Available online at www.elixirpublishers.com (Elixir International Journal)

Agriculture

Elixir Agriculture 46 (2012) 8418-8421

ISSN: 2229-712X

Prediction of banana volume using capacitive sensing method

Javad Taghinezhad[1], Reza Alimardani[2] and Mahmoud Soltani[2]

[1]Department of Agricultural Machinery Engineering, Faculty of Agricultural Engineering & Technology University of Tehran, P.O. Box 4111, Tehran 13679-47193, Iran.

[2]Department of Agricultural Machinery Engineering, Faculty of Agricultural Engineering & Technology University of Tehran, P.O. Box 4111, Karaj 31587-77871, Iran.

ARTICLE INFO

Article history:
Received: 18 March 2012;
Received in revised form:
3 May 2012;
Accepted: 19 May 2012;

Keywords
Volume,
Measurement,
Banana,
Electrical properties,
Capacitive Sensor.

ABSTRACT

An electronic device based on capacitive sensor was developed to predict the volume of banana fruit. This system, which is used for volume measurement has four components: a rectangular parallel plate capacitor, electronic circuitry, microcontroller, and display unit. After calibrating the electronic system, the results were verified with calibrated curve by means of linear regression and paired t-test. The coefficient of determination (R^2) for 1, 10, 100, and 450 kHz frequencies were obtained as 0.934, 0.88, 0.932, and 0.935, respectively. The acquired P-values for 1, 10, 100, and 450 kHz frequencies were 0.541, 0.448, 0.132, and 0.064. The results indicated that banana fruits size has no effect on the accuracy of the computed volume. The results for banana fruits showed that the predicted volume and actual volume are highly correlated and this method is ideal for determining the volume of fruits and it can be developed for other fruits, too.

Introduction

The physical characteristics of agricultural products are the most important parameters in determining the proper standards of design for grading, conveying, processing, and packaging systems. The major physical properties of fruits are shape, size, density, porosity, volume, mass of fruits, friction against various surfaces, and moisture content (Omid et al., 2010).

One of the most important applications of electronics and computer in agriculture is designing systems for measuring physical properties of agriculture products such as moisture content and friction. Volume is another property that needs a precise and fast measurement for grading the fruits. Volume can be used for harvest time prediction (Hahn and Sanchez, 2000). For instance, volume used as a fruit and vegetable sorting feature shows a 0.91 correlation coefficient with length on jalapeno chilli grading (Hahn et al., 1997). Different mathematical models and numerical analysis methods have been applied to extract a representation of volume (Soltani et al., 2010). Some commonly used methods include geometric mean diameter, water displacement method (WDM), and gas displacement method (Omid et al., 2010).

Traditionally, the volume is measured using the WDM, in which the object will be entirely submerged in water and the weight of the displaced water is measured. In spite of the fact that this method is quite accurate, it is not ideal for objects that absorb water and some products (Wang et al., 2007); (Soltani et al., 2011). Even so, there are disadvantages associated with some of these procedures. For example, the WDM can promote microbial growth due to its moistening the surface of materials being measured (Jarimopas et al., 2005); also, this method is a time-consuming process.

Another way of measuring the volume of fruits is image processing (IP). Also, this method is used for physical measurement of a wide variety of food products that have been implemented automatically in the literature. Du and sun (2006) estimated the surface area and volume of ellipsoidal ham using this method. Sharifi et al. (2007) studied some physical properties of orange with image processing procedure. Omid et al. (2010) estimated the volume and mass of citrus fruits by image processing technique. However, this method is accurate and reliable but the IP technique requires using expensive equipment (Jarimopas et al., 2005).

In this research we are after a low cost, simple and quick machine to measure the volume of fruits. The present paper reports the study of the volumes in ripe banana fruit; the banana was selected because it was not used in IP method and therefore, this research presents a new method for predicting the volume of banana by using a capacitive sensing method.

Material and methods

Instrumentation

In order to predict the volume of banana fruit, an electronic unit was designed and developed. The device for volume measurement has four components: a rectangular parallel plate capacitor, electronic circuitry, microcontroller, and display (Fig. 1). Measuring the voltage is performed after the banana is placed on the capacitive sensor plates. Voltage measurements are shown on the display.

The circuit diagram of the system for predicting the volume of banana fruit is shown in Fig 1. The ATmega-32 microcontroller is the principal part of the system. The ATmega-32 converts analog voltage to digital voltage and can be calibrated and programmed to predict the volume of banana fruit. The output voltage from sensor is converted to DC current by a diode bridge, and then the ADC unit of ATmega-32 measures the output voltage. Finally, the result of the banana volume prediction is displayed on a 16×2 characters LCD.

To estimate the volume of banana, a rectangular parallel plate capacitor with 25 cm in length and 10 cm in width was

Tele:
E-mail addresses: j.taghinezhad@ut.ac.ir

constructed as a standard hardware instrument (Soltani et al., 2011).

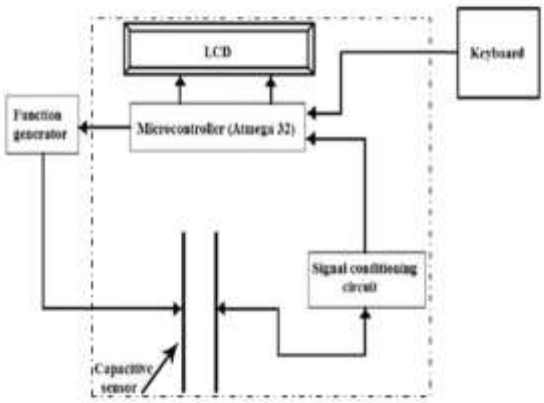

Fig 1. Block diagram of instrument for predicting the volume of banana fruit.

Sample preparation

Forty-three fingers of *Cavendish* variety of banana fruit were randomly selected from banana boxes provided by a local market and transferred to the Physical Properties of Materials Laboratory, Department of Agricultural Machinery Engineering, Faculty of Engineering and Technology, University of Tehran, Karaj, Iran. Twenty-nine of them were used for calibration and the others, for tests. The experiments were conducted in the controlled temperature room at 25.5 °C.

Measurement of moisture content

To study the effect of moisture content on the output of sensor, a cutting cylinder with inner diameter of 20 mm and height of 50 mm was utilized for determining the moisture content sample of each banana fruit. Each sample was cut from the middle part of the banana fruit on its lateral surface.

Due to a lack of uniformity in the thickness of banana fruits, after preparing the samples, the height of each sample was determined using a digital vernier caliper having an accuracy of ±0.01 mm. The mass of the specimens were measured by a digital balance with ±0.01 mg accuracy; the mass of the specimens peel were also measured separately. The moisture content was determined by placing 20 mm diameter banana slices with peel in a single layer aluminum dish in a hot air oven, at 130°C for 1.5 h (Kachru et al., 1995). Afterwards, pulp and peel of the samples mass were measured and the percent of moisture content of the pulp and peel were determined separately.

Volume determination

The actual volume of banana fruits was measured using water displacement method (WDM). The procedure is as explained in the coming section: the container is first weighed on a scale and then banana fruit was dipped into water with a fixture shown in Fig. 2. The weight of the displaced water is then calculated by subtracting the weight of the water-filled container from the weight of the container with fruit. The resulting value is then used to calculate the volume of the fruit by using the following formula (Mohsenin, 1970):

$$Volume = \frac{Weight\ \ of\ \ displaced\ \ water\ \ (kg)}{Water\ \ density\ \ \left(kg/cm^3\right)} \qquad (1$$

The measured volume was added to the volume of moisture content of sample and hence the total volume of banana fruits was determined.

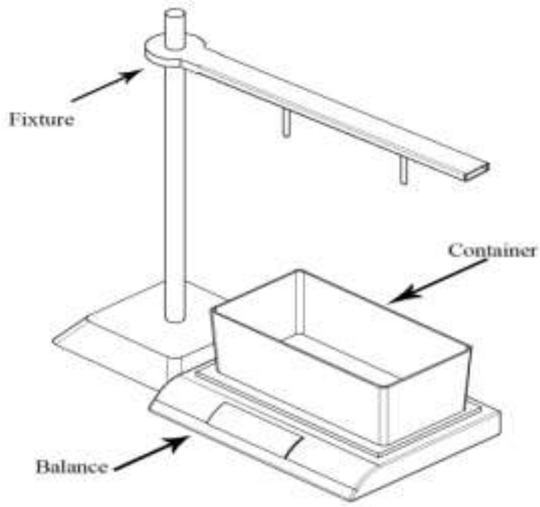

Fig 2. Equipment for WDM method

Statistical analysis

Twenty-nine fingers of banana fruits were used for calibration of the instrument and fourteen samples were used for verification. Dielectric voltage measurement of banana fruits was carried out at 4 levels of frequencies at 1, 10, 100, and 450 kHz. The linear regression was used to determine the correlation between the output voltage and the actual volume of banana fruits; In order to study the correlation between the volume estimated by the capacitive sensor method (CSM) and actual volume (WDM), a linear regression was used. Additionally, a paired t-test was used for studying the correlation significance level of CSM and WDM. The SPSS software (Version 16.0, 2007) was used to analyze the data and determine the regression models between the studied attributes.

Results and discussion

The actual volume of banana fruits was measured using WDM (Eq. (1)). Also, moisture content of pulp and peel of banana fruits were separately measured. A summary of the descriptive statistics of the examined banana fruits is shown in Table 1.

Fig. 3 shows the result of the correlations between actual volume and measured voltage for 1, 10, 100, and 450 kHz frequencies, respectively. The coefficient of determination (R^2) for 1, 10, 100 and 450 kHz frequencies were obtained 0.876, 0.878, 0.917, and 0.891, respectively.

The R^2 values are an indication of the proportion of variances between the voltage of the system and the actual volume measurements. The higher R^2 value is obtained at 100 kHz frequency.

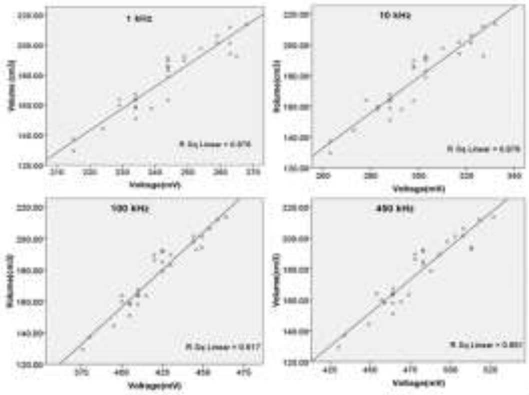

Fig 3. Calibrating curves for various frequencies and relationship between moisture content and measured volume

According to Fig. 4, there was not a good correlation between the measured voltage and the moisture content of banana fruit in this method.

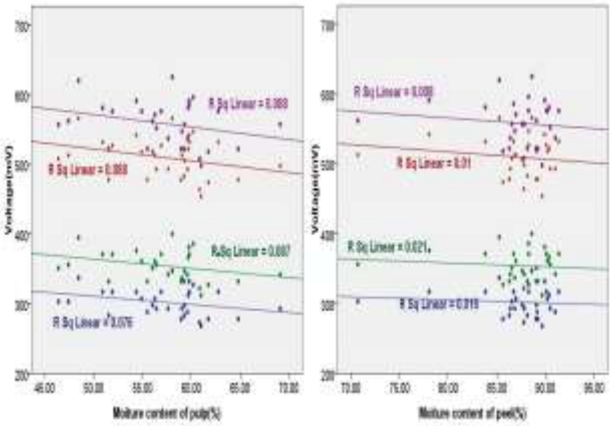

Fig 4. Relationship between moisture content and measured voltage

After calibrating the instrument, fourteen other samples of banana fruit were tested for showing the result of the calibration. The minimum, maximum, average values and standard deviation of banana fruits volume (measured with WDM and predicted with CSM) for 1, 10, 100, and 450 kHz frequencies are presented in Table 2.

The results of correlation between predicted and measured volume of banana fruits for 1, 10, 100, and 450 kHz frequencies are shown in Fig. 5. The R^2 value for 1, 10, 100, and 450 kHz frequencies were calculated as 0.934, 0.88, 0.932, and 0.935, respectively. The higher the R^2 values, the closer the CSM results are to the WDM results. The submitted CSM provided above 93% accuracy in appraising the banana volume at 1, 100, and 450 kHz frequencies.

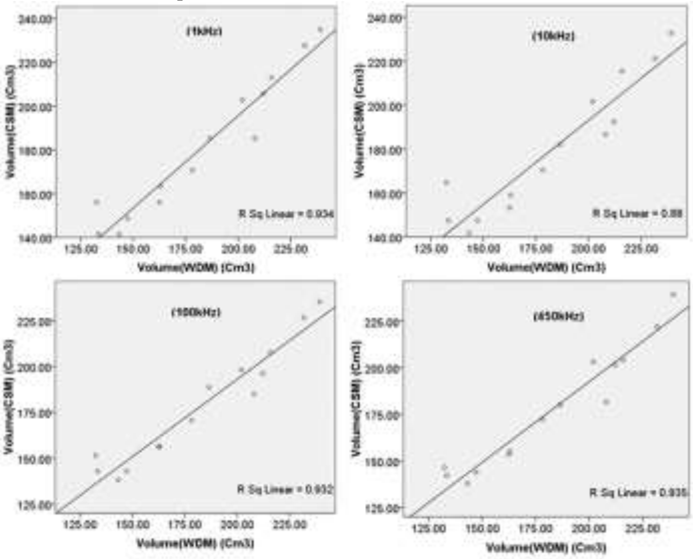

Fig 5. Comparison of estimated (CSM) and measured volume (WDM) of banana fruits

The next comparison was provided by means of the paired t-test results. The mean volume difference between CSM method and the Standard Deviation (Std) of the volume differences are presented in Table 3. The obtained P-values for 1, 10, 100, and 450 kHz frequencies were 0.541, 0.448, 0.132, and 0.064, respectively. Consequently, the paired t-test results confirm the volumes estimated with CSM and WDM that were not statistically significant at the 5% level (P > 0.05). The corresponding Standard Deviations (Std.) for the volume differences were 9.97, 13.34, 10.03, and 9.61 cm^3, respectively (Table 3).

The average differences, reported in Table 3, were 1.67, 2.79, 4.31, and 5.21, respectively. From these results, it can be seen that banana fruits' size has no effect on the accuracy of the determined volume (P > 0.05).

Conclusion

In order to predict the volume of banana fruit, an electronic system was designed, developed and tested. The best results of calibration were obtained at 100 kHz. The paired t-test results confirmed the volumes computed with CSM and WDM were not statistically significant at 5% level (P > 0.05), but it can be concluded that with an increase in the frequency, the results approach the significant value. Then, the capacitive sensor method is adequately a reliable method for measuring the volume of banana; and it needs to be calibrated for measuring other fruits volume.

References

Du Ch, Sun Da. Estimating the surface area and volume of ellipsoidal ham using computer vision. Journal of Food Engineering. 2006; 73, 260–268.

Hahn F, Mota R, Vazquez M. Nobel automatic jalapeno chili classifier fits inside a Trailer. ASAE Paper. 1997; No. 973054.

Hahn F, Sanchez S. Carrot volume evaluation using imaging algorithms. Journal of Agricultural Engineering Research. 2000; 75, 243-249.

Jarimopas B, Nunaka T, Nunak N. Electronic device for measuring volume of selected fruit and vegetables. Postharvest Biology and Technology. 2005; 35, 25–31.

Kachru R. P, Kotwaliwale N, Balasubramanian D. Physical and mechanical properties of green banana (Muss paradisiaca) fruit. Journal of Food Engineering. 1995; 26: 369-378.

Mohsenin N. N. Physical properties of plant and animal materials. New York, NY: Gordon and Breach Science Publishers. 1970.

Omid M, Khojastehnazhand M, Tabatabaeefar A. Estimating volume and mass of citrus fruits by image processing technique. Journal of Food Engineering. 2010; 100, 315–321.

Sharifi M, Rafiee S, Keyhani A, Jafari A, Mobli H, Rajabipour A, et al. Some physical properties of orange (var. Tompson). Int. Agrophysics. 2007; 21, 391-397.

Soltani M, Alimardani R, Omid M. A new mathematical modeling of banana fruit and comparison with actual values of dimensional properties. Modern Applied Science. 2010; 4(8), 104-113.

Soltani M, Alimardani R, Omid M. Design and development of a portable banana ripeness inspection system. Journal of American Science. 2011; 7(6), 401-405.

Soltani M, Alimardani R, Omid M. Evaluating banana ripening status from measuring dielectric properties. Journal of Food Engineering. 2011; 105, 625–631.

SPSS. SPSS User's Guide: Statitics.Ver. 16. SPSS, Inc., Tehran, Iran. 2007.

Wang T.Y, Nguang S.K. Low cost sensor for volume and surface area computation of axi-symmetric agricultural products Journal of Food Engineering. 2007; 79, 870–877.

Table 1. Statistics summary of the measured values of banana fruits mass, volume, voltage and moisture content

Descriptive statistics	Mass (g)	Volume (cm^3)	Measured voltage (mV)				Moisture content (%)	
			1 kHz	10 kHz	100 kHz	450 kHz	Pulp	Peel
Min	123.06	129.49	215	263	376	430	46.40	70.71
Max	205.65	213.54	268	332	464	527	69.11	91.36
Mean	169.13	176.92	243	299	422	479	57.29	87.31
Std	22.77	22.53	14	18	23	25	5.04	4.06

Table 2. Comparison of measured (WDM) and estimated volume of banana fruit used in the analysis

Parameters	Volume (cm^3)				
	WDM	CSM			
		1 kHz	10 kHz	100 kHz	450 kHz
Min	132.52	141.49	141.79	138.17	137.94
Max	239.29	234.88	232.71	235.17	239.21
Mean	182.56	180.89	179.77	178.25	177.35
Std	36.34	31.67	29.66	31.81	32.53

Table 3. Paired t -Test analysis between the two volume measurement methods

Frequency (kHz)	Paired t -test	R^2	Std (cm^3)	Mean volume difference (cm^3)	95% Confidence Interval of the Difference	
					Lower	Upper
1	0.541	0.934	9.97	1.67	-4.08	7.43
10	0.448	0.880	13.34	2.79	-4.91	10.49
100	0.132	0.932	10.03	4.31	-1.48	10.10
450	0.064	0.935	9.61	5.21	-0.35	10.76