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A LOW COST FIELD USABLE PORTABLE DIGITAL GRAIN MOISTURE METER WITH DIRECT DISPLAY OF MOISTURE (%)

A.K. Rai[1], Sivadasan Kottayi[2], S.N. Murty[1]

[1]Directorate of Instrumentation, Jawaharlal Nehru Agriculture University,
Adhartal PO, Jabalpur (M.P.)- 482004, India.
[2]Faculty of Electrical Engineering, Defence University, Debrizeit, Ethiopia.i

ABSTRACT:- *Moisture content of grain is one of the important parameters always considered when deciding the quality and price of grain, at the stage of harvesting, storage, processing and marketing. Grain having excess moisture content, if stored for long duration, will spoil due to insect/fungus infestation. Portable, field usable, and easy-to-use direct moisture (%) display Grain Moisture Meter is a necessity for the benefit of farmers. The types of Grain Moisture Meters available in the market are with look-up tables, which cause inconvenience when carrying out measurements. We have developed a grain moisture meter, which due to its novel design, eliminates this problem and gives moisture (%) directly on a LCD display. The novelty of this instrument is that it is compact, easy-to-use, portable, and field usable. The moisture meter is based on the principle of dielectric constant variations due to change in moisture. Changes of moisture content affect the dielectric constant of the grain, which in turn makes variation in capacitance. The resultant capacitance variation is converted to voltage variation and calibrated in terms of moisture percentage. On the basis of rigorous experiments the meter has been calibrated for wheat, paddy, soybean, sunflower & mustard. However, the user can calibrate the meter at his level for other grains also. The developed instrument is working satisfactorily for all practical purposes in the range of 5-25 % of grain moisture with an accuracy of ± 1% .*

INTRODUCTION

The quality of grain is influenced by its moisture content. Knowledge of the moisture content of food grains is required for various reasons such as the need to know the optimum stage of harvesting, whether the grains could be stored for extended period of time, to decide the price of grains, and for research and development (R & D) purposes. Conventional methods of moisture measurements in grains like oven-dry method, distillation method, drying with desiccants etc., are time-consuming laboratory methods. Fast as well as field usable portable Grain Moisture Meter is a necessity to meet the requirements of farmers, grain storage personnel, and agricultural products marketing corporations. The paper explains the design and development of a low cost portable Digital Grain Moisture Meter.

The methods for determining moisture content of grains can be divided into direct and indirect methods. Oven-dry method, distillation, drying with desiccants etc., are direct methods, whereas those based on either electrical resistance, dielectric (capacitance), chemical, hygrometry, nuclear magnetic resonance or microwave spectroscopy etc., are indirect methods.

Oven-dry method is a widely recognized method [1,2] for determining moisture of grains. It is a basic method against which other indirect method based moisture meters are calibrated. Two general procedures are available in oven-dry method: (i) Grind the grain and dry it in the oven for 1 to 2 hours at 130 °C or (ii) Place the whole grain in the oven at a temperature of 100 °C for 72 - 96 hours. After heating the grains are transferred to a desiccator where they are allowed to cool to room temperature. The loss in weight is determined and the moisture content calculated either by wet basis or dry basis.

In the distillation method [1,2] moisture is removed by heating the grain in oil and the loss of weight of the sample determined. In the case of desiccant drying [1,2], moisture content of a product is determined by placing the sample near an efficient drying agent like anhydrous sulphuric acid in a closed container. The loss in weight is determined and moisture (%) is calculated.

All the above-mentioned methods have the disadvantages of being time-consuming laboratory methods, and chances of errors occurring during measurements are more if the measurements are not done carefully.

Indirect methods involve the measurement of certain property of the material, which depends upon the moisture content. Any one of the direct methods explained above is used to calibrate the systems based on indirect methods. Chemical method for moisture measurement normally adds certain chemicals, which decompose or combine with water. Calcium carbide method [3], calcium hydride method [1] and Karl Fischer method [4] etc. are some of the chemical methods. In hygrometry method [2] relative humidity of the air in equilibrium with the material (grain) is used as a measure of the moisture content.

Moisture measurement by nuclear magnetic resonance (NMR) depends on the detection of the hydrogen nuclei within the material. The magnetization in the sample is converted to a voltage, which is proportional to the number of hydrogen nuclei present in the sample. This method is not specific for moisture itself but is specific for hydrogen nuclei [11]. An advantage of this method is that it is rapid, has high accuracy, and is a non-destructive measurement technique. Its disadvantages are that the method senses total hydrogen rather than water, and requires expensive equipment.

Microwave spectroscopy [1] is yet another method in which the attenuation of microwaves vary with moisture content of grain, but the method is quit expensive. Another indirect method is electrical resistance or conductivity method [1,2] and the principle is based on the resistance or conductivity of the material under test. That resistance is influenced by many factors other than moisture content, the error due to non-uniform distribution of moisture, and physical contact with the material are major problems in this method. Furthermore the method cannot give accurate results [5] if moisture level is less than 7% or greater than 23%.

Another popular method of moisture measurement is the capacitance (dielectric) method [1,2]. Instruments based on this technique are subject to less error that arise from non-uniform distribution of moisture and physical contact with the material under test. This method permits moisture measurement over a wider range than conductance method, and properly calibrated capacitance type grain moisture meters work satisfactorily within ±1% accuracy, which serves almost all practical purposes in agriculture. The paper explains the development of grain moisture meter based on the capacitance principle.

MATERIALS AND METHODS

The Working Principle of the Capacitance-based Moisture Meter

The functional block diagram of the system is shown in Fig. 1. Parallel plates (aluminum) capacitor of size 16 x 14.5 cm separated by 3 cm and encapsulated in an acrylic container acts as sensor. Grain sample is placed inside the container.

The capacitance C of a parallel plate capacitor is [6]:

$$C = \frac{\varepsilon_0 \varepsilon_r A}{d} \quad Farad \tag{1}$$

where: $\varepsilon_o = 8.8419 \text{ x } 10^{-12}$ Farad/meter is known as the absolute permittivity of free space, ε_r is the relative permittivity of the dielectric or the dielectric constant of the material, *A* is the area of the plate, and *d* is the distance between the plates.

The grain whose moisture content is to be measured is filled between the plates, and acts as the dielectric medium of the parallel plate capacitor. Thus the sensor of the instrument can be modeled as a capacitor of composite dielectric medium consists of water, dry grain matter, and air, with dielectric constants $\varepsilon_{r1}, \varepsilon_{r2}, \varepsilon_{r3}$ respectively. The capacitance of such a composite capacitor may be obtained from the expression [7]:

$$C = \frac{\varepsilon_0 A}{\frac{d_1}{\varepsilon_{r1}} + \frac{d_2}{\varepsilon_{r2}} + \frac{d_3}{\varepsilon_{r3}}} \tag{2}$$

where *d1*, *d2* and *d3* are the thickness of the dielectric medium contributed by the water of the grain, dry grain

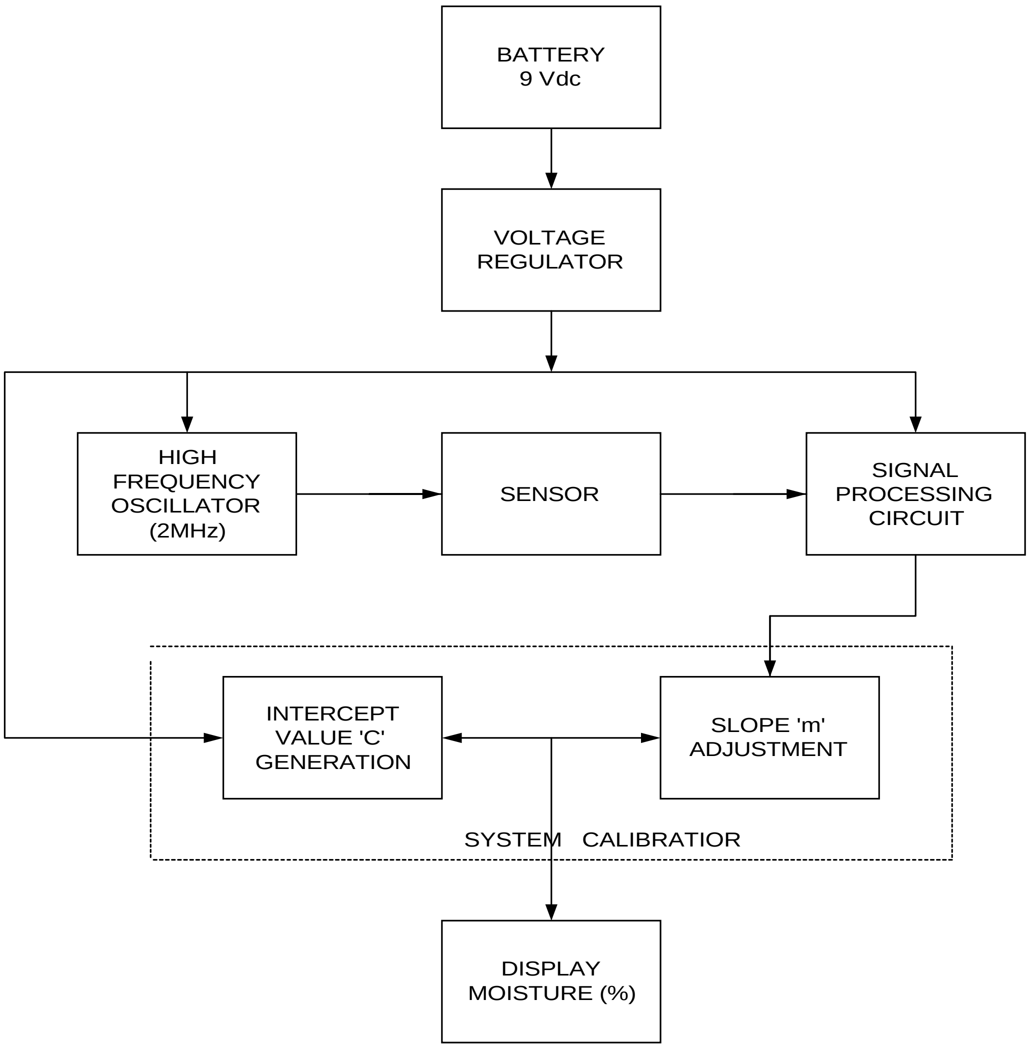

Figure 1: Functional Block Diagram of the capacitance-based moisture meter

matter, and air gaps in the grain filled portion of the sensor respectively. Since the ratio of the dielectric constants of water, dry matter of grain, and air is 80: 5:1 [1, 8], the sensor can be approximated as a capacitor with dielectric medium of water and the capacitance of such capacitor may be:

$$C = \frac{\varepsilon_0 A}{d_1 / \varepsilon_{r1}} \qquad (3)$$

Hence, the capacitance change in the sensor is predominantly due to the moisture content of the grain.

Development of the Grain Moisture Meter

The electronic circuit of the system is depicted in Fig. 2. A high frequency square wave oscillator working in 2 MHz excited the sensor. The output across the sensor was fed to a signal conditioning circuit, which consists of a voltage doubler [9] i.e., IC 7661, which was used to double the output of the sensor. This was followed by a RC circuit, which gives the DC voltage variation against capacitance change in the sensor. The voltage variation against moisture (%) of grain was approximated to a straight line

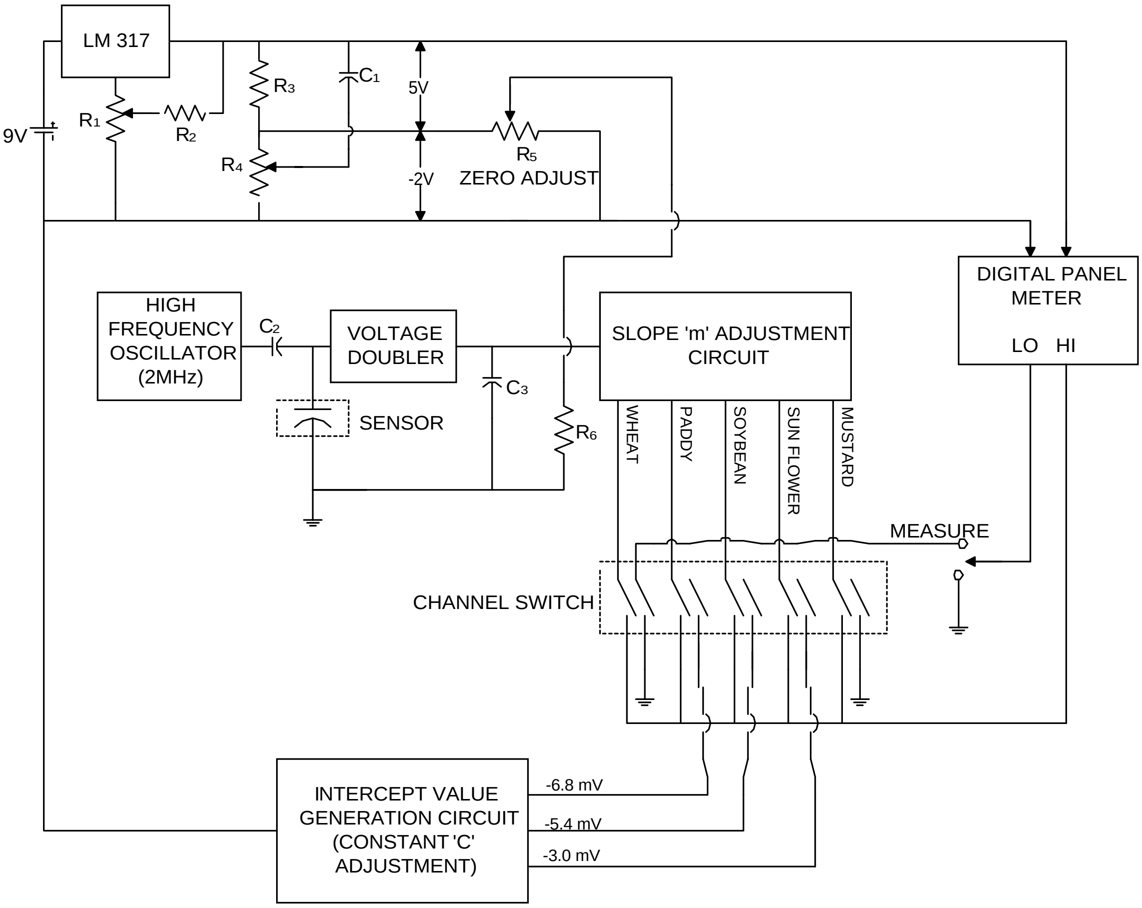

Figure 2: The electronic circuit of the grain moisture meter

and the instrument calibrated by adjusting slope, '*m*' and Y-axis intercept value '*c*' of the calibration curve by the electronic circuit so that direct display of moisture (%) is possible on a LCD display. A separate channel switch was provided for each commodity (type of grain).

The prototype of the system was calibrated for five commodities (wheat, paddy, soybean, sunflower and mustard), but it can be calibrated for any number of commodities by giving separate push switch for each channel.

The schematic diagram of the developed prototype system is depicted in Fig. 3. The meter has two compartments; the first compartment, ABCDEFGH is the grain holder where capacitor type sensor is fitted. The other compartment, EFGHIJKL occupies the electronic circuit of the system. A knob for adjusting zero reading before filling the sample into the grain holder is also provided.

Calibration of the Moisture Meter

The meter has been calibrated for wheat, paddy, soybean, sunflower and mustard. To calibrate the system for the said commodities, the output (mV) of the system should be recorded against different samples with varying moisture (%). To perform this, a set of samples with varying moisture (5 - 25%) of the above mentioned commodities were conditioned. For conditioning, the grains were first cleaned, foreign materials, and shrivelled grains removed. Samples with lower moisture content were prepared by drying the grain in an oven, by placing the trays containing grain of layer thickness of about 1.5 cm, at a temperature below 45°C [10]. After a time of 5 to 6 hours, the grain was removed from the oven and allowed to cool to room temperature, and from this 600 gm. of the grain was filled into the sample jar. A small quantity of this sample was taken and its moisture determined by oven dry method. The moisture (%) was determined in wet-basis [2]. The remaining grain was again kept inside the

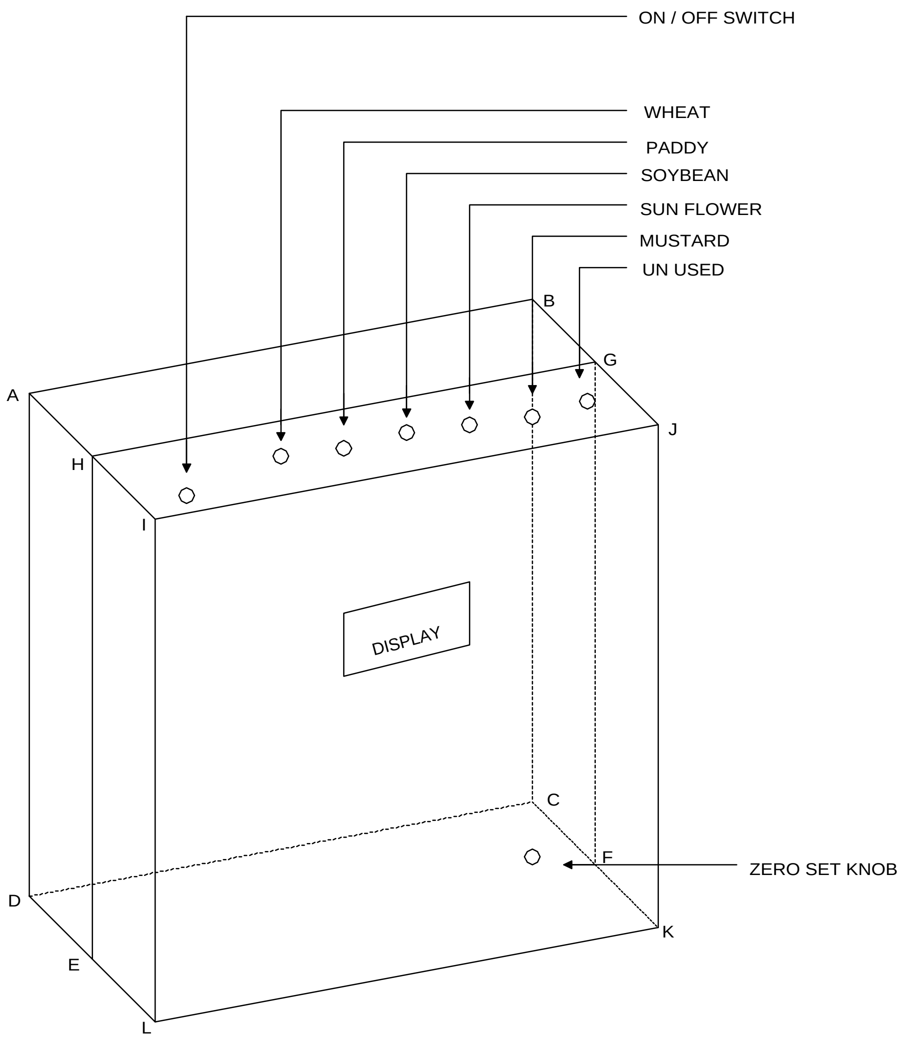

Fig. 3: The schematic diagram of the grain moisture meter

oven and dried. After 5 to 6 hours the grain was once again removed for preparing another sample. This process was continued until the required number of samples of varying moisture (%) for calibration purpose had been made.

Samples with higher moisture (%) were prepared by placing the samples (600 gm) in different containers and water was added in the desired quantity. After closing the jar, the samples were thoroughly shaken for about one minute with an interval of half an hour for four hours. All the samples were maintained at room temperature and an equilibrium period of one week was allowed for the samples to achieve the desired moisture level uniformity. The samples thus prepared were used for calibrating the system. A separate push switch was provided for each commodity the moisture content of which was measured by pressing the corresponding push switch. The push switch connects the corresponding Y-axis intercept value adjustment circuit, which determines the intercept value of the appropriate curve. This novel arrangement distinguishes our developed system from other moisture meters for which look-up tables for finding the moisture percentage have to be provided, a, cause inconvenience to the users.

At present our system is calibrated for five commodities as mentioned above, but can be calibrated for any number of commodities using separate push switches for each commodity provided the obtained calibration curves can be approximated as straight lines which enables direct display of moisture (%) on the LCD display of the system.

RESULTS AND DISCUSSIONS

The electrical output (mV) against different samples of varying moisture (5 to 25%) for wheat, paddy, soybean, sunflower and mustard are shown in Table 1. These readings were taken after adjusting the slope *'m'* to a desired value using the slope adjustment circuit. The correlation coefficient of the obtained data in the case of wheat, paddy, soybean, sunflower and mustard were found as 0.999, 0.987, 0.991, 0.999, and 0.999 respectively. Using a commercial regression analysis software package, lines of regression were obtained for these commodities as $Yn = mnXn + Cn$; $n = 1, 2…5$. The values of *'m'* and *'c'* for wheat, paddy, soybean, sunflower and mustard were found to be 1.0 and 0, 1.4 and 6.8, 1.8 and 5.4, 1.3 and 3.0, and 1.0 & 0 respectively. These regression lines considered as calibration curves are plotted in Fig. 4. The *'c'*values were adjusted using the Y-axis intercept value adjustment circuit, which generates corresponding *'c'* values with negative polarity wherever necessary.

Laboratory Testing and Field Trials

The developed system was tested in the laboratory for different samples of the commodities mentioned above. The test results are given in Table 2. Each record of the table is the average of five readings. The performance of the system is evident from the table as the error in measurement lies between ± 1%, which is the quoted specification of the system and is sufficient for at the farmer's level for field uses.

The system was also sent to Central Instruments Organisation (CSIO), Chandigarh, India, a National Laboratory under Council of Scientific and Industrial research (CSIR) for testing, thereafter, it was taken for field trail by making it available to different farmers through Secretary, Madhya Pradesh, Krishi Vipnan Board, Jabalpur, India. Field trial reports were found satisfactory.

Table 1: Electrical output of the moisture meter for different samples

Sample No.	Wheat		Paddy		Soybean		Sunflower		Mustard	
	X (%)	Y (mV)	X (%)	Y (mV)	X (%)	Y (mV)	X (%)	Y (mV)	X (%)	Y (mV)
1	9	9	9.3	7	7.5	7.5	5	3.5	5	5
2	10.8	10.7	9.9	7.4	8.2	8.4	6.5	5.7	7.4	7.5
3	11.3	11.2	11.1	8.6	9.1	10	7.1	6	9.3	9.1
4	11.9	12	11.5	8.9	9.6	11.7	9	8.5	10	10.2
5	12.4	12.4	12.1	9.7	10.4	12.6	10.2	10.2	11.6	11.4
6	12.9	13	12.9	10.2	11.1	14.2	11.8	12.5	12.8	12.9
7	14	14	13.3	10.9	11.8	16.5	13.3	14.2	13.5	13.6
8	16.1	16	14.4	12.2	14.9	22.5	14.8	16	14.4	14.4
9	16.9	17	14.7	13	16.4	25.4	17.9	20	16	16.2
10	19	19.1	16.2	15.7	20	30	19	21.5	17.8	18
11	21.1	21	20	21.5	23.1	34	21.5	25	19.2	19.4
12	23.8	23.7	21.5	23	25	38.3	23	27	20.2	20.1

Note *: X = Moisture(%)*

Y = Voltage output(mV) of the system

Each record of the table is the average of five readings

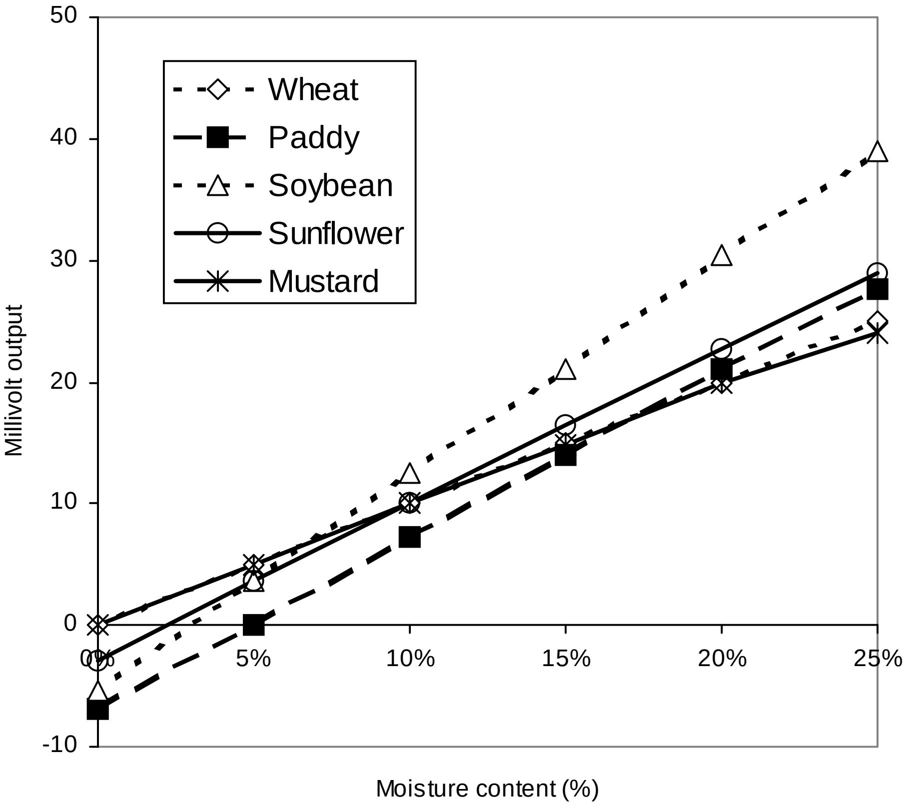

Figure 4: The moisture content calibration curves for different types of grains

Table 2: The laboratory test results of the developed moisture meter

Sample No.	Wheat			Paddy			Soybean			Sunflower			Mustard		
	MC_a	MC_m	E_r	MC_a	MC_m	E_r	MC_a	MC_m	E_r	MC_a	MC_m	E_r	MC_a	MC_m	E_r
1	10.2	10	0.2	10.8	11	0.2	8.2	8	0.2	6	6.2	0.2	7.5	7.6	0.1
2	11.5	11.4	0.1	11.4	11.5	0.1	8.9	8.8	0.1	7.2	7	0.2	8.2	8	0.2
3	12	12	0	12.1	12	0.1	9.6	9.9	0.3	9.3	9	0.3	9.3	9	0.3
4	13.6	13.8	0.2	12.8	13.1	0.3	10.4	10.7	0.3	10.8	10.9	0.1	10.1	10.4	0.3
5	14.5	14.8	0.3	13.5	13.8	0.3	11.2	11.5	0.3	12.1	12	0.1	11.6	11.4	0.2
6	15.1	15	0.1	14	14	0	12	12.4	0.4	13	13.1	0.1	12.4	12.1	0.3
7	16	16.4	0.4	14.9	15.1	0.2	12.8	12.9	0.1	13.9	13.6	0.3	13	13.2	0.2
8	16.8	17	0.2	15.6	15.5	0.1	14.1	14.3	0.2	14.2	13.1	0.1	13.9	14.1	0.2
9	17.5	17.8	0.3	16	16.3	0.3	15.2	15.5	0.3	15.5	15.8	0.3	14.3	14.4	0.1
10	18.1	18.3	0.2	17.2	17	0.2	16.3	16	0.3	16.8	17	0.2	15.2	15.6	0.4
	Average Error 0.2			Average Error 0.18			Average Error 0.25			Average Error 0.19			Average Error 0.23		

Note: *MC_a = Actual moisture content(%) by oven method*
MC_m =Measured moisture content (%) using the developed moisture meter
E_r = Error (%)

CONCLUSIONS

A portable, a field usable digital grain moisture meter weighing approximately 500 gm, and operating with single 9V battery has been developed. Whereas grain moisture meters using capacitor type of sensors are available in the market, all such systems provide printed look-up tables along with their instruments, from which the moisture percentage of diverse commodities have to be obtained. Our system has an edge-over compared to these other systems because of the direct display of moisture (%) of different commodities using simple techniques explained above.

Since the sensor of our system is based on capacitance method and the grain is acting as dielectric medium of the sensor, temperature variations in grain introduce minor error in meter reading. It is anticipated that lack of density correction may slightly affect the accuracy of the measurements. However the developed instrument is working satisfactorily for all practical purposes in the range of 5 - 25% of grain moisture with an accuracy of ±1%.

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