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Mass determination of Sugarcane Stalks by dielectric technique

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ABSTRACT

Electrical properties of sugarcane stalks were studied in order to develop a rapid and non-destructive assessment technique and to determine the mass of sugarcane stalks. A 5 V sine wave AC power supply and a rectangular parallel plate capacitor sample were used to span the difference in capacitance caused by the insertion of sugarcane stalks between the plates. To remove the effect of air gap between the plates, an equivalent capacitor was derived. The correlation between mass of sugarcane stalks and output voltage from the device for each sample was investigated. Experiments indicated a high correlation between mass and output voltage for each sample of sugarcane stalks and a quadratic trend line was best fitted to the data. The coefficient of determination (R^2) between actual mass and presented voltage was 0.955. For testing results, the coefficient of determination (R^2) of mass prediction was obtained as 0.969. This method can confidently predict the mass of sugarcane stalks and it can be used in different machines and agricultural mechanism.

Introduction

Sugarcane (Saccharum officinarm L.) is an important raw material for the sugar industries (Frank, 1984). Sugar cane is a perpetual agricultural crop grown primarily for the juices extracted from its stalks. Raw sugar produced from these juices are later refined into white sugar. As a perennial crop, one planting of sugarcane will generally allow for three to six or more annual harvests before replanting is necessary. In Iran, sugar cane is widely cultivated on an area of about 68352 ha with an annual production of about 5685090 ton (FAO 2010).

Size is an important physical property of all agricultural crops. Determination of mean crop size and quantity is important in counting amount of planting crop, monitoring crop growth, predicting yield and assessing optimal levels of fertilization and irrigation (Pordesimo et al. 2004). Crop size determination is also useful in transportation operations. Crop can be measured according to different physical parameters, such as diameter, length, weight, volume, circumference, projected area, or any combination of these (Peleg 1985). The size of an agricultural product is frequently represented by its weight because it is relatively simple to measure. In the field non-destructive estimates of this parameter can be used as a maturity index to predict optimum harvest time (Hahn and Sanchez 2000), predict yield (Mitchell 1986). In the context of postharvest operations, crop size determination is important for several reasons.

Measurement of amount of plant in duration of harvesting is detrimental, more costly and time consuming (Reese et al. 1980). According to Jones et al (2006), several methods to appraise amount of crops remotely and quickly have been generated. These methods comprise plant growth indices to directly determine amount of crops using experimental equations (Das et al. 1993; Guevara et al. 2002; Moges et al. 2004; Tucker 1979), leaf area index (LAI) and intercepted radiation estimates integrated in crop simulation models as the Monteith model (Asrar et al. 1985). Although, the truth of these methods is failed by dynamic atmospheric and agronomic factors (Serrano et al. 2000). In addition, some of the test techniques are destructive, expensive, more time consuming and less attractive for farmers.

Researchers have tested different techniques of using the dielectric properties of agricultural crops to estimate different physical parameters. For example Campbell et al. (2005) designed and developed a system based on capacitive sensor for monitoring bees passing through a tunnel. Jarimopas et al. (2005) designed and developed an electronic device with a cylindrical capacitive sensor to measure the volume of selected fruits and vegetables. Ragni et al. (2006) used a sine wave radio frequency oscillator with parallel plate capacitor sample probe to predict the quality of egg during storage period. Afzal et al. (2010) estimated leaf moisture content by measuring the dielectric constant of leaves in five different types of crops. Soltani et al. (2011) studied electrical properties of banana fruit in order to develop a rapid and non-destructive appraisal technique and to control its ripening treatment by using capacitive sensor. Soltani et al. (2011) designed and developed an electronic device with capacitive sensor basis to predicting corn and lentil moisture content using dielectric properties.

The object this paper was to study the electrical impedance technique by developing a model in order to estimating the mass level of sugarcane stalks, and also aims to apply the capacitive technique to an automatic control system for the weighting process of sugarcane stalks.

Materials and Methods

Sample preparation

Sugarcane stalks harvested on October, 2011 from the field in Debel Khazaie, Ahvaz, Iran and transported to the Physical Properties of Materials Laboratory, Department of Agricultural Machinery Engineering, Faculty of Engineering and Technology, University of Tehran, Karaj, Iran. The collected sugarcane was stored (1 week) indoors until experiments in a laboratory having air conditions of about 25° C and relative humidity of about 55%. Samples of sugarcane stalks of

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approximate length of 25 cm were cut using a bandsaw with fine blade.

Moistur***e content measurement***

In order to investigation of moisture content effect on sugarcane stalks' mass each sample was prepared in five level of moisture content. Thus to approach the higher moisture level, sugarcane stalks must be placed near the vapor of water, so the samples were placed in saturated air in an isolated box at 30˚C for 24 hours. To achieve the lower moisture content level, the oven method was used at 103˚C for preparing 5 level of moisture content with time duration of 2 hours for each level.

Instrumentation

In order to predict the various moisture contents of sugarcane stalks, an electronic device with capacitive sensing basis was designed and developed. The device for mass measurement has four components: a rectangular parallel plate capacitor, electronic circuitry, microcontroller, and display (**Error! Reference source not found.**). Measuring of voltage is presented after the sugarcane billet is placed in the capacitive sensor plates. Voltage measurements are shown on the display in mili volt (mV).

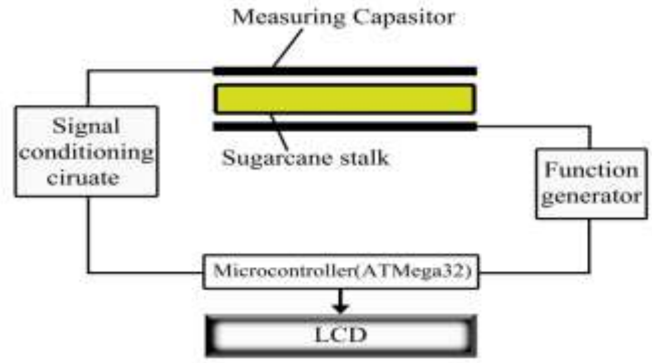

Fig. 1 Block diagram of instrument for predicting the moisture content of sugarcane billet

Experimental

Because moisture content of sugarcane stalks has an important role in its' mass then first we study the effect of moisture content on prediction of mass. There for after reduction of moisture content the mass and voltage of each sample was measured and this work repeated for five levels. For weighting samples digital balance with ± 0.01 gr accuracy was used. Finally samples kept in oven at 103˚C for 72 hours to determining the absolute moisture content of samples in each level. . Moisture content (M.C) was computed on dry basis by Eq.1.

$$M.C\% = \frac{w_w}{w_d} \times 100 = \frac{w_i - w_d}{w_d} \times 100 \qquad (1)$$

where w_i is the initial weight of sample, w_w is the weight of sample water and w_d is the weight of dried sample.

For studying relationship between mass and measured voltage and calibrating device hundred fifty four samples of sugarcane stalks were used and actual mass and voltage of each samples was measured for each sample. After that for testing results forty five samples was selected and relationship between presented results studied.

For analyzing data and presenting regression models Microsoft Excel 2010 was used also SPSS.16 (2007) software was used to T-test comparison for testing results.

Result and discussion

Investigation the effect of moisture content in relationship between actual mass and measured voltage

Error! Reference source not found. presented relationship between measured voltage (mV) and mass (gr) for five selected sugarcane stalk samples. When the mass of samples was increased, an increase in measured voltage was observed. This increase was clear in each sample and was independent from shape of samples and its physical properties and it can be revealed that there was high correlation between the mass and measured voltage for each sample. In each curves maximum mass for sample was located in the top of the curve with maximum voltage and minimum mass of samples was located in the bottom of the curve with minimum voltage this upholded the reduction of voltage with decreasing the mass of the samples also in each samples.

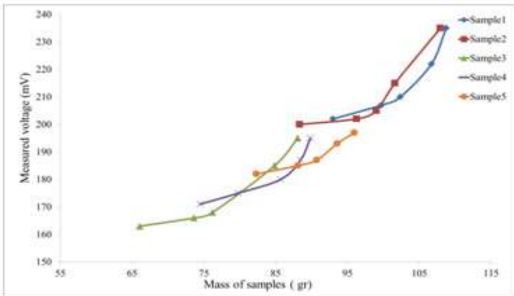

Fig. 2 Correlation between mass (gr) of sugarcane stalk and Measured voltage (mV)

From **Error! Reference source not found.** that is appeared the best equation that fitted to data was found as a quadratic function. Results of regression analysis (R^2) are shown in Table 1. A high relationship was perceived between measured voltage and mass of each sample. The lowest value of coefficient of determination was found in sample 2 (R^2 = 0.957) which is an acceptable value. It means that quadratic function can be fitted to relation of voltage-mass content as well.

Table 1. Summarized mass and voltage for five selected sample and coefficient value (R^2) between there

		Min	Max	Mean	Std	R^2
Sample 1	Mass	92.98	106.69	102.09	5.55	0.982
	Voltage	202	235	215.2	11.89	
Sample 2	Mass	88.36	107.95	98.64	6.44	0.991
	Voltage	200	235	211.4	12.88	
Sample 3	Mass	66.03	88.06	77.74	7.92	0.999
	Voltage	163	195	175.4	12.44	
Sample 4	Mass	59.58	76.61	68.27	5.59	0.957
	Voltage	155	175	165.6	6.62	
Sample 5	Mass	82.3	95.94	90.12	4.72	0.992
	Voltage	182	197	188.8	5.46	

Relation between mass and voltage in all samples

Fig. 2 shows the result of the correlations between actual mass and measured voltage for hundred fifty four sugarcane samples, and the best equation that fitted to data was found as a quadratic function.

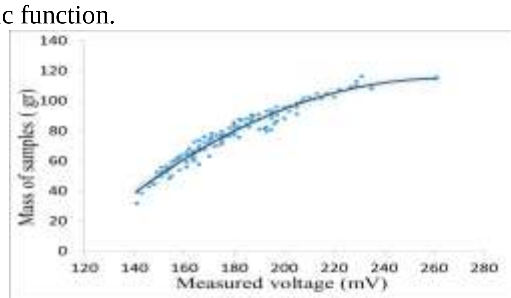

Fig. 3 Relationship between measured voltage and mass of samples

The actual mass of sugarcane stalks was measured using digital balance. A summary of descriptive statistics of the examined sugarcane stalks are shown in Table 2.

Equation between measured voltage (v) and actual mass (M) of samples is presented in Table 2. Also results of regression analyze (R^2) is shown. The value of coefficient of determination (R^2) was found 0.955 which is a reliable value. It means that quadratic function can be fitted to correlation of voltage-mass content as well. The R^2 values are an evidence of the proportion of variances between the voltage of the system and the actual mass measurements.

Table 2. Summary statistics of the measured values of stalks mass (gr) and voltage (mV).

	Min	Max	Mean	Std	Equation	R^2
Mass(gr)	31.82	116.11	76.07	17.29	$M = -0.0049v^2 + 2.6111v - 229.94$	0.955
Voltage(mV)	141	261	178.30	22.08		

Testing results

For showing the result of calibrating forty five number of sugarcane stalks sample were selected and actual mass of samples measured by balance and predicted mass of samples presented by electronic device were measured. The minimum, maximum, average values and standard deviation of sugarcane stalks (measured with balance and predicted with capacitive sensing method) are presented in Table 3.

Table 3. Relationship between actual and predicted mass

	Min	Max	Mean	Std	R^2
Actual mass (gr)	34.96	118.96	22.55	17.95	0.969
Predicted mass (gr)	35.81	117.38	23.13	17.61	

The results of correlation between predicted and measured mass of sugarcane stalks are shown in **Error! Reference source not found.**. The R^2 value was calculated as 0.969 for linear relationship between two groups. The higher the R^2 values, the closer the predicted results are to the actual measured mass results. The submitted capacitive sensing method provided about 97% accuracy in determining the sugarcane stalks.

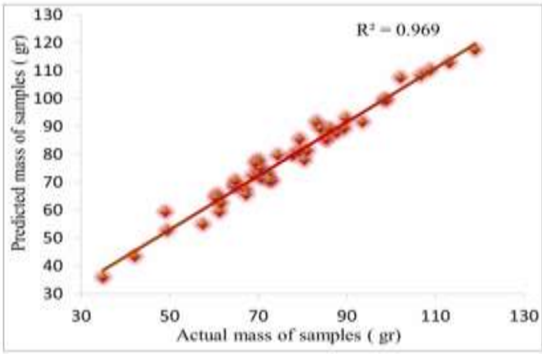

Fig. 4 Relationship between actual and predicted mass of sugarcane stalks.

The paired T-test analyze comparison was used for investigation the relationship between actual measurements and predicted mass of sugarcane stalks. The mean mass difference (gr) between actual measurements and prediction with capacitive sensor method and, the Standard Deviation (Std) of the mass differences are reported in Table 4. The obtained P-value was 0.000. There for, the paired T-test results confirm the mass estimated with electronic device and actual mass had not statistically significant difference at the 5% level ($P > 0.05$). The corresponding Standard Deviations (Std) for the differences between two groups was 3.184 (Table 4).

Table 4. Paired t -Test analyze between actual measurement and prediction.

Groups	Mean (gr)	Std (gr)	Mean difference (gr)	95% Confidence Interval of the Difference		T	Sig. (2-tailed)
				Lower	Upper		
Actual and Predicted mass	1.980	3.184	0.475	1.023	2.936	4.172	0.000

The average difference, presented in Table 4, was 0.475. From these results, it can be seen that sugarcane stalk's size and shapes has no effect on the accuracy of determined mass ($P > 0.05$).

Conclusion

The sugarcane mass determination by means of the designed and developed parallel plate capacitance sensor appeared to be a reliable way. The results revealed a strong quadratic trend line relationship between the mass of the wet sugarcane crop material put through the sensor between its plates and the tested measuring capacitance sensor circuit output voltage. This system can be used for different machines and mechanism in agriculture for predicting the mass of sugarcane. For example it can be used in stalks delivery location in planters for investigation of planter efficiency or determining the mass of planted material. Also it can be used in discharge chute of harvester for determining amount of harvested crop or to surveying the efficiency of discharge chute.

It is easier to recalibrate the machine for different crops and materials because it is not necessary to adjust all the ejection points individually; the electronic weighting can achieve a more accurate weight measurement; and higher operating speeds are possible.

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