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Ripeness evaluation of melon by using surface acoustic wave

弾性表面波によるメロンの成熟度評価

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1. Introduction

Firmness is one of the major quality indices for fluits evaluation. Acoustic techniques have been widely used to monitor firmness or matulity of watermelon and melon[1]. In the acoustic impulse response method [2] for studying the natural frequency of watermelon with a pendulum hitting device, the sensory firmness or maturity is correlated with characteristic parameters composed of the resonant frequency of the detected sound waveform, and the mass and density of the watermelon sample. Sugiyama et al. [3,4] found that the velocity of an acoustic impulse decreased as melons ripened. A portable firmness tester, incorporating an impact plunger and two microphones, was also developed to measure the velocity, which correlates well with the apparent elasticity.

Ikeda et al. [5] measured Rayleigh-wave velocity on watermelon flesh in the frequency range of 800-2400 Hz. The measured velocity was correlated well with a sensory firmness evaluation by 78 numbers of students. Choi et al. [6] reported that the surface wave velocity on watermelon flesh can be predicted from the frequency dependence of the surface wave velocity on pericarp, suggesting the nondestructive evaluation of elasticity of watermelon flesh. In the present study, we show that the ripeness of melon can be estimated from the measurement of suface wave velocity.

2. Experimental

1.1 Principle

Melon is composed of hard pericarp (fruit skin) and relatively-soft flesh. Properties of surface-wave propagation on the pericarp is affected by the underlying flesh which has inhomogeneous elasticity. The surface-wave velocity at different frequency depends on elastic property of medium at different depth. Thus the velocity dispersion on the pericarp may provide a measure of elasticity of flesh.

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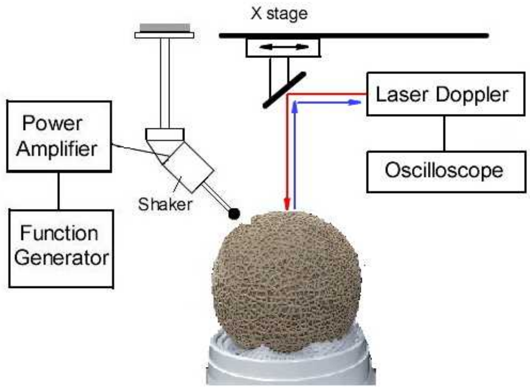

Fig. 1. Experimental system of measuring surface-wave velocity on melon. A pulsed wave at constant frequency was excited and detected by a laser Doppler vibrometer.

1.2 Experimental system

Experimental system is shown in Fig.1. Surface waves are excited by an oscillator (a metal bar with a length of 25 mm and diameter of 4 mm) connected to a shaker (LDS V101, Bruel & Kjaer). The edge of the oscillator gently touched the surface of the pericarp. A pulsed-wave signal with a duration of 10 cycles at 400–5000 Hz was applied to the oscillator by using a function generator (33522B, Agilent) and a power amplifier (PM4400, Marantz). The pulsed wave was detected using a laser Doppler vibrometer (NLV-2500, Polytech) and was displayed on an oscilloscope (DSO7012B, Agilent). Signals were recorded with 2 mm increment of propagation distance by moving the sliding stage supporting a laser mirror. The time shifts of the detected peaks were plotted as a function of the propagation distance between the oscillator and the detecting laser, from which the surface wave velocities were obtained. The measured region was near equator of the sample. Melon samples (a variety of earls) with a weight of approximately 1.7 kg was obtained from a market.

3. Results and discussion

A typical example of surface-wave velocity on a melon measured as a function of frequency is shown in Fig. 2. The velocity gradually increases with increasing frequency. This frequency dependence is similar to that for watermelon [6]. The velocity at lower frequency may include the information of the elasticity of underlying soft flesh. The wavelength at 1 kHz is predicted to be 40 mm, which surface region includes the pericarp (a skin part) and soft part of the flesh. The wavelength at 5 kHz is predicted to be 12 mm, which surface region includes the pericarp and firm part of the flesh. The surface-wave velocity on flesh was also measured after cutting the melon into half. The velocity near the central part exhibited a constant value of about 30 m/s in the range of 0.3-3 kHz, as shown in Fig. 3. These results indicate that the surface wave velocity at lower frequencies is affected by a deeper substrate, i. e. soft flesh, and that at higher frequencies has influence from hard pericarp. The velocity at high-frequency limit, however, may not represent the value in pericarp. Farnell et al. [7] showed that surface wave propagating in a hard layer deposited on a soft substrate does not localize in the layer at high-frequency limit but leaks bulk wave towards the substrate.

For evaluating the degree of ripeness, we investigated a time dependence of the surface-wave velocity. The measurements started on a day the sample was obtained and repeated several times during two weeks. About a week after started is ready to eat. Figure 4 shows the frequency dependence of the surface-wave velocity obtained at five different days. The velocity decreased as time proceeds at all frequencies measured, indicating the softening of melon flesh. This result suggests the possibility of the surface wave technique as a tool of ripeness evaluation of melon.

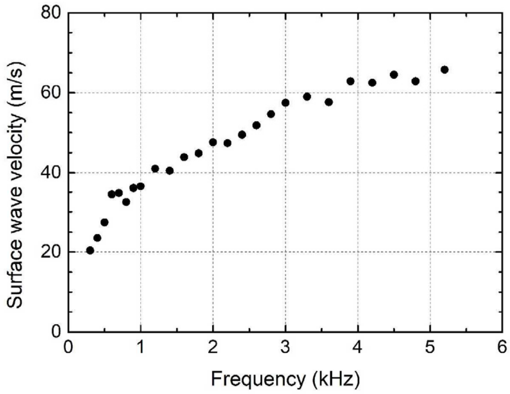

Fig. 2. Typical velocity dispersion of surface acoustic waves on melon.

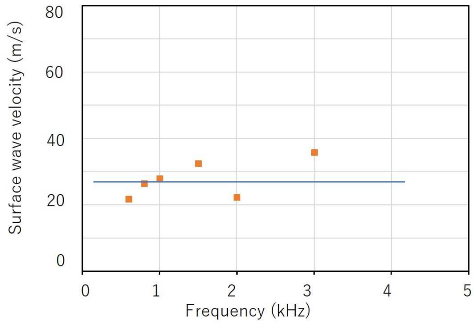

Fig.3. Surface-wave velocity measured on the melon flesh.

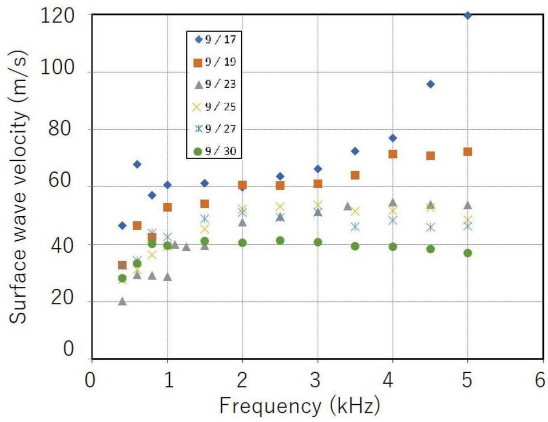

Fig. 4. Surface-wave velocity on the pericarp of melon measured during two weeks.

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