface.

Thus, we can expect that the distribution characteristics of luminance may play an important role in the mechanism of our visual freshness perception. In the present study, we used this insight and investigated whether optical features affect our visual perception of freshness in cabbages. We chose a cabbage as the sample because a fresh cabbage looks glossy and leafy vegetables like this one are highly perishable. In addition, the freshness of cabbage is generally proportional to its appetizing appearance. First, we took digital photographs of the freshness degradation process of the cabbage over 32 h. As visual stimuli, we used two different sets of images: original images and matched images. The first set was the original images consisting of 512×512 pixel patches of the original pictures. Using them, we investigated whether the freshness of cabbage would be adequately perceived with visual cues. The other set was the matched images consisting of 512×512 pixel patches of the artificial images created by modifying their luminance distribution. We used this set to clarify the effect of the luminance distribution on freshness perception leaving aside the effects of other visual attributes, such as colour and shape. Participants were required to rate the freshness of the cabbage in the images which they observed. The current study provides the first attempt to examine the effect of image statistic parameters on the perception of the visual freshness of food.

Methods

The psychophysical experiment consisted of two separate sessions, which were different only in the visual stimuli observed by the participants. In the first experimental session, we used the original images of the cabbage at various freshness degradation stages. In the second session, the matched images that had been generated artificially were used as the visual stimuli. Participants were asked to estimate the freshness of the cabbage in the images using a Visual Analogue Scale (VAS) in all trials of both sessions.

Participants

There were 9 participants, 5 females and 4 males ranging in age from 23 to 41 years old, in both experimental sessions. All of them had normal colour vision, and normal or corrected to normal visual acuity. No experts on cooking, trading, farming vegetables, or sensory evaluation of food were included. We conducted no specific training for participants. Written informed consent was obtained after a complete explanation of the study. The study was approved by the institutional ethics committee of the National Food Research Institute.

Apparatus and stimuli

Apparatus

The visual stimuli were presented on a 22-in. CRT monitor (Iiyama HM204DA) using ViSaGe (Cambridge Research Systems Co. Ltd.). The viewing distance between the display and the chinrest was about 57 cm.

Sample

We used one leaf from a fresh head of cabbage that we randomly selected from a local market on January 18th, 2008. The photographs used in the experiments were taken on the date of and the date after purchase.

Original images

The images used in the experiment, and which we call original images, were taken in a darkroom in which the humidity and the temperature were kept at 6% and 30 °C, respectively. A digital camera (Nikon COOLPIX P5100) was set using a tripod stand in a box designed for taking photographs (D' CUBE J; $116 \times 100 \times 100$ cm). Illumination was achieved with 2 floor lamps having a colour temperature of 5400 K. We took 3000×4000 pixel photos every hour for 32 h, automatically. As original-images stimuli, we used patches of 512×512 pixels of the pictures of the freshness degradation process taken at 1, 2, 3, 5, 8, 11, 15, 19, 23, 27, and 32 h (see Fig. 1a). All images were cropped at the same approximate coordinates. The purpose of this selection was to investigate whether observers could perceive freshness as a negative function of degradation time.

Fig. 2 shows the most common statistics that characterize the luminance histogram distribution of the original images (a) and the matched images (b); standard deviation, skewness, and kurtosis on a normalized scale on the vertical axis, and time on the horizontal axis. This figure shows that the luminance distribution of the matched images are almost the same as those of the original images, and the luminance distribution features change, as anticipated, as a function of the degradation duration.

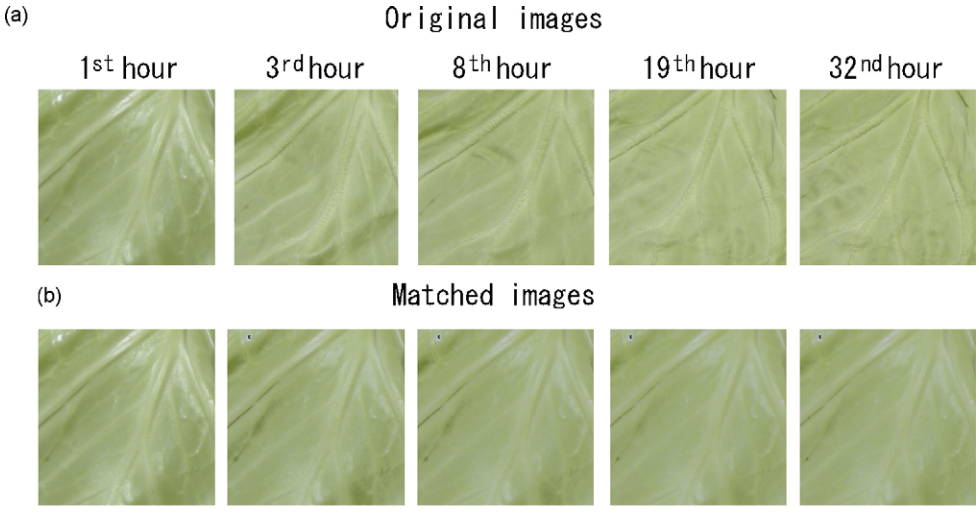

Fig. 1. Examples of visual stimuli. (a) Original images of 1st, 3rd, 8th, 19th, and 32nd, hours; (b) matched images of 1st, 3rd, 8th, 19th, and 32nd, hours.