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LOCALLY MADE HALF BRIDGED RESISTANCE TYPE MOISTURE CONTENT PREDICTING DEVICE FOR GRAINS

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ABSTRACT

The percentage of moisture in grains is a parameter essential in controlling the market value, rate of drying and control of chemical and fungi activities. The importation into Nigeria of the so called sophisticated moisture meters which are calibrated differently for conditions cost lots of foreign exchange. This paper presents a Nigerian made resistance type moisture measuring device for grains with four copper cup electrodes out of which two were used as the gauging electrodes while the other two electrode cups were used as dummies giving the half (1/2) Wheatstone bridge configuration to measure %moisture contents on dry basis of three different grains namely paddy rice, guinea corn and millet during drying. The predictive empirical relationships between the resistance and percentage moisture content generated after comparison with the direct oven method suggest that the locally developed device could predict the moisture content of grains once it has been calibrated.The high negative coefficients of correlation (ϒ) between the resistance and percentage moisture content obtained for the paddy rice, Guinea Corn and Millet tested were respectively -0.88308,-0.94033 and -0.53088.

Keywords: Grains, Predicting, Moisture, Resistance, Device, Half bridged

INTRODUCTION

Drying is one of the essential steps in the postharvest technology of grains, such as maize and rice which require mechanical drying. Grains are dried on the farm and off the farm, depending on the country of production. For instance, in the United States of America (USA) the bulk of the maize is farm dried; in France, almost all the maize is dried off the farm at local grain depots. Drying is one of the most common and least understood postharvest operations with dryer design depending mainly on experimental data [1]. The measurement of moisture content of grains in the process of drying is a very important parameter on drying [2].Under drying may result in the formation of mildew, bacterial growth and agglomeration of the particles and even clogging of machinery.

Over drying may cause deterioration of product in quality and quantity. A great deal of energy is wasted when grains are over dried. The need to monitor moisture content level during drying is very critical in some products. For example cotton with too high moisture content level will not easily separate into single locks and if the moisture content is too low, it will stick to the metal surface [3,4].Soil moisture content level has been proven to determine characteristic such as texture as it is been reported by other researchers[5].

Also moisture content affects most of the important properties of wood, and it can vary widely depending on the environment and history of the wood. Effective use of wood and wood-base materials, therefore, requires efficient and reliable methods of measuring wood moisture. The two basic methods of determining wood moisture content are the oven drying method and the distillation method. The oven drying method is generally accepted for basic laboratory work and as a standard for calibrating other methods by the American Society for Testing and Materials [6].It is a known fact that in the drying (roasting) of Cassava particulate for 'Gari' production, inadequate drying is injurious to human health [4].

Three types of electric moisture meter, each based on the fundamental relationship between moisture content and different electric property are in common use namely: the conductance type (resistance-type), the power-loss type and the capacitance type. The conductance or resistance-type moisture meters [7, 8] use the relationship between moisture content and direct current conductance while the Power-loss types [8] use the relationship between moisture content and the dielectric loss factor of the materials. The capacitance types [9] utilize the relationship between moisture content and the dielectric constant of the materials.

To be able to measure moisture content of grains during harvesting, the most practical option is to use the resistance type moisture meter that gives quick results and only uses small samples. A low cost version of the resistance type moisture meter for moisture- measuring is presented in this paper. The change in the resistance of grains is used as a measure to indicate the percentage of its moisture content. The device is initially calibrated using thermo-gravimetric method (oven drying method) of simple analysis which is widely accepted as the most direct, near accurate and basic reference method. The instrument employs a basic Half Wheatstone bridge circuit to measure the grain resistance with a sensitive, high impedance electronic multimeter.

MATERIALS AND METHODS

The developed device include the four copper cup electrodes of equal dimension of Ø20mm x 20mm (height), top and bottom plates of Ø130mm and thickness 5mm made of mild steel, the plunger (made of Teflon) and the base with four drilled holes also made of Teflon to house the copper cup electrodes. Then copper wires of equal length of 200mm were soldered to the copper cup electrodes using the soldering burner to ensure good contact. Two of the four copper cup electrodes were designed such that they can serve as the point of measurement, based on the half Wheatstone bridge operation intended, while the remaining three copper cup electrodes were designed to serve as dummies whenever they are been used[10]. To calibrate the device, the grains were then dried for intervals of 10 minutes after which it is weighed again in the digital balance to measure the loss of moisture. The samples were then put inside the device while the weight of the plunger of mass 544g (0.554kg) was used to apply pressure using bolt and nut arrangements. The connection was then made with a sensitive, high impedance electronic multimeter to measure the resistance, as it was used in other studies [4, 10]. The same methods were used for all the different grains namely paddy rice, guinea corn and millet [10]. In this method, terminals of the dummy electrodes were joined together as one terminal while the terminals of the gauging electrodes were joined to form the second terminal. The open ends of the stainless steel cylinder was then fixed to the bottom plate with the base housing the copper cup electrodes, depending on the Wheatstone Bridge arrangements being investigated .Samples of the rice grains of known percentage moisture content was determined on dry basis by oven dried method using the hot air oven [11].They were then placed inside the cylinder of the moisture measuring device. The cylinder was covered with the top cover attached to plunger. The top plate was then bolted to the bottom plate with the help of the bolt and nut to exert approximately constant pressure. These two terminals were then connected directly to a multimeter to measure and record the resistance. These procedures were repeated for different known percentage moisture content of paddy rice. The whole procedures were also repeated for guinea corn and millet grain samples to meet up with the objectives of the work as carried out by Lawal [10]. For the calibration of the device, since it has been established by [4, 10] that a linear relationship form $\%\boldsymbol{MC} = \boldsymbol{aR} + \boldsymbol{b}$ exists between the percentage moisture content (%MC) and the resistance (R) where a and b are constants, a linear regression equations as provided by [12, 13, 14] and used by [10] could be used to generate the predictive empirical equations using the experimental results presented in table 1. But for the purpose of this paper, the predictive equations were simply obtained from the trendlines options of the linear graphs as shown in Figures 2, 3 and 4.

The device during measurement is as shown in Plate 1a and the half Wheatstone bridge arrangements of the copper cup electrodes is shown in Plate 1b.

Plate 1a: The Resistance Type

Plate 1b: Half Bridge Wheatstone

RESULTS AND DISCUSSION

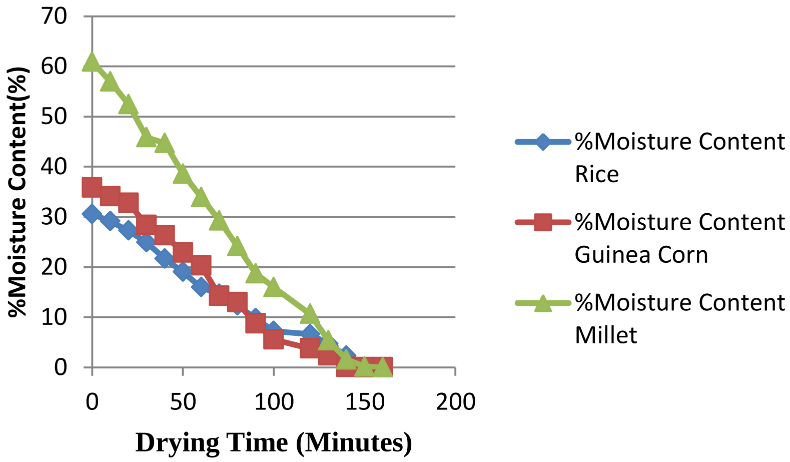

Figure 1: % Moisture Content of Rice, Guinea Corn and Millet against drying time.

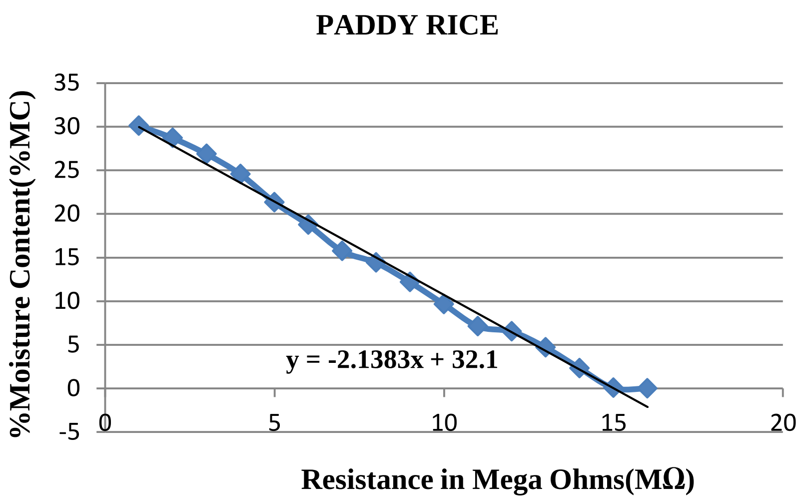

Figure 2: %Moisture Content versus Measured Resistance of Rice

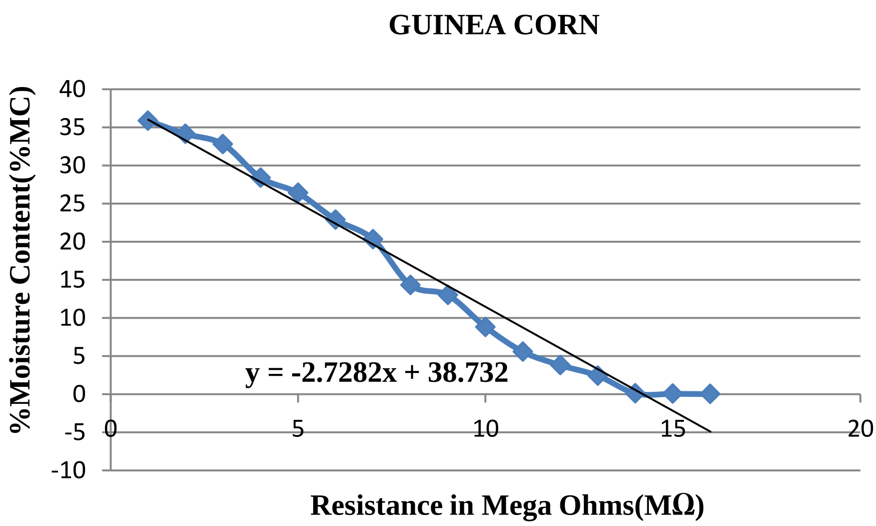

Figure 3: %Moisture Content versus Measured Resistance of Guinea Corn

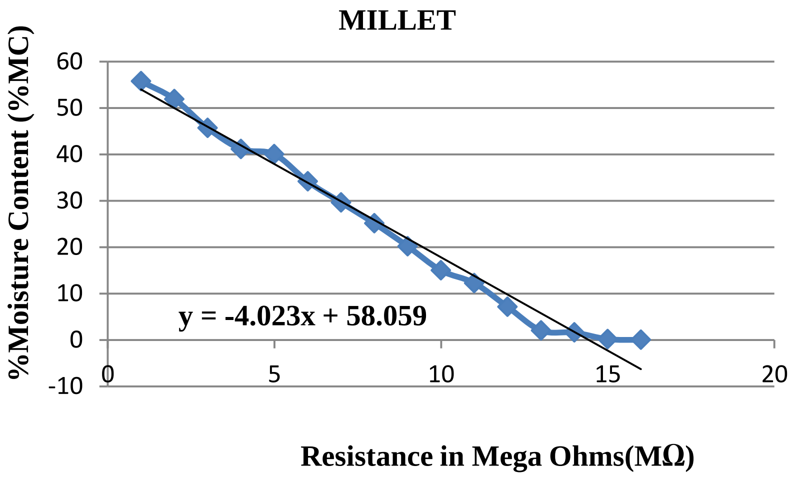

Figure 4: %Moisture Content versus Measured Resistance of Millet

The moisture content decreases as the time of drying increases due to loss of moisture as shown clearly in Figure 1 for all the grains samples used [4,10]. For each of the grains, the resistance is found to be increasing as the moisture decreases as shown in Figures 2, 3, and 4 as also confirmed by[4,10].

Since there is established linearity between the dependent variable y (in this case %Moisture Content as shown Figures 2,3 and 4) and the independent variable x (in this case the Resistance R as shown in Figures 2.3 and 4) in the form $\%\boldsymbol{MC} = \boldsymbol{aR} + \boldsymbol{b}$ (1)
Therefore, the predictive empirical equations (Model) obtained are as follows:
For the Paddy Rice:
The Predictive empirical equation (Model) was found to be $\%\boldsymbol{MC} = \mathbf{32.1} - \mathbf{2.1383}\boldsymbol{R}$ (2)
The coefficient of correlation $\Upsilon = \mathbf{-0.8830}$ [10] (3)
The Guinea Corn grain sample
The Predictive empirical equation (Model) was found to be $\%\boldsymbol{MC} = \mathbf{38.732} - \mathbf{2.7282}\boldsymbol{R}$ (4)
The coefficient of correlation $\Upsilon = \mathbf{-0.94033}$ [10] (5)
The Millet grain sample
The predictive empirical equation (Model) % $\%\boldsymbol{MC} = \mathbf{58.059} - \mathbf{4.023}\boldsymbol{R}$ (6)
The coefficient of correlation $\Upsilon = \mathbf{-0.5308}$ [10] (7)

The predictive models (the empirical equations) were used to calculate some predicted values for the various grain samples used. The comparison between the direct oven method (often used as reference standard for its accuracy) and the predicted values using this resistance type moisture measuring device are shown in figures 5, 6, and 7 below.

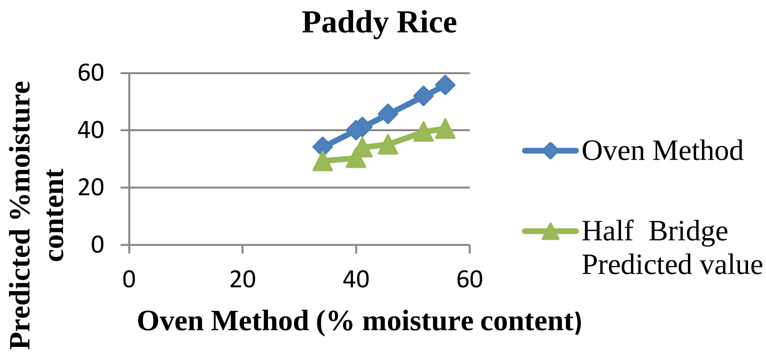

Figure 5: Predicted %moisture content of Paddy rice versus Oven Method

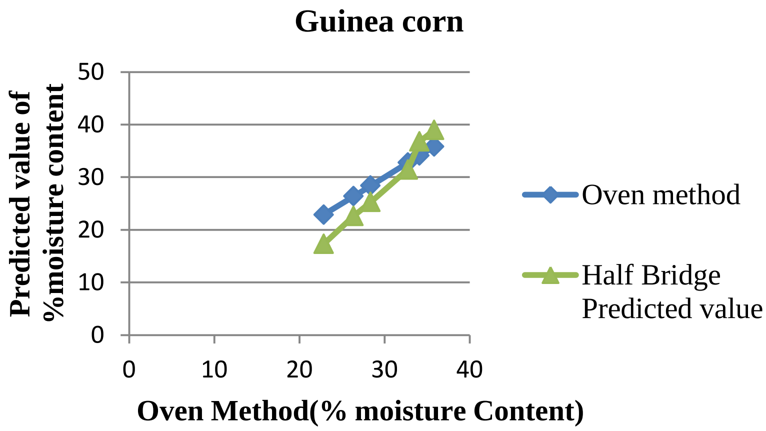

Figure 6: Predicted %moisture content of Guinea corn versus Oven Method

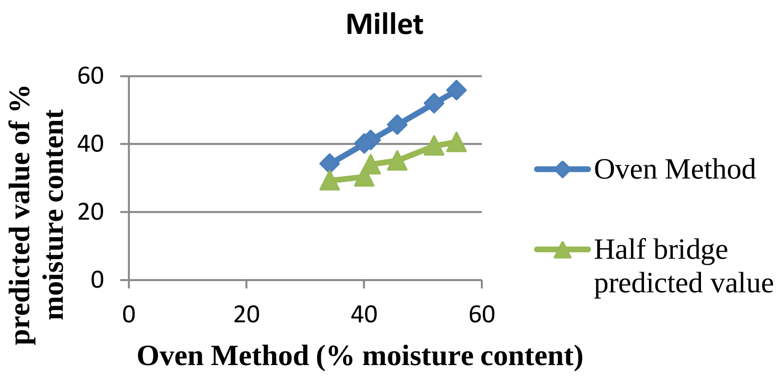

Figure 7: Predicted % moisture content of Millet versus Oven Method.

From Figures 5, 6 and 7 that presented a comparison between the percentage moisture content obtained from the device and the direct oven method for paddy rice, guinea corn and millet respectively, it could be seen clearly the level of correlation thereby suggesting the efficiency of the device for use to predict the moisture content of grains.

CONCLUSION

The following conclusions can be deduced from the developed resistance type moisture measuring device that was used to measure percentage moisture content of paddy rice, guinea corn and millet when the copper electrode cups are half bridged.

(a) This device can be used to predict or estimate the percentage moisture content of grains during drying on dry basis as locally available alternative in the absence of the other sophisticated moisture tellers.

(b) The resistances for all the grains actually increase as percentage moisture content decrease.

(c) The developed resistance type moisture content measuring device for grains developed is very sensitive and consistency when taking readings at high percentage moisture content.

(d) This device could explore for calibration MATLAB CODES to formulate the coefficient of correlation and linear regression equations (predictive model) relating percentage moisture contents of paddy rice, guinea corn and millet with resistances.

(e) Percentage moisture contents of grains are found to have high negative coefficient of correlation.

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APPENDIX

Table 1: experimental data for the calibration of the locally made device

S/N	PADDY RICE		GUINEA CORN		MILLET	
	%Moisture Content	Resitance (MegaOhms)	%Moisture Content	Resitance (MegaOhms)	%Moisture Content	Resitance (MegaOhms)
1	30.09255	0.9	35.85862	0.9	55.76481	1.0
2	28.67934	1.0	34.13403	1.4	51.94608	1.3
3	26.8374	1.1	32.77426	2.6	45.6684	2.5
4	24.52364	1.2	28.39173	4.0	41.15557	2.8
5	21.31612	1.3	26.38524	4.6	40.04217	3.8
6	18.73696	1.5	22.88631	5.8	34.15299	4.1
7	15.72906	1.8	20.31128	5.9	29.6449	4.4
8	14.39525	1.9	14.2847	6.2	25.13681	5.6
9	12.16541	3.4	12.97704	6.5	20.19283	5.9
10	9.640686	4.5	8.805344	6.9	14.97406	6.9
11	7.10235	5.5	5.555161	7.3	12.24978	7.4
12	6.50803	6.6	3.788	-	7.113922	7.7
13	4.693	-	2.407	-	2.018336	-
14	2.319	-	0.09	-	1.589	-
15	0.05	-	0.04	-	0.171	-
16	0	-	0	-	0	-