ISSN (Online): 2305-0225
Issue 15(3), May 2014, pp. 437-440

Evaluation of Forage Moisture Content Measurement using Capacitance Sensor

Nadia Delavarpour, Mohammad Loghavi, Masoud Barati

Abstract— Moisture is one of the most important factors during and after the harvest in forage crops. Hay moisture content has a considerable impact on different stages of harvest and post harvest such as baling, transportation, storage, etc. and therefore its role is very evident in production processes. The conventional method of moisture measurement in forage is based on weighting method that is time-consuming and costly and the product sample will lose its original properties. In this study a capacitive sensor for real-time and continuous measurement of hay moisture content was designed, fabricated and evaluated. Alfalfa samples used in laboratory evaluation were obtained from alfalfa fields of the College of Agriculture research farm at Shiraz University, at three levels of moisture content, three levels of density and five levels of capacitor plates spacing. The results showed that there is a significant relationship between moisture content and capacitance sensor's output. Also temperature has a significant effect on the sensor's outputs.

Keywords— Alfalfa, Capacitance, Moisture content, Precision Agriculture, Real-time measurement.

I. INTRODUCTION

One of the biggest problems facing the harvested forage is the need to reduce the initial moisture content of about 80 percent to 20 percent (wet basis). Moisture content of 20% is appropriate for forage baling and storage and does not lead to fermentation and corruption (savoie et al., 1982). Most of the existing devices used for measuring moisture content of agricultural products are stationary and manually operated. By highlighting the importance of precision farming and site-specific farm management decisions, the need for tools for continuous and on-the-go measurement of forage moisture content during baling operations in the field becomes more important. So, in this study we tried to design and fabricate an instrument to measure forage moisture content continuously and simultaneous with baling. Here also the economic aspect of the project was considered such that the device be low-cost and affordable. The moisture content of forage is measured using two methods: direct and indirect methods. In direct method, a specific mass of forage is placed in oven at a specific temperature for a specified time. Then, the dried sample is precisely weighed to obtain the moisture content. Although these methods are more common than the indirect methods, but they are very expensive and time consuming and need laboratory equipment. Thus, its preferred to use indirect methods that measure moisture content in field (Zazueta & Xin, 2005). Indirect methods are usually based on measuring a property of material that has a close relationship with moisture content. On-line moisture measurement methods include: Resistance, capacitance, sonic, near-infrared radiation, nuclear magnetic resonance and microwave methods. Among them the most important and common method for measuring moisture content is based on measuring capacitance or dielectric properties of products. This property changes with the type of materials in addition to change with moisture content of materials. Dielectric constant of a material is its ability to store electrical energy. Capacitance can be changed by varying three factors: The spacing between capacitor plates, plates surface are and dielectric type. So, the capacitive-type moisture meter is capable of measuring moisture content of a material. Many studies in the field of moisture measurement of agricultural products and their dielectric properties were conducted by employing capacitive sensors. Osman et al. (2002) built a parallel plate capacitor with variable plate spacing for hay and forage moisture measurement. Their results indicated that the sensor could not directly determine the moisture content. However, a good correlation was observed between the output of the sensor and the amount of water within the volume of the capacitor. The frequency drop and the amount of water correlated more closely at low moisture contents than at high moisture contents. McIntosh and Kasada (2008) designed another sensor for measuring moisture content for agricultural products. This sensor was rod shaped and to measure moisture content it was inserted into the bulk of agricultural products. The sensor was composed of three capacitors and for measuring the moisture content, the electric field formed by capacitor (local field) was used (MacIntosh & Casada, 2008). Knowing the moisture content of hay bales is essential during baling and subsequent processes including storage. The purpose of determining forage moisture during baling is to enhance the power of decision making regarding continued process of baling operations.

ISSN (Online): 2305-0225
Issue 15(3), May 2014, pp. 437-440

The main objectives of this study included design and fabrication of a capacitance type real-time moisture sensor for alfalfa hay and investigating the effect of hay moisture content and capacitor plates spacing on its performance.

II. Material and Methods

A. Design and fabrication of the capacitance sensor

For designing a moisture sensor based on the basic principle of capacitance, two metal electrodes as capacitor plates are required to enclose the forage sample as a dielectric material. In this study, two 50×50 cm aluminum plates with 1 mm thickness and coated with Teflon insulation were used to make capacitor plates. In order to carry out the tests at various plate spacing and also to create bale density observed in field conditions, at laboratory, a 50×50×50 cm chamber with was made. Aluminum studs for holding the capacitor plates were installed at intervals of 50, 40, 30, 20 and 10 cm on two inner sides of the chamber. Schematic of the chamber design by ANSYS software is shown in Figure 1 and also Figure 2 shows actual picture of the chamber and how the capacitor plate are installed.

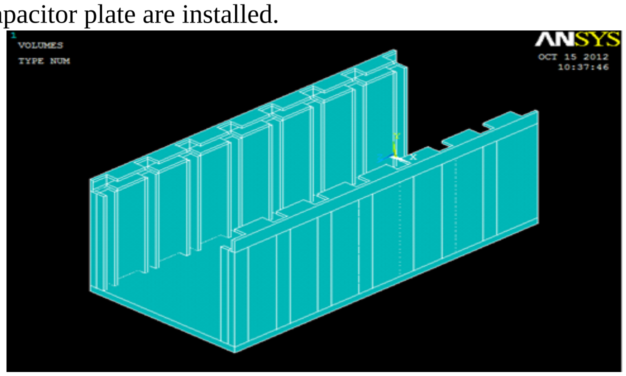

Figure 1. Schematic view of the chamber

Figure 2. The actual picture of the chamber showing aluminum studs and capacitor plates in the chamber chamber

By using the aforementioned capacitor chamber, the capacity changes due to different alfalfa hay moisture contents and capacitor plates spacing were measured..

B. Electronic circuitFigures

An IC 555 was used to generate a square wave in electronic circuit. An Arduino 2560 microcontroller was used to process a SHT10 temperature sensor and IC555 data. A 16-character LCD was used to display temperature and capacitor variation.

C. Moisture sensor test

In order to test and evaluate the moisture sensor, laboratory experiments were performed at constant temperature. The experiments were carried out with three levels of moisture content (10%, 20% and 30%), three levels of hay density (80, 100 and 130 kg.m-3 and five levels of capacitor plates spacing (10, 20, 30, 40 and 50 cm). Three replicates were considered for each treatment and totally 135 tests were performed. Given hay density and container volume at any capacitor plates spacing, the needed hay mass to obtain the required density was calculated. These calculated densities are given in Table 1:

Table 1 The needed hay masses to obtain required density at different capacitor plates spacing

50	**40**	**30**	**20**	**10**	***Distance(cm)***
					Density(kg/m^3)
9kg	7.5kg	5.5kg	3.5	2kg	*80*
11kg	9.6kg	7kg	4.5kg	2.5kg	*100*
14.5kg	12kg	9kg	6kg	3kg	*130*

III. Results and Discussion

After laboratory measurement, the following graphs were plotted between the recorded data. As shown in Figures 3, 4 and 5 the circuit output (capacitance) has a decreasing trend with any increase in plates spacing in every three levels of hay moisture content (10%, 20% and 30%).

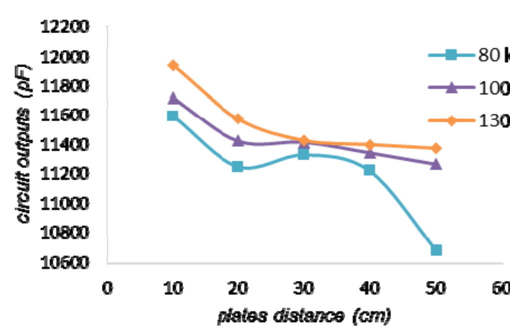

Figure 3. Capacitance changes vs. plate spacing for alfalfa hay at 25°C and 10% moisture content..

ISSN (Online): 2305-0225
Issue 15(3), May 2014, pp. 437-440

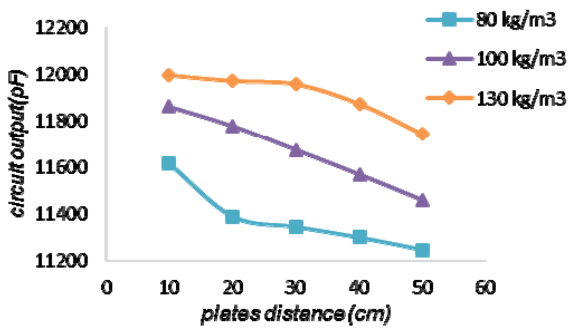

Figure 4.Capacitance changes vs. plates spacing for alfalfa hay at 25°C and 20% moisture content.

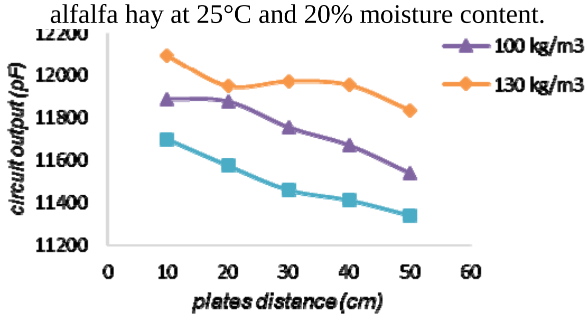

Figure 5. Capacitance changes vs. plates spacing for alfalfa hay at 25°C and 30% moisture content

Figures 6, 7, 8, 9 and 10 show the effect of moisture content on capacitance. The circuit output shows an increasing trend with any increase in hay moisture content at all three levels of haydensity.

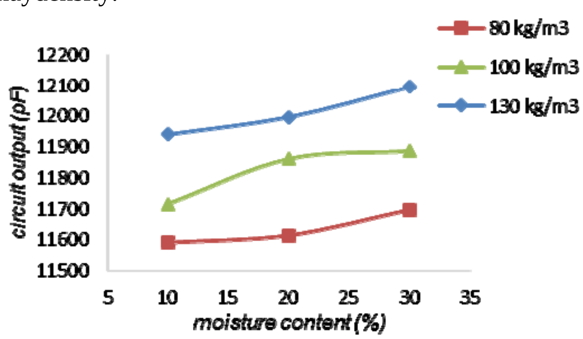

Figure 6. Capacitance changes vs. different hay moisture contents at 25°C and 10 cm plates spacing

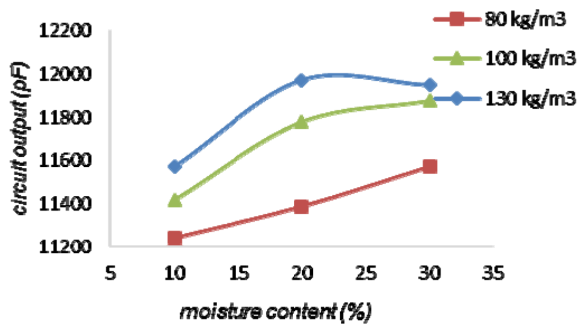

Figure 7. Capacitance changes vs. different hay moisture contents at 25°C and 20 cm plates spacing

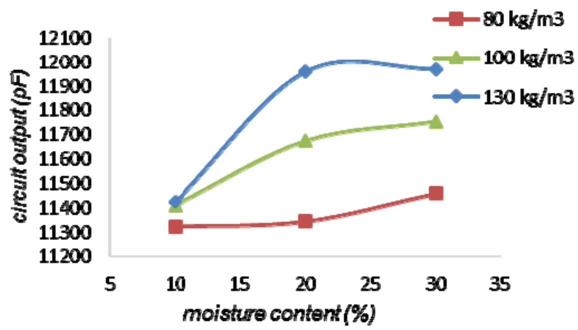

Figure 8. Capacitance changes vs. different hay moisture contents at 25°C and 30 cm plates spacing

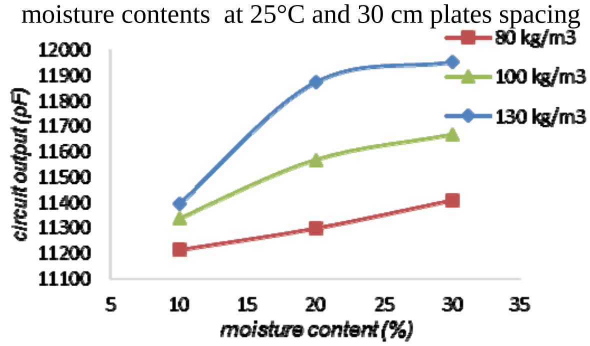

Figure 9. capacitance change vs. different moisture content at 25°C for circuit of LM 555 in 40 cm

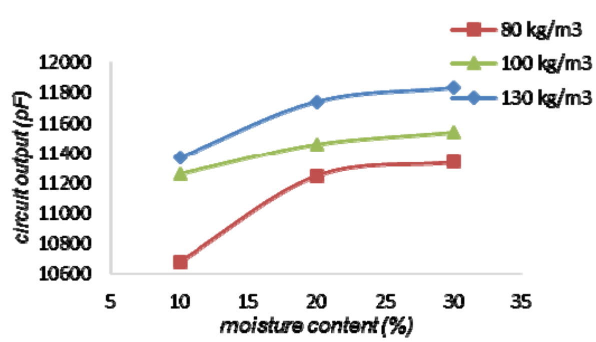

Figure 10. Capacitance changes vs. different hay moisture contents at 25°C and 50 cm plates spacing

ISSN (Online): 2305-0225
Issue 15(3), May 2014, pp. 437-440

The effect of hay density on capacitance changes were also studied. The results as presented by Figures 11, 12 and 13 show that sensor output increases with increasing hay density.

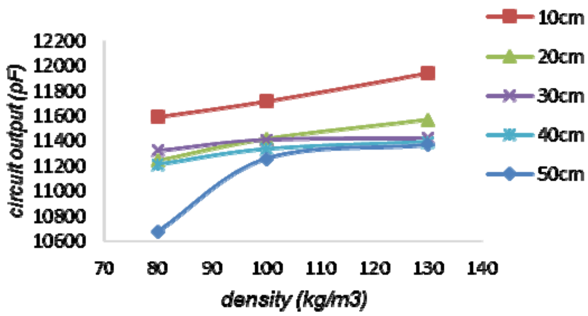

Figure 11.Capacitance changes vs. different hay density at 25°C and 10% moisture content

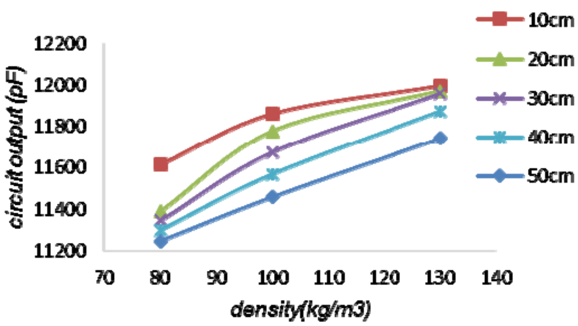

Figure 12. Capacitance changes vs. different hay density at 25°C and 20% moisture content

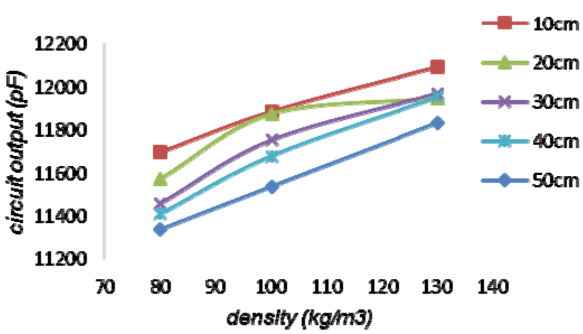

Figure 13. .capacitance changes vs. different hay density at 25°C and 30% moisture content

IV. Conclusions

1. The results showed that non-destructive method of using capacitance sensor can estimate the moisture content of alfalfa hay.

2. Statistical analysis of capacitance data showed thattemperature has significant effect on capacitance such that capacitance decreases with increasing temperature.
3. Results showed that capacitance increased with increasing both hay moisture content and bale density..

References

[1] ASAE Standard (S358.2). (1999). Moisture measurement, forages, ASAE, St. Joseph, MI.
[2] Baskin, G. R., Mayeux, M. M., and Sistler, F. E. (1982). A monitor for crop moisture and combine cylinder speeds. Trans. of the ASAE 25(5): 1220-1224.
[3] Eubanks, J. C., Birrell S. J. (2001). Determining moisture content of hay and forages using multiple frequency parallel plate capacitors. ASAE paper No. 01-1072, ASAE, St. Joseph, Michigan.
[4] Hooper, A.W. (1980). Estimation of the moisture content of grass from diffuse reflectance measurements at near infrared wavelengths. Journal of Agricultural Engineering Research, 25:355-366.
[5] Kandala, C. V. K., Nelson, S. O. and K. C. Lawrence. (1996). Determining moisture content in small wheat samples by dual frequency RF impedance sensing . Trans. of the ASAE 39(3):1185-1188.
[6] Kumhala, F., Kviz, Z., Kmoch, J., and Prosek, V. (2006): Laboratory measurement with improved dielectric sensor for forage weighing. Acta Technologica Agriculturae, 9: 51–54.
[7] Lawrence, K. C., Funk, D. B., and Windham, W. R. (2001): Dielectric moisture sensor for cereal grains and soybeans. Trans. of the ASAE, 44: 1691–1696.
[8] Mathews, J., (1963). Automatic moisture content control for grain drier. Journal of Agricultural Engineering Research 8(3): 207-220.
[9] McIntosh, R. B, and Casada, M. E. (2008). Fringing Field Capacitance Sensor for Measuring the Moisture Content of Agricultural Commodities. IEEE SENSORS JOURNAL. 8(3): 240-247.
[10] Nelson, S. O. (1991). Dielectric properties of agricultural products (Measurements and applications). IEEE Transactions on Electrical Institution. 26(5):845-869.
[11] Osman, A. M., Savoie, P., Grenier, D. and Theriault, R . (2002): Parallel-plate capacitance moisture sensor for hay and forage. ASAE Paper No. 021055, ASAE, St. Joseph, Michigan.
[12] Savoie P., Lemire P. and Theriault R. (2002). Evaluation of five sensors to estimate mass-flow and moisture of grass in a forage harvester. Applied Engineering in Agriculture, 18: 389–397.
[13] Zazueta, F. S. and Xin, J. 2005. Soil moisture sensors. Available on the: http://edis.ifas.ufl.edu/Eh226. Accessed on 24/01/2006