Determination of Density in Intact Sakurajima Radish by Acoustic Impulse Response

著者	Chen Jie Yu, Miyazato Mitsuru, Ishiguro Etsuji, Nanba Naohiko
journal or publication title	Memoirs of the Faculty of Agriculture, Kagoshima University
volume	30
page range	105-111
URL	http://hdl.handle.net/10232/2872

Mem. Fac. Agr. Kagoshima Univ., **30**, 105-111, 1994

Determination of Density in Intact Sakurajima Radish by Acoustic Impulse Response

Jie Yu CHEN, Mitsuru MIYAZATO, Etsuji ISHIGURO
and Naohiko NANBA*
(*Laboratory of Agricultural Systems Engineering,*
* *Laboratory of Water Control Reclamation Engineering*)
Received for Publication September 10,1993

Introduction

The relationship between the density and the quality of agricultural products has been studied by a lot of researchers for more than a century. Zaltzman et al[10]. presented a comprehensive literature review of previous studies related to the quality evaluation of agricultural products, basing on density differences. On the one hand, it is apparent that a change in density is to be brought about with maturity, and on the other hand, certain types of damage and defects, such as frost damage in citrus, insect damage in fruits and grains, puffiness in tomatoes, bloaters in cucumbers, brood in radishes, and hollow heart in potatoes tend to reduce the density of the products. These changes in density reflect the overall quality characteristic of the commodities, and the differences in density are usually a direct and consistent display of maturity and other quality characteristics.

In spite of the potential of using density as the parameter for realizing the quality sorting of agricultural products, only limited number of attempts have been made, and quite few commercial prototypes are available for a successful sorting of agricultural products. The most common way of using density sorting is by the method of flotation in liquid solutions. Kunkel[1] reported mechanical grading of potatoes which is to be carried out according to density. They developed a method of using a brine solution of 1.0863 specific gravity. Potatoes were washed prior to be immersed in the brine solution and were washed again, after removal, to rinse off the salt from the surface. The results showed higher accuracy of sorting. Mueller et al[3]. used density as an indicator of quality for sorting the edible nuts. In black walnuts, the specific gravity for good nuts is 1.011±0.028 and for bad nuts the figure of 0.774±0.097 at the 95% probability level, was obtained. Wolfe et al[6]. investigated criterion for maturity sorting of high bush blueberries. They reported a good relationship between the density and the maturity of blueberries. In another study, Wolfe et al[7]. successfully sorted mechanically harvested blueberries. They found that the sorting effectiveness was considerably improved by pre-wetting the fruits. Patzlaff[5] proposed an apparatus for sorting the ripe and unripe blueberries, using density differences in the water stream. Zaltzman et al[8-9]. utilized a fluidized bed medium for separating potatoes from clods and stones. Besides, Mizrach et al[4] investigated gravitational motion of sphere in a fluidized bed. This method has the inherent advantage that there is no need of singular devices are necessary. However, primary disadvantages of liquid flotation devices are the contamination and the pre-washing and post-washing procedures, which were usually detrimental to quality and resulted in some storage problems. In addition, the liquid process using brine solution or alcohol water mixture is usually expensive and is accompanied with environmental hazards. The liquids tend to get contaminated during the sorting process and change their specific gravity, requiring periodic corrections.

In order to reduce these effects and increase the accuracy in measurement, a potential to determine density using electrical properties of agricultural products was proposed by Kato[2]. This method successfully predicted the volume of fruits and vegetables. But an application of the method to an automatic sorting system was limited by the need for complicated apparatus and complex fruit handling. Therefore, a simple method for measuring density of Sakurajima radishes, using an acoustic impulse response was investigated.

Materials and Equipments

1.Materials

Sakurajima radishes used in this research were harvested during the winter of 1992 from the area of Sakurajima, kagoshima Prefecture, Japan. After harvesting, the fundamental physical measurements of such items as density and an acoustic impulse responses, were made immediately. The density was calculated by dividing the mass by the volume of samples.

2.Apparatus and Methods

Schematic diagram of the experimental apparatus is shown in Fig. 1. Pendulum device was used in the striking part of the experimental apparatus. The striking velocity could be changed by changing the falling angle of the pendulum. The fulcrum of the pendulum could be adjusted up and down so that it become very easy to make the striker tap at the point of equator of each sample.

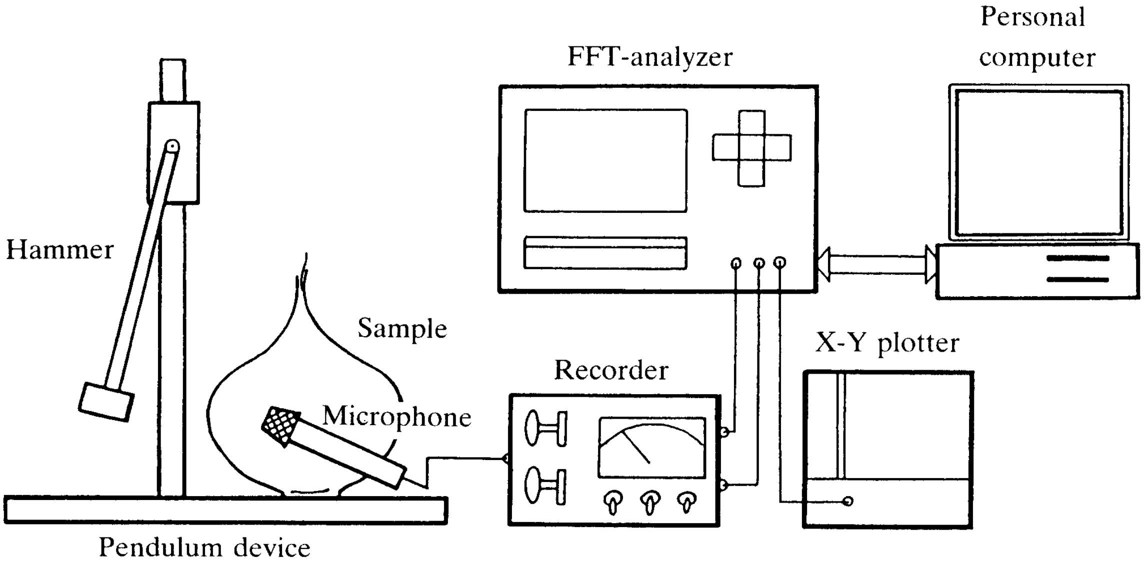

Fig. 1. Schematic diagram for the experimental apparatus.

Samples were kept on the flat plate of the device and the pendulum with a wooden hammer was allowed to tap at the samples from the predefined angle. The acoustic signals caused by the impact forces were measured with microphone (RION NA-20). The output from the microphone was sent to a FFT analyzer (ONO SOKKI CF-920S) and then to a computer (NEC PC-9801). The FFT contained an AD converter capable of running at high speed. It also stored the resulting data in the internal memory, processing the signals into a frequency spectrum usable for the computer.

A number of Sakurajima radishes with different densities were collected and the densities of the respective samples were measured by a conventional method. Then, these samples were kept on the pendulum device and the acoustic data measurement was made, and then the frequency spectrum was obtained by the experiments. Further, the curve fitting procedure on the frequency spectrum was performed. And the relationship between the density and the regressive coefficients for the frequency spectrum was discussed.

Results and Discussion

1.The frequency spectrum

Fig. 2 shows the frequency spectra of the same sample having different impact velocities of hammer at contact, which are obtained by changing the falling angle of the pendulum. The fitted smooth curves were obtained by using an iteractive least square method for each frequency spectrum. Ignoring the superimposed noise, we found that the amplitudes at various frequencies in the frequency spectrum increased as the impact velocity of the wooden hammer increased, but the shape of the frequency spectrum hardly changed. This fact could be demonstrated by these fitted smooth curves which were almost parallel. These patterns have been noted to be consistent over a number of trials.

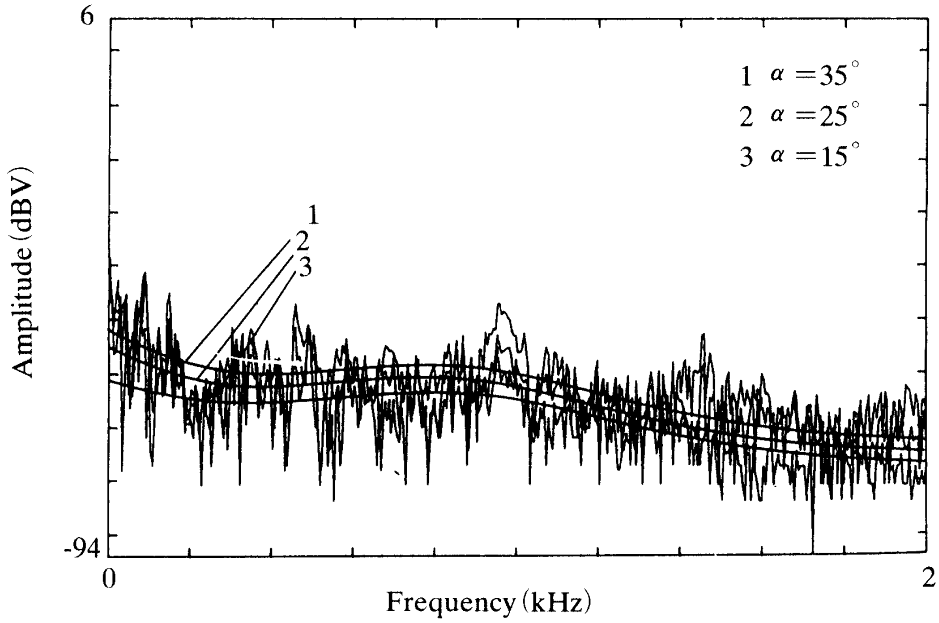

Fig. 2. Effect of impact force on the frequency spectrum.

Fig. 3 shows the frequency spectrum and the fitted curves of the samples having different densities. We found that the fitted curves changed with the densities of samples. In fact, this change could be represented by the curves fitting to the frequency spectrum and might be measured quantitatively by locating the points at which the curves cross the vertical lines of 0.2kHz and 0.8kHz. At these points, horizontal lines were drawn along the axis, revealing that Sakurajima radish of density of 0.92kg/cm^3 had -56dBV at the frequency of 0.2kHz and -52 dBV at 0.8kHz, while Sakurajima radish of density of 0.76kg/cm^3 had -46dBV for 0.2kHz and -59dBV for 0.8kHz. As the sample density increased, the frequency of the maximum magnitude increased, too. This gives us one of the possible determination for different densities. Based on the result (Fig.3) and the previous result (Fig.2), We could determinate the density of any Sakurajima radish.

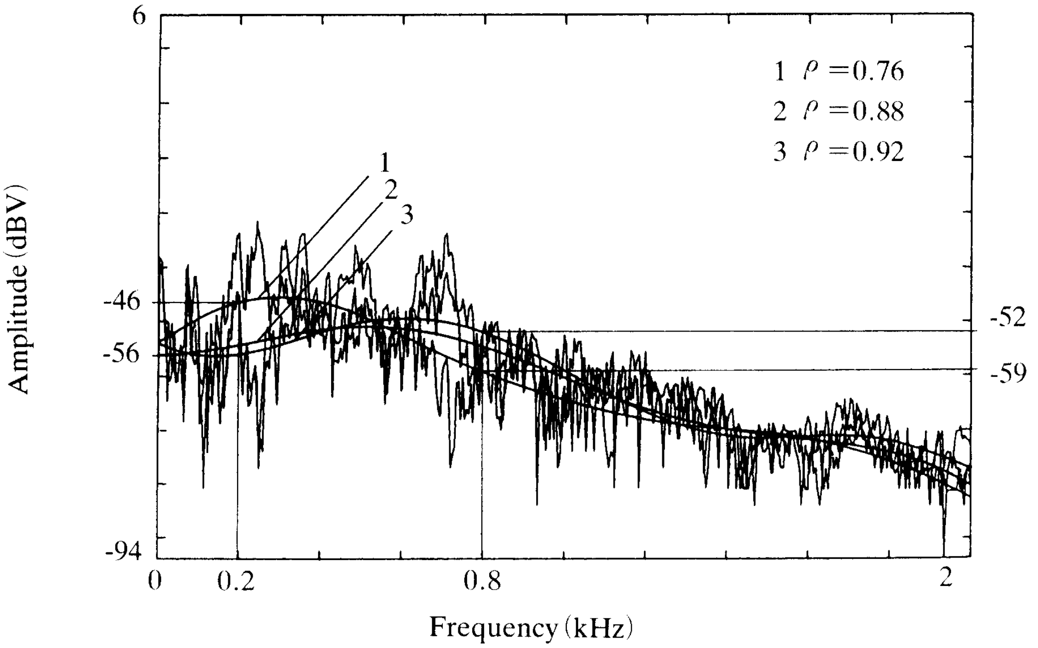

Fig. 3. Effect of density on the frequency spectrum.

2.Curve fitting routine

The frequency spectrum process revealed visual trends with the change of densities of the Samples. The next logical procedure was developed so that the frequency spectrum could be quantitatively parameterized quickly and accurately. An empirical approach was adopted to accomplish this task.

In order to develop a better empirical expression of the curves fitted to the frequency spectrum, a number of mathematical expressions were attempted. A polynomial expression of x was finally chosen as the mathematical equation for fitting curve, which is expressed as follows:

$$F(x) = \sum_{0}^{n} a_n X^n \qquad (1)$$

where F(x) is amplitude at various frequencies in frequency spectrum,

a_n is coefficient related to the density of sample,

x is frequency.

Terms beyond the sixth power of x does not significantly improve the function and the resulatant expression turns out to be

$$F(x) = \sum_{0}^{5} a_n X^n \qquad (2)$$

These coefficients were determined, using an iterative least square method.

Because the impact velocity only affected the amplitude at various frequencies in frequency spectrum not affecting the shape of the frequency spectrum (Fig.2), the impact velocity affected only the coefficient a_0, leaving the other coefficients a_n unaffected. Besides, from Fig.3, the coefficients a_1, ………, a_4 and a_5 were related to the densities of Sakurajima radishes.

Let the density of any Sakurajima radish (say density denoted by ρ) be given by the linear model of a_1,a_2,a_3,a_4,a_5 and the cross products. So

$$\begin{aligned}\rho = {} & k_0+k_1a_1+k_2a_2+k_3a_3+k_4a_4+k_5a_5+k_6a_1a_2+k_7a_1a_3+k_8a_1a_4 \\ & +k_9a_1a_5+k_{10}a_2a_3+k_{11}a_2a_4+k_{12}a_2a_5+k_{13}a_3a_4+k_{14}a_3a_5 \\ & +k_{15}a_4a_5+k_{16}a_1a_2a_3+k_{17}a_1a_2a_4+k_{18}a_1a_2a_5+k_{19}a_1a_3a_4 \\ & +k_{20}a_1a_3a_5+k_{21}a_1a_4a_5+k_{22}a_2a_3a_4+k_{23}a_2a_3a_5+k_{24}a_2a_4a_5 \\ & +k_{25}a_3a_4a_5+k_{26}a_1a_2a_3a_4+k_{27}a_1a_2a_3a_5+k_{28}a_1a_2a_4a_5 \\ & +k_{29}a_1a_3a_4a_5+k_{30}a_2a_3a_4a_5+k_{31}a_1a_2a_3a_4a_5\end{aligned} \tag{3}$$

For a number of values of ρ , equation 3 can be written in matrix form as follows:

$$\begin{bmatrix}\rho_1\\ \rho_2\\ \rho_3\\ \cdot\\ \cdot\\ \cdot\\ \cdot\\ \rho_n\end{bmatrix} = \begin{bmatrix}1 & a_{11} & a_{12} & \cdots\cdots & a_{11}a_{12}a_{13}a_{14}a_{15}\\ 1 & a_{21} & a_{22} & \cdots\cdots & a_{21}a_{22}a_{23}a_{24}a_{25}\\ 1 & a_{31} & a_{32} & \cdots\cdots & a_{31}a_{32}a_{33}a_{34}a_{35}\\ \cdot & \cdot & \cdot & \cdots\cdots & \cdot\\ \cdot & \cdot & \cdot & \cdots\cdots & \cdot\\ \cdot & \cdot & \cdot & \cdots\cdots & \cdot\\ \cdot & \cdot & \cdot & \cdots\cdots & \cdot\\ 1 & a_{n1} & a_{n2} & \cdots\cdots & a_{n1}a_{n2}a_{n3}a_{n4}a_{n5}\end{bmatrix} \begin{bmatrix}k_0\\ k_1\\ k_2\\ \cdot\\ \cdot\\ \cdot\\ \cdot\\ k_{31}\end{bmatrix}$$

If $n=32$, the coefficients k_0,k_1,k_2,k_3, ……… k_{31} can be determined from the above mentioned simultaneous algebraic equations. If $n>32$, the solution is over determinant. For calibration purpose, it is necessary to use an iterative least square method and therefore, the values of coefficients k_0,k_1,k_2,k_3, ……… k_{31} should be such as in the following:

$$\sum_{0}^{n} (\rho_n - \rho_{np})^2 = \text{minimum} \tag{4}$$

where ρ_n is actual value of Sakurajima radish density and ρ_{np} is predicted value of Sakurajima radish density.

Using the coefficients, a_1,a_2,a_3,a_4,a_5 and the coefficients k_0,k_1,k_2,k_3, ……… k_{31}, the densities of Sakurajima radishes were predicted. A subroutine program was written in BASIC, to solve for the coefficients. In the experiment, seventeen-five Sakurajima radishes with different densities from 0.76kg/cm^3 to 0.98kg/cm^3 were used and some excellent predictions of densities were obtained for Sakurajima radish. A comparison of actual values of densities with the corresponding predicted values was shown as in Fig. 4.

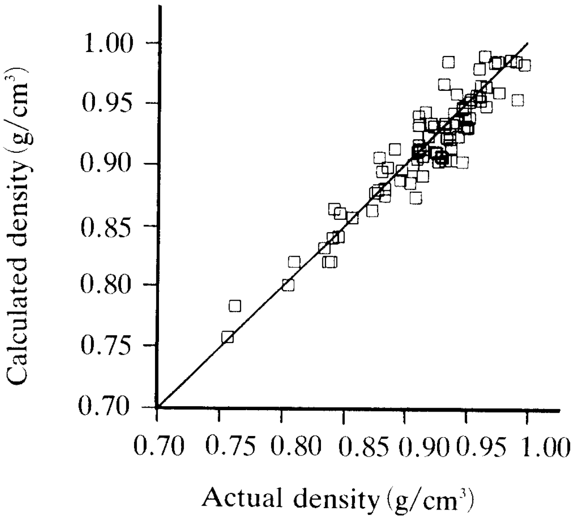

Fig. 4. Plot of actual density and calculated density.

Comparison of the density values obtained by the acoustic impulse response and conventional method showed that two methods gave extremely close results, indicating that the method of using the acoustic impulse response seemed to be suitable one for determining the density of intact Sakurajima radishes.

Summary

In the research, an acoustic impulse response of Sakurajima radishes was used for measuring its density related to the marketing quality. At first, relationship between the frequency spectrum of acoustic data and impact forces, and that between it and the densities of the samples were investigated. Besides, a polynomial expression was fitted to the frequency. As the result, the curve fitting procedure successfully predicted the densities of the respective samples, and the excellent correlation between the density values obtained by acoustic impulse response and those of conventional method for measuring mass and volume of samples, was obtained. And hence, the result showed that the method was suitable for determining the density of Sakurajima radishes.

References

1) Kunkel, R.: Gravity grading of potatoes. *Amer. Potato Jour.*, **27**, 59-64, (1950)
2) Kato, H.: Valuation of qualities of fruit and vegetables by electrical method. *Symp. Japan. Soc. Hort. Soc. Autumn Meet.*, 206-219, (1992)
3) Mueller, R. A., P. B. Brooker and J. J. Cassidy.: Aerodynamics properties of black walnuts: Application in separating good from bad walnuts. *Trans. of the ASAE.*, **10**,57-61, (1967)
4) Mizrach, A., A. Zaltzman, G. Manor and Z. Nir.: Gravitational motion of spheres in a fluidized bed. *Trans. of the ASAE.*, **27**(6),1674-1678, (1984)
5) Patzlaff, A. W.: Hydrodynamic blueberry sorting. *United States Patent.*, **4**, 225-424, (1980)
6) Wolfe, R. R., W. Y. Chan and A. P. Cobianchi.: Criteria for maturity separation of highbush blueberries. *Trans. of the ASAE.*, **17**(6),1117-1120, (1974)
7) Wolfe, R. R., H. S. Jalli, M. J. Ceponis and R. A. Cappellini.: Evaluation of density separation for removing immature fruit from mechanically harvested blueberries. *Trans. of the ASAE.*, **18**(4),760-764,769, (1975)

8) Zaltzman, A., R. Feller, A. Mizrach, Z. Schmilovitch.: Separating potatoes from clods and stones in a fuidized bed medium. *Trans. of the ASAE.*, **26**(4),987-990,995,(1983)
9) Zaltzman, A., Z. Schmilovitch.: An evolution of the potato fluidized bed medium separator. *Paper of the ASAE.*, **No.85,** 6016,(1985)
10) Zaltzman, A., B. P. Verma, Z. Schmilovitch.:Potential of quality sorting of fruits and vegetables using fluidized bed medium. *Trans. of the ASAE.*, **30**(3),823-831,(1987)