

Calibration of Capacitive Cell for Measuring Moisture Content in Grains

Harinder Singh, Babankumar S. Bansod, Ritula Thakur, Tejbir Singh, Jeewan Sharma

Abstract—Moisture is considered as one of the key factor for food storage. High moisture levels of grains during harvest can deteriorate and ferment the quality of grains. In the present study a capacitive moisture sensor cell has been used for moisture measurement in grains. The sensor cell has acrylic body with stainless steel electrodes. Different grain moisture samples are prepared with moisture content varying from 5% to 25% by method described in ISO 712:2009. The capacitive cell is attached to LCR meter to measure the capacitive signal generated from different moisture samples. The capacitive signal of the cell was sensitive to applied frequencies varying from 500 Hz to 1 MHz. Graphical plots suggest that capacitive cell shows good response to moisture content. For every moisture content sample, the capacitance decreases with increase in frequency suggesting that low frequencies are favorable for these measurements.

Index Terms—Capacitive cell, moisture content, sensor, wheat grains

I. INTRODUCTION

MOISTURE content (MC) of grains is an important characteristic to determine its quality. For farmers, it is important to know the proper time for harvest and the potential for safe storage [1]. If grains have very low MC, then there is a risk of damage from kernel breakage or shattering losses. Grains with high MC are subject to attack by grain storage fungi and stored-grain insects [2].

Moisture measurement is an important aspect in harvesting, drying, storing and processing of grains. The grains, when freshly harvested, may have a MC in the range of 20–40% [3]. It is a high value of moisture content for trading, processing or storing of grains. The moisture level should be decreased to a recommended level, which is up to 13%, 13.5% and 10.5% for shelled corn, soft red winter wheat and peanuts, respectively [4]. Moisture content in grains badly effect the selling price of

grains because the dry matter of grain has more value in the market. Traditionally, an oven based method is employed for measuring moisture content in grains which has high accuracy but it is time-consuming, laborious and involves a complicated procedure. Particularly, it is not suitable for field use and the grain trade in general [5].

Hence, different techniques for indirect testing methods have been studied for replacing the standard oven method with the use of conductance, capacitance, X-rays, neutrons, and microwaves. These methods have fast response time and are easily applied under field conditions [6]. The most common method is the capacitive method which has advantages of low cost, small volume and fast detection, although it lacks high precision [7].

Electrical techniques are used since early twentieth century when Briggs discovered a linear relationship between the dc electrical resistance of wheat and its moisture content [8]. Nelson *et al.* first reported the quantitative data on the dielectric properties of grain along with a method for measurement of these properties in the 1–50 MHz frequency range [9]. Sokhansanj & Nelson found moisture dependence of the dielectric constant of aqueous materials which led to the development of moisture meters that use certain dielectric related measurements for moisture determination [10]. Kandala *et al.* measured the MC of peanuts using impedance and phase angle at 1 and 5 MHz of a parallel plate capacitor holding the corns between the plates [11].

In present work, an effort has been made to calibrate the sensor cell for different moisture contents of wheat grains with respect to applied frequency. Different moisture samples have been prepared for the study. Results establish the fact that capacitive cell has potential to be used as moisture sensor and has scope in improving its sensitivity to enhance its performance. Section II contains the experimental details which include sample preparation and details of set up used for sensing. The results have been given and discussed in section III.

II. MATERIALS AND METHODS

A. Sample Preparation

The standard procedure for sample preparation has been specified in ISO 712:2009 [12]. Wheat grains were used to prepare moisture samples. Five samples of low, medium and high moisture values were prepared. Samples were stored in airtight polythene bags. Desired quantity of distilled water was added dropwise using a graduated pipette to each sample, the samples were shaken energetically over four days as described in Table 1. All the samples were kept at a temperature of approximately 2–6 °C.

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TABLE I
DURATION AND TIME OF SHAKING FOR SAMPLE PREPARATION

S. No.	Day	Period	Duration of shakings (seconds)
1.	1 st Day	As soon as water has been added	60
		First Hour	15
		Second Hour	15
		Third Hour	15
		Between the third hour and end of the first day	15
2.	2 nd Day		15
2.	3 rd Day		15
4.	4 th Day		15

8479 pF and 19641 pF for 5%, 7%, 15%, 20% and 25% moisture content samples. The details of capacitance measured at various frequencies and moisture samples has been represented in table II.

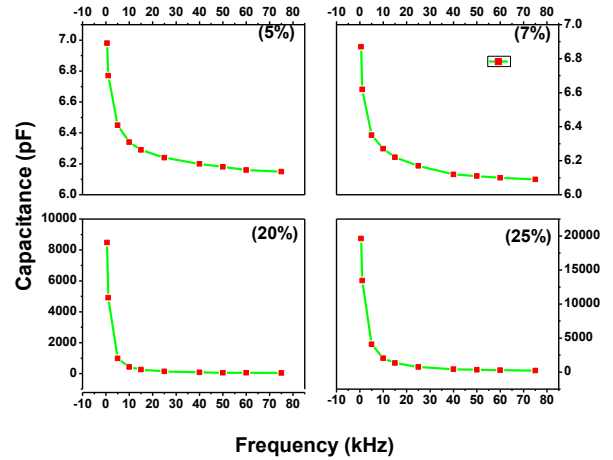


Fig. 3. Capacitance vs Frequency plot for 5%, 7%, 20% and 25% moisture sample

B. Experimental set-up

The experimental set up of capacitive sensor cell is shown in figure 1, where sensing system is followed by LCR meter for data measurement and acquisition.

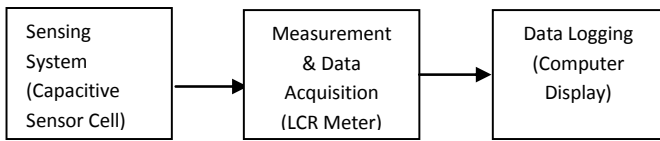


Fig. 1. Experimental setup for Capacitive Sensor Cell

A rectangular cell was fabricated from acrylic sheet with outer dimensions of 44.0 mm × 41.5 mm × 11.5 mm. Figure 2 (a) shows stainless steel electrodes having dimension 42.7 mm × 33.4 mm. Capacitive moisture sensor is shown in working mode in figure 2 (b)



Fig. 2. Set up of capacitive sensor cell (a) electrodes (b) moisture sensor in working mode

III. RESULTS AND DISCUSSION

The capacitance has been recorded at different moisture content levels corresponding to different frequency levels. The variation of capacitance as a function of frequency has been represented in figure 3. Good response in capacitance measurement has been observed at low frequencies. At 0.5 kHz, the capacitance measured is 6.98 pF, 6.87 pF, 306.8 pF,

TABLE II
CAPACITANCE RECORDED FOR DIFFERENT MOISTURE SAMPLES AT VARIOUS FREQUENCIES

S No	Frequency (kHz)	Capacitance (pF) recorded at various moisture contents				
		5%	7%	15%	20%	25%
1	0.5	6.98	6.87	306.8	8479	19641
2	1	6.77	6.62	166.8	4911.5	13464
3	5	6.45	6.35	45.6	986	4075
4	10	6.34	6.27	28.0	436.1	2046
5	15	6.29	6.22	21.9	266	1327
6	25	6.24	6.17	16.9	141.7	754.0
7	40	6.20	6.12	14.1	80.7	441.0
8	50	6.18	6.11	12.7	62.5	339.3
9	60	6.16	6.10	12.1	51.2	272.8
10	75	6.15	6.09	11.4	40.5	208.5
11	100	6.08	6.14	10.7	30.8	147.1
12	200	6.05	6.07	09.5	18.2	064.9
13	500	-	6.00	08.3	17.2	028.4
14	1000	-	5.86	07.8	12.6	019.0

The variation of capacitance with moisture content (5%, 7%, 15%, 20% and 25%) at four specific frequencies i.e. 500 Hz, 50 kHz, 500 kHz and 1 MHz has been represented in

figure 4. It is evident from the results that capacitive signal shows good response to moisture in grains. Capacitive sensor operates efficiently at low frequencies and for high moisture content samples. It is evident that capacitance is dependent on moisture content as well as on operating frequencies. Lower frequencies are more favorable for measuring moisture in wheat grains.

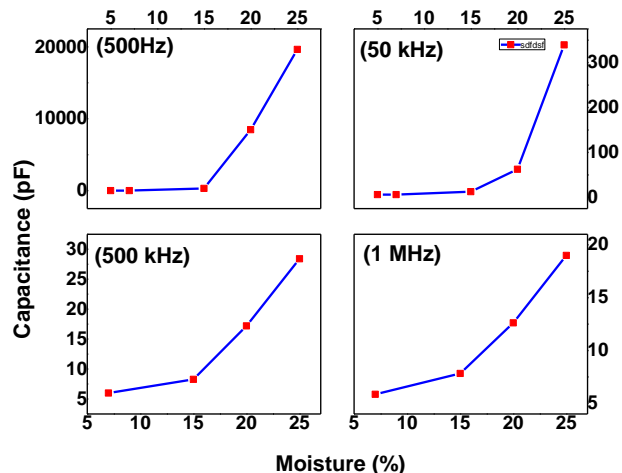


Fig. 4. Capacitance vs Moisture content at 500 Hz, 50 kHz, 500 kHz and 1 MHz frequencies

IV. CONCLUSION

A capacitive moisture sensor cell has been used for moisture measurement in grains. Method described in ISO 712:2009 is applied to prepare samples with moisture content from 5% to 25%. The moisture cell has two stainless steel electrodes, is attached to LCR meter to measure the capacitive signal generated from different moisture samples. Samples have been tested from very low (500 Hz) to high frequency range (1 MHz). Results have shown that capacitive cell shows good response to moisture content. Calibration data suggest that low frequencies are favorable for measuring the moisture content in wheat grains.

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