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Non-Destructive Measurement of Watercore in Japanese Pear (*Pyrus pyrifolia* Nakai) 'Hosui'

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Abstract

Using a low frequency ultrasonic flow detector and an X-ray-computed tomograph, we determined whether it would be possible to carry out non-destructive measurement of a watercore in the Japanese pear 'Hosui'. The traveling speed of the longitudinal ultrasound waves of the low frequency ultrasonic flow detector was found to be higher with increased development of the watercore in fruits with ground color values of the calyx end below 3.5, based on a color chart for Japanese pear ground color[6,12)], but not in fruits with a ground color value above 3.5. On the other hand, using an industrial X-ray-computed tomograph, the photographs of the fruits with watercore represented by white points that were obtained by selecting CT-values from +0020 to +0050, nearly corresponded to the extent of the development of the watercore. The results obtained indicate that X-ray-computed tomography could be used for non-destructive measurement of the occurrence of a watercore in the Japanese pear Hosui.

Discipline: Horticulture
Additional key words: X-ray-computed tomography, low frequency ultrasonic flow detector

Introduction

Some Japanese pear cultivars frequently develop a watercore in the flesh during the maturity process[7)]. The fruits with extensive watercore in the flesh, which sometimes show a pithiness and black brown color, have a lower commercial value and market evaluation due to the low fruit quality and poor storage.

It is difficult to detect the presence of a watercore based on the external appearance of the fruit, except when the watercore is extensive and occurs just under the skin. In apples, light transmittance through the fruit[1,2,10,11)] can be applied for measuring the extent of the watercore non-destructively. In addition, the fruit temperature affects the Δ OD value[3)], unlike the 810 nm single wavelength[4)] which might be useful for determining the extent of the watercore in apples. However, in 'Hosui' fruits we failed to determine the extent of the watercore non-destructively by light transmittance (data not shown). Thus, in the present paper, we determined whether it would be possible to carry out non-destructive measurement of the extent of a watercore in the Japanese pear Hosui by using a low frequency ultrasonic flow detector and an X-ray-computed tomograph.

Materials and methods

1) Materials

Mature fruits of Japanese Pear (*Pyrus pyrifolia* Nakai) Hosui were harvested in the middle of September from an orchard located at the National Institute of Fruit Tree Science, and they were stored in a refrigerator until use.

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2) Non-destructive measurement using a low frequency ultrasonic flow detector

Non-destructive measurement was performed according to the following procedures by using a low frequency ultrasonic flow detector (DT500C type, Hitachikenki Co. Japan). Two relative measuring points of the traveling speed of longitudinal ultrasound waves were fixed in the equatorial plane of the fruit, and the distance between the 2 relative points was measured. Transmitting or receiving probes came into contact with each measuring point, and the traveling speed of the longitudinal ultrasound waves (100 KHz) between the 2 measuring points was measured.

3) Non-destructive measurement using an X-ray-computed tomograph

Non-destructive measurement was carried out on intact Hosui fruits using an industrial X-ray-computed tomograph (TOSCANER-20000, Toshiba Co. Japan). A section of the equatorial plane of the fruit whose ground color value at the calyx end ranged from 3 to 4 was represented as an image using the industrial X-ray-computed tomography equipment. The relationship between the picture of the section of the fruit equatorial plane (hereafter referred to as "tomogram") and the extent of the watercore was determined just after imaging.

4) Evaluation of the ground color value of the calyx end and the extent of watercore

The ground color value of the calyx end of Hosui was evaluated using a color chart for Japanese pear ground color[6,12] after measurement of the traveling speed of the longitudinal ultrasound waves, and the fruit was cut through the same measuring points along the equatorial plane. The extent of the watercore was assessed using a watercore index with 4 grades (0: no watercore~ 3: extensive watercore).

Results

The relationship between the occurrence of the watercore and the traveling speed of longitudinal ultrasound waves is shown in Fig. 1. The traveling speed values varied considerably among the fruits measured, ranging from 200 to 1,100 m/sec. The traveling speed of the longitudinal ultrasound waves tended to be higher with increased development of the watercore.

Based on Fig. 2 which depicts the relationship between the ground color of the calyx end and the traveling speed of longitudinal ultrasound waves, the speed of the waves was higher when the ground color became deeper and the value was below 3.5, while when the ground color value was above 3.5, there was no further increase in speed.

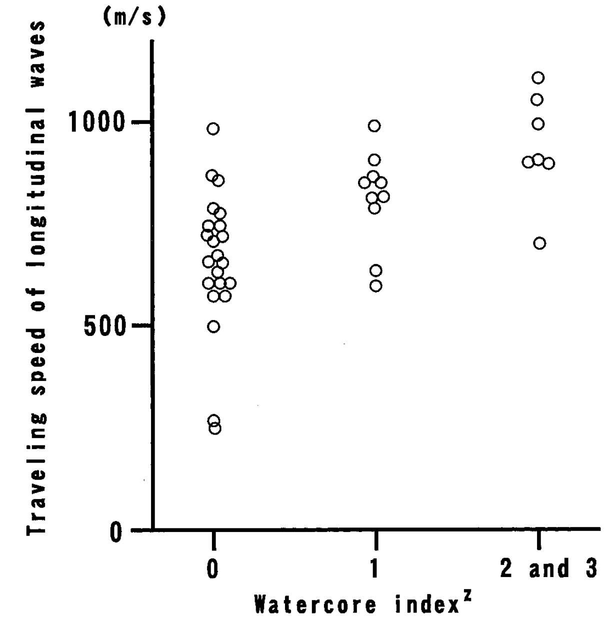


Fig. 1. Relationship between the traveling speed of longitudinal waves and the occurrence of watercore in Japanese pear 'Hosui' fruits

The traveling speed of longitudinal waves was 100 KHz.

z: 0 (No watercore) ~3 (Extensive watercore).

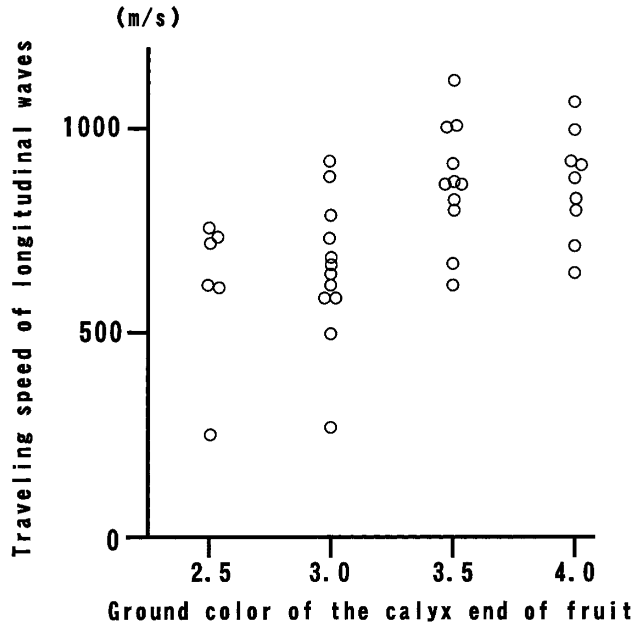
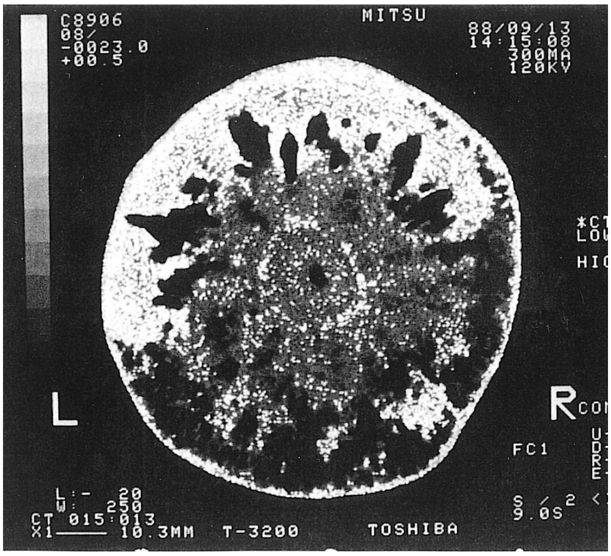


Fig. 2. Relationship between the traveling speed of longitudinal waves and the ground color of the calyx end in Japanese pear 'Hosui' fruits

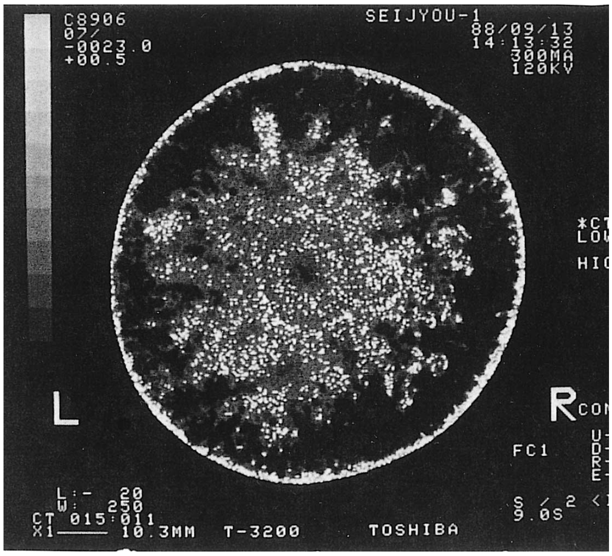
The ground color values were determined by using a color chart for Japanese pear fruit.

Fig. 3-a shows a tomogram of a fruit obtained by using an industrial X-ray-computed tomograph, and Fig. 3-b shows a photograph of a cut surface of the same area. Since this fruit exhibited an extensive watercore, it is likely that its market value would have decreased due to the poor taste. Fig. 3-a shows a picture in which the CT-values ranging from +0020 to +0050 were selected from the CT-picture, and white points indicate the range. Finally, all the white points were put on the original CT-picture. The contrast between the white and black points in the tomogram expresses the relationship between the measured material and its density, and the CT-value was

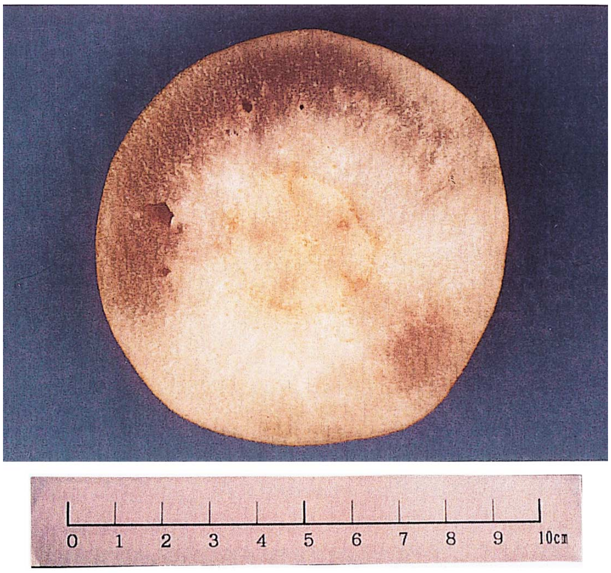
3-a



4-a



3-b



4-b

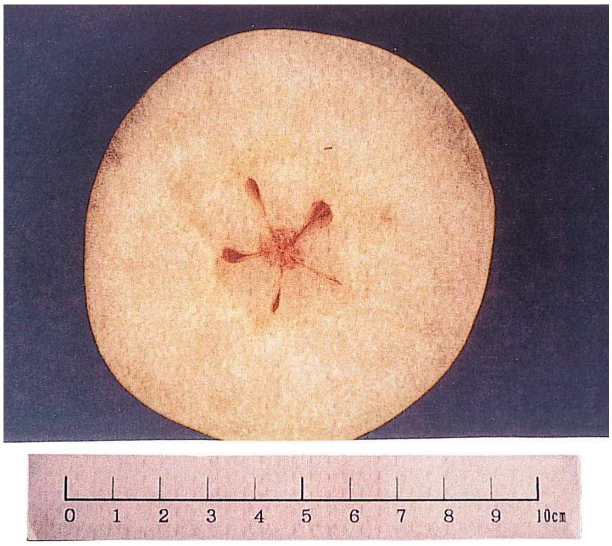


Fig. 3-a. Tomogram of fruit with extensive watercore
CT-values from +0020 to +0050 were selected from the original CT-picture, and the range is indicated by white points.
3-b. Photograph of the cut surface of the same area as that shown in 3-a.

Fig. 4-a. Tomogram of fruit without watercore
CT-values from +0020 to +0050 were selected from the original CT-picture, and the range is indicated by white points.
4-b. Photograph of the cut surface of the same area as that shown in 4-a.

used to indicate the differences in degree (the CT-value of distilled water is zero). When considering only the density of the material, the CT-value was positive and the picture showed clear points (white points) when the density increased. On the other hand, when the density decreased because of the presence of a wide air phase within the intercellular spaces, the CT-value was negative, and the picture showed dark points (black points). The extent of the watercore which actually appeared on the cut surface of the fruit (Fig. 3-b) nearly corresponded to the picture in which the watercore was represented by white points after selection of CT-values from +0020 to +0050 using an industrial X-ray-computed tomograph (Fig. 3-a).

In fruits with a limited watercore, the extent of the watercore which actually appeared on the cut surface of the fruit nearly corresponded to that of the picture in which the watercore was represented by white points after selection of the CT-values from +0020 to +0050 (data not shown).

A CT-picture after selection of the CT-values from +0020 to +0050 on the original CT-picture and a picture of the cut surface of the same area are shown in Fig.4-a and Fig. 4-b, respectively. The picture of the fruit which had no symptoms of watercore did not show white points even when the CT-values were selected from +0020 to +0050.

Discussion

Non-destructive measurements using ultrasound waves have been performed in some agricultural fields. Because ultrasonic waves are harmless to animals and humans, the waves may be suitable for the non-destructive measurement of some foods. Generally, the traveling speed of the ultrasound waves changes depending on the target materials, and environmental conditions such as temperature. For example, at 1.013×10^3 hPa and 0ºC, the traveling speed is 331 m/sec in air but 1,410 m/sec in water. Since the intercellular air spaces in the watercore tissues of the Japanese pear are replaced by sugar and water, a watery area appears in the flesh. Therefore, it is considered that the traveling speed of ultrasound waves would be higher in a larger watercore because the intercellular spaces of the watercore tissues contained more liquid than air. However, no accurate determination could be made by using a low frequency ultrasonic flow detector. Since the detector measures only one point of the flesh, the point measured may be different from the portion affected by the watercore. Therefore, it may be necessary to measure several points in the flesh to obtain consistent data.

Industrial X-ray-computed tomograph which can produce a high quality picture of a cross-section in a short time without destroying the materials, is utilized to inspect the internal structure of semiconductors, the configuration of pipes in industrial fields and damage caused to wood by insects or foreign substances in food processing in agricultural fields. As stated above, we were able to utilize an industrial X-ray-computed tomograph successfully for the non-destructive measurement of a watercore in Hosui by using the image represented by white points after selection of CT-values ranging from +0020 to +0050.

It was shown that the specific gravity of the Hosui fruits decreased when they were exposed to conditions conducive to watercore development, and that the occurrence of a watercore actually led to a decrease of the specific gravity of the fruits[5,8]. Since the CT-value is determined by the relationship between a material and its density, it expresses the difference in the specific gravity between the areas with and without watercore. Therefore, the pictures obtained after processing of the CT-values within a range from +0020 to +0050 might correspond exactly to the area of development of a watercore.

However, the specific gravity of Japanese pear fruits varies considerably from year to year[9]. Further experiments should be carried out to analyze the effect of the variation in the specific gravity among years on the non-destructive measurement of a watercore. It is concluded that non-destructive measurement of a watercore using an industrial X-ray-computed tomograph might be an effective method for determining the occurrence of a watercore.

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