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Postharvest quality evaluation of "Fuyu" and "Taishuu" persimmons using a nondestructive vibrational method and an acoustic vibration technique

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ABSTRACT

We investigated time-course changes in the elasticity index (EI) and texture index (TI) of two persimmon (*Diospyros kaki* Thunb.) cultivars ("Fuyu" and "Taishuu") during the postharvest period. EI was determined using the formula $\mathrm{EI} = f_2^2 m^{2/3}$, where f_2 is the second resonance frequency of a sample, and m is the mass of the sample. A nondestructive vibrational method employing a laser Doppler vibrometer (LDV) was used for measuring the second resonance frequency (f_2) of the persimmon samples. The changes in the EI of both cultivars showed quasi-exponential decays. An improved texture measurement device was used for measuring the TI of the cultivars. The TI was defined by $(1/T)\sum|V_i|$, where T (s) is the sampling period and V_i (V), the amplitude of each data point. The pattern of time-course changes in TI differed between "Taishuu" and "Fuyu" persimmons; a sharp decline was observed in the TI of "Fuyu." Along with the sensory test, we determined the optimum eating ripeness of persimmons in terms of their EI to be $2.9\text{–}6.0 \times 10^4\ \mathrm{kg}^{2/3}\,\mathrm{Hz}^2$ ("Taishuu") and $4.8\text{–}6.4 \times 10^4\ \mathrm{kg}^{2/3}\,\mathrm{Hz}^2$ ("Fuyu").

1. Introduction

Persimmons continue to ripen and become soft after harvest. Consumers are interested in the optimum eating ripeness of fruit that makes its quality optimal for eating. Monitoring the ripening process and classification of such produce according to the degree of ripeness helps both distributors and consumers to determine when to ship and when to eat.

Various nondestructive methods for evaluating the quality of fruit have been reported. One such method is measuring the mechanical resonance of fruit samples (Abbott et al., 1968; Finney, 1971; Yamamoto et al., 1980; Yamamoto and Haginuma, 1982; Abbott, 1994). Muramatsu et al. (1997b) used the velocity of sound transmitted in a kiwifruit to measure its firmness and Muramatsu et al. (1997a) showed that a method involving the use of a laser Doppler vibrometer (LDV) was advantageous for detecting the firmness of fruit. This method has been applied to monitoring the ripeness of kiwifruit (Terasaki et al., 2001b,c) and pears (Terasaki et al., 2006). Postharvest ripening has been studied not only by mechanical but also by chemical methods. For instance, Tsuchida et al. (2003) investigated the degradation of polysaccharides (arabinose and galactose) in persimmons that accompanies their softening.

Methods for the measurement of factors determining the food texture such as crispness have been extensively studied because food texture is an important attribute of fresh produce, and consumers use it to evaluate quality and freshness. Measurement methods include both mechanical and sensory evaluation. Early work on the acoustic measurement of food texture was conducted by Drake (1963, 1965) and mechanical and acoustic methods of measuring food texture have been well reviewed by Duizer (2001) and Roudaut et al. (2002). Most acoustic studies on measurement of food texture have involved the use of a method of recording the sound produced by the mastication of food (Lee et al., 1990; Vickers, 1991; Dacremont, 1995). One problem associated with this method is that intrinsic texture information can be lost because of the resonance of the palate or the mandible. Furthermore, the soft tissues in the mouth absorb or dampen higher-frequency sounds (Vickers, 1991). However, Christensen and Vickers (1981) suggested that the vibrations produced by fracturing crisp foods might underlie the perception of crispness. Vincent (1998, 2004) later introduced a materials science method to evaluate the texture of fruit and vegetables. Acoustic emission associated with crushing a potato tuber was detected to investigate susceptibility to mechanical damage (Zdunek and Konstankiewicz, 2004). Sensory

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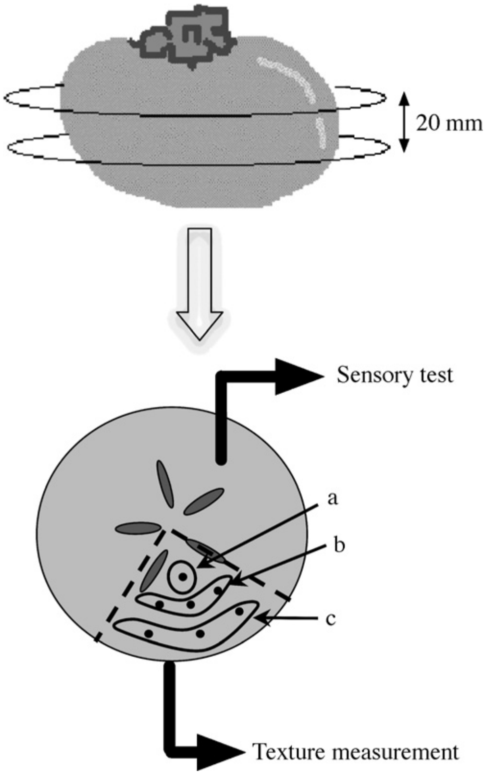

Fig. 1. Preparation of the persimmon samples for the sensory test and texture measurement. Each persimmon was sliced along the equatorial plane. A quarter of the slice was used for texture measurement and the remainder, for the sensory test. The dots represent the points where the probe was inserted (a: inner, b: middle, c: outer part).

evaluation is another widely used method to evaluate the quality of food (Mehinagic et al., 2004). In this method, a panel evaluates food samples and grades them according to predetermined standards. The relationship of instrumental measurements to specific sensory attributes was studied by Harker et al. (2006) who showed the possibility of discrimination of the firmness of apples as measured by a sensory test against that measured using an instrument.

The objectives of the present study were to (a) measure the elasticity index (EI) of persimmon samples by a previously described nondestructive method using an LDV and measure their texture index (TI) using an improved texture measurement device (Taniwaki et al., 2006b); (b) to report the time-course changes in the TI, EI, and the sensory test index of persimmons during the postharvest period; (c) to investigate the relationship between the sensory test index and the measured parameters (EI and TI); and (d) to determine the EI and TI of persimmons at the point when they reached optimum eating ripeness. Based on the results obtained, we discussed whether the period of optimum eating ripeness can be determined by a nondestructive method. EI was determined using the formula $\mathrm{EI} = f_2^2 m^{2/3}$ (Cooke, 1972; Terasaki et al., 2001a), where f_2 is the second resonance frequency of a sample, and m is the mass of the sample. A nondestructive vibrational method employing a laser Doppler vibrometer was used for measuring the second resonance frequency (f_2) of the persimmon samples. The TI was determined by the “amplitude density”, which is the integration of the amplitudes of texture signals divided by the sampling period (Taniwaki et al., 2006a).

2. Materials and methods

2.1. Persimmon samples

We used two cultivars of persimmon (*Diospyros kaki* Thunb.), namely, “Fuyu” and “Taishuu,” for our investigations. The samples were provided by the Grape and Persimmon Research Station, National Institute of Fruit Tree Science (Higashi-Hiroshima, Japan). We used 32 samples of “Taishuu” and 50 samples of “Fuyu”. The samples were stored at room temperature (ca. 20 °C, RH ca. 50%) for 20 d throughout the measurement period. The method of preparation of the samples for texture measurement and for the sensory test is described in Fig. 1. A 20-mm thick slice along the equatorial plane was obtained from each persimmon sample. A quarter of the slice was used for texture measurement and the remainder for the sensory test.

2.2. Human sensory test

The sensory test was performed by six experienced panelists (three males and three females). Each panelist graded the samples for sweetness, juiciness, thickness, hardness, fragrance, appearance, and overall acceptability. Here, “overall acceptability” meant the degree of acceptability for eating for a panelist taking into account all the attributes. The samples were rated on a sensory test index in a scale of 1–5 (1: over-ripe, 3: ripe, and 5: immature).

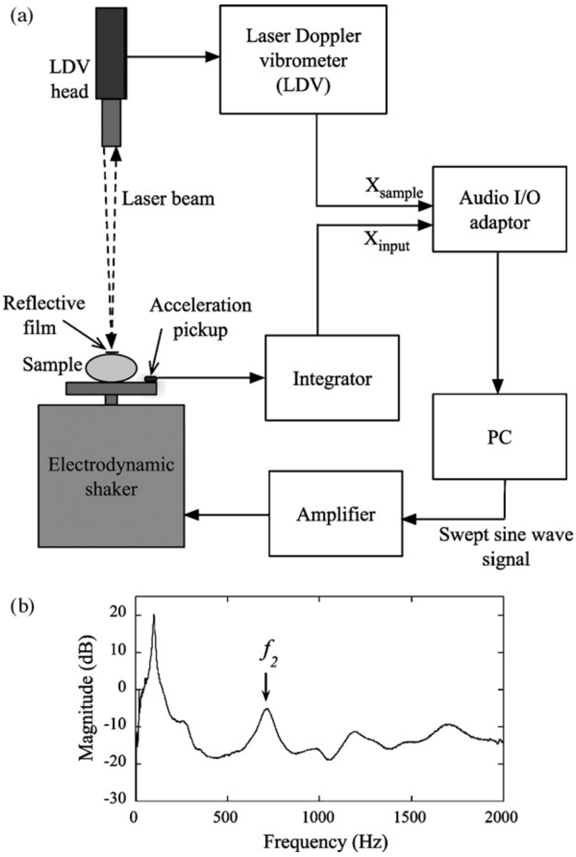

Fig. 2. (a) The experimental setup for the nondestructive measurement of the elasticity index of the persimmon samples. A sample was mechanically excited by a shaker that was driven by swept sine wave signals. The response at the opposite side of excitation was sensed by a laser Doppler vibrometer (LDV). (b) A typical response spectrum of a “Fuyu” sample; f_2: the second resonance peak that was used for determining the elasticity index.