



INFLUENCE OF MOISTURE AND CURRENT FREQUENCY ON ELECTRICAL POTENTIAL OF SORGHUM GRAINS (SORGHUM BICOLOUR (L.) MOENCH)

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Abstract

Non-destructive quality parameter determination of agricultural produce is the latest technological trend in agricultural metrology. This study tends to establish the use of electrical potential values to determine moisture content of sorghum grains at certain current frequency range. Electrical potential values of sorghum grains at 10, 13, 16, 19 and 22% db were measured using a circuit arrangement consisting of functional generator, grain sample holder and oscilloscope. These measure grains were carried out at current frequencies of 1, 500, 1000, 1500 and 2000 kHz using three (white, red and yellow) varieties of sorghum. Measured values obtained across all varieties ranges from – 0.2 to -14.36 volts. Statistic analysis carried out on these data shows that moisture, current frequency and variety with their interactions has significant effect at $p \leq 0.05$ on electrical potential. The study also shows that Behavioral trend between moisture and electrical potential are more visible at current frequency range of 1000 to 1500 kHz in all varieties. Regression equations were developed to predict moisture using electrical potential values.

Keywords

moisture, current frequency, sorghum, variety, electrical potentials

1. Introduction

Sorghum (*Sorghum bicolor* (L.) Moench) is an indigenous crop to Africa, and though commercial needs and uses may change over time, sorghum will remain a basic staple food for many rural communities. Sorghum belongs to the grass family Gramineae [1]. According to Kimber [2] Sorghum is a cultivated tropical cereal grass. It is generally, although not universally, considered to have first been domesticated in North Africa, possibly in the Nile or Ethiopian regions as recently as 1000 BC. Today, sorghum is cultivated across the world in the warmer climatic areas. It is quantitatively the world's fifth largest most important cereal grain, after wheat, maize, rice and barley. World annual sorghum production is over 60 million tonnes, of which Africa produces about 20 million tonnes. Oluwakemi and Omodele [3] reported that the highest producer of sorghum USA produces 10,400,000 metric tonnes alone while Nigeria produces 6,300,000 metric

tonnes making it the highest in Africa and the third highest in the world.

Electrical properties of agricultural products are very important attributes of the products to be noted by Engineers, scientists and farmers in order to understand the behaviour of these products around electrical field [4]. These properties include: Electrical potential (Voltage), resistance, resistivity, conductance, conductivity, capacitance, dielectric constant, Permittivity, impedance, capacitance reactant etc. These properties can also be used to predict, determine, measure and preserve the quality of agricultural products and its environments. Other importance of electrical properties to agricultural products includes: drying, ohmic heating, bio-sensing (in instrumentation, processing, harvesting, grading, storage and environmental control), automation and robotization of agricultural operations [5-8].

Electrical potential (Voltage) is measures in Joules/Coulomb, or Volts. It is the energy per unit charge required to transport any electric charge in the electric field from one point to another. It is a scalar quantity with no direction and said to be a property of the source charges. Knowledge of electrical potentials is used in batteries and capacitors. Electrical potential can also be called electrical potential difference [9]. Electrical potential can also be related theoretically with electrical potential energy, electrical work done and electrical field (see equation 1-4).

$$\Delta V = V_2 - V_1 \quad (1)$$

$$\Delta V = \frac{\Delta U}{q} \quad (2)$$

$$\Delta V = -\frac{W}{q} \quad (3)$$

$$\Delta V = -\int_1^2 E \, ds \quad (4)$$

Where ΔV is electrical potential in volts, V_2 is voltage at point 2, V_1 is voltage at point 1, ΔU is electrical potential energy in Joules, q is electric charge in coulomb, W is electrical work done in joules, E is the electric field in Newton/ coulomb and S is distance in meters.

Most researches that pass electrical current through agricultural seeds and measure the voltage used it to correlate with the seeds germinating power and plant growth [9-13]. This research wants to look at electrical voltage through sorghum in order to develop

moisture content measuring equipment using electrical potential. Although other researchers have developed moisture meters using other electrical properties like resistance, conductance and dielectric properties. It is always cheaper to use direct voltage measurement.

The objective of this research is to study the effect of moisture and current frequency on electrical potential of some sorghum varieties, with and intend of using these information to develop a grain moisture meter. To also generate regression equations relating moisture content to electrical potential.

2. Material and Methods

Sample

Sorghum (*Sorghum bicolor* (L.) Moench varieties that were considered in this study are; NGB 01907 (red sorghum), NGB 01589 (White sorghum), NGB 01227(yellow sorghum). Samples were acquired at the National Center for Genetic Resources and Biotechnology (NACGRAB), Ibadan, Nigeria. The samples were divided into their respective varieties and their moisture content determined according to ASAE standard [14]. The samples were then conditioned as described by Sangamithra et al [15] to 10, 13, 16, 19 and 22% db.

Determination of Electrical potential

Grain samples were poured into constructed grain sample holder shown in Figure 1. Sample holder was connected to the complete circuit for the measurement as shown in Figure 2. The circuit is made up of a functional generator, Digital Oscilloscope, sample holder and connecting wires. Input and output voltage readings from the oscilloscope were used to calculate the electrical potential using equation 5. Current frequency ranges used in this research were 1, 500, 1000, 1500 and 2000 kHz. All readings were replicated three times.

$$\Delta V = V_{input} - V_{output} \quad (5)$$

Statistic Analysis

A univariate analysis of variance (ANOVA) was done on the data collected from the experiment using SPSS software version 21. Means separation was carried out using Turkey HSD test. Regression equations were generated using Microsoft excels software.

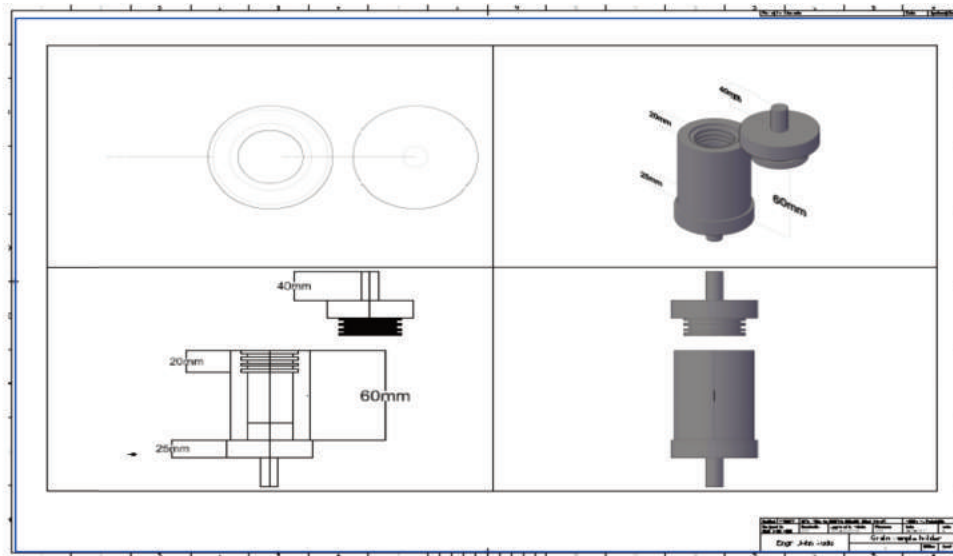


Figure 1. Grain Sample holder

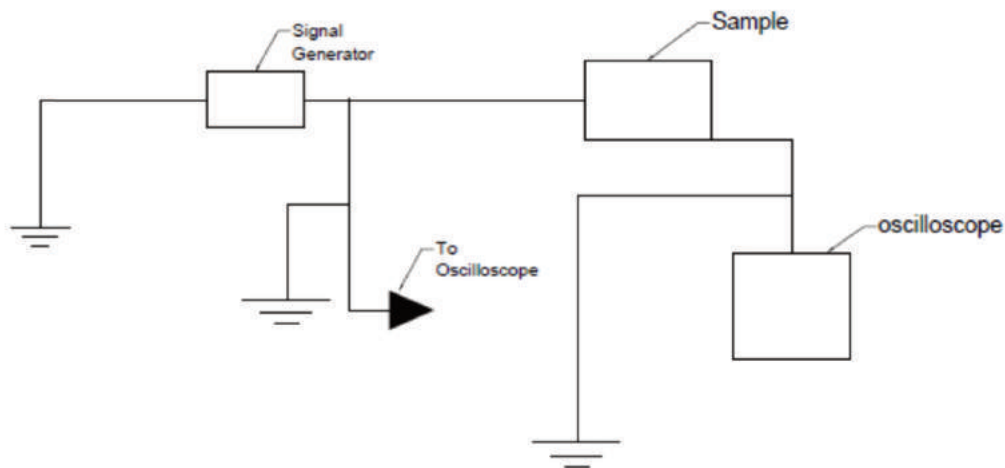


Figure 2. Circuit diagram for measuring Electrical potential

Table 1. Mean Results showing the effect of Moisture, current frequency and Variety on electrical potential (Δv)

*Different alphabets along row or column are statistically different from each other according to Tukey HSD ($P \leq 0.05$, Harmonic Mean Sample Size = 45.000, Mean Square (Error) = 0.072)

Varieties	Moisture	1 kHz	500 kHz	1000 kHz	1500 kHz	2000 kHz	Total
NGB 01589a	10%	-11.437	-13.187	-12.750	-12.613	-10.213	-12.040
	Std. Dev.	2.284	0.012	0.052	0.115	0.115	1.415
	13%	-10.300	-11.480	-11.540	-11.560	-11.560	-11.288
	Std. Dev.	0.000	0.000	0.000	0.000	0.000	0.512
	16%	-10.000	-11.520	-11.560	-11.600	-11.440	-11.224
	Std. Dev.	0.000	0.000	0.000	0.000	0.000	0.636
	19%	-0.200	-4.400	-5.800	-6.600	-6.800	-4.760
	Std. Dev.	0.000	0.000	0.000	0.000	0.000	2.516
	22%	-14.240	-14.767	-3.200	-4.800	-12.400	-9.881
	Std. Dev.	0.000	0.058	0.000	0.000	0.000	5.064
NGB01907b	Total	-9.235	-11.071	-8.970	-9.435	-10.483	-9.839
	Std. Dev.	5.001	3.674	3.899	3.235	2.039	3.685
	10%	-10.840	-11.317	-11.280	-11.720	-12.080	-11.447
	Std. Dev.	0.010	0.006	0.000	0.000	0.000	0.436
	13%	-3.800	-9.280	-9.160	-9.120	-9.280	-8.128
	Std. Dev.	0.000	0.000	0.000	0.000	0.000	2.241
	16%	-9.700	-11.200	-11.600	-11.760	-11.560	-11.164
	Std. Dev.	0.000	0.000	0.000	0.000	0.000	0.781
	19%	-9.120	-10.400	-10.480	-10.680	-10.520	-10.240
	Std. Dev.	0.000	0.000	0.000	0.000	0.000	0.587
NGB 01227c	22%	-14.360	-13.160	-13.240	-13.520	-13.400	-13.536
	Std. Dev.	0.000	0.000	0.000	0.000	0.000	0.446
	Total	-9.564	-11.071	-11.152	-11.360	-11.368	-10.903
	Std. Dev.	3.528	1.317	1.388	1.495	1.446	2.082
	10%	-11.390	-11.953	-12.920	-12.600	-12.997	-12.372
	Std. Dev.	0.010	0.011	0.001	0.000	0.006	0.635
	13%	-10.160	-10.980	-11.000	-11.000	-11.000	-10.828
	Std. Dev.	0.000	0.000	0.000	0.000	0.000	0.346
	16%	-12.000	-11.760	-11.480	-11.720	-11.760	-11.744
	Std. Dev.	0.000	0.139	0.346	0.000	0.000	0.222
Overall Total	19%	-8.360	-9.880	-10.240	-10.480	-10.360	-9.864
	Std. Dev.	0.000	0.000	0.000	0.000	0.000	0.806
	22%	-11.280	-13.120	-13.080	-13.640	-13.440	-12.912
	Std. Dev.	0.000	0.000	0.000	0.000	0.000	0.871
	Total	-10.638	-11.539	-11.744	-11.888	-11.911	-11.544
	Std. Dev.	1.330	1.115	1.146	1.169	1.205	1.256
	10%	-11.222	-12.152	-12.317	-12.311	-11.763	-11.953b
	Std. Dev.	1.178	0.823	0.781	0.447	1.230	0.988
	13%	-8.087	-10.580	-10.567	-10.560	-10.613	-10.081d
	Std. Dev.	3.216	0.999	1.081	1.107	1.029	1.925
	16%	-10.567	-11.493	-11.547	-11.693	-11.587	-11.377c
	Std. Dev.	1.083	0.253	0.181	0.072	0.140	0.639
	19%	-5.893	-8.227	-8.840	-9.253	-9.227	-8.288e
	Std. Dev.	4.283	2.879	2.282	1.992	1.821	2.953
	22%	-13.293	-13.682	-9.840	-10.653	-13.080	-12.11a
	Std. Dev.	1.511	0.814	4.980	4.390	0.510	3.327
	Total	-9.813d	-11.227a	-10.622c	-10.894b	-11.254a	-10.762
	Std. Dev.	3.584	2.301	2.706	2.369	1.674	2.634

3. Results and Discussion

Mean values obtained for electrical potentials after experimentation are shown in table 1. These values are obtained at a current frequency range of 1 – 2000 kHz. All electrical potential values obtained in this study had a negative sign. This shows that sorghum like other agricultural grains offer resistance to electrical currents. Similar observation had been reported by Oluwakemi and Omodele [3], Burubai [16], Kardjilova et al. [17] Shyam et al. [18], Moisés and Marcos [19] and Hlaváčová Z. [20].

For NGB 01589 variety electrical potential values obtained ranges from - 0.2 to - 14.767 volts. The electrical potential trend in this variety show, that it had low values at higher moisture content and high values at lower moisture content across all current frequencies. This occurrence may be due to the fact that water molecules form ions when electric current pass through it therefore carrying electric current faster between sorghum grain

surfaces. The faster the electric current moves through the grains, the lower the electrical potentials. Also Physical examination of data from this variety show, that increasing current frequency within the frequency range of study does not increase or reduce the electrical potential. The trend has a sinusoidal behaviour. It shows that increasing the current frequency from 1 – 500 kHz, produces almost the same electrical potential as increasing it from 1000 – 2000 kHz. This Phenomenon could be because at certain current frequency the molecular ions carrying electrical charges had reached their excitement peak and then it begins to lose this excitement caused by current frequency. Among individual current frequency used in this study, only 1000 and 1500 kHz shows a steady pattern. This pattern shows that increase in moisture content produces decrease in electrical potential values. These two current frequencies range are the recommended frequencies range to be used to measure moisture content when using electrical potential values for this variety.

The values obtained for NGB 01907 variety ranges from -3 to -14.36 volts. The electrical potential trends for increase in moisture show a wave like fluctuations along their paths. This behaviour could be because of the cellular structural arrangement or the present of colour pigment found in this variety. Low potential values are found within 13% moisture content. Below or above this moisture level the electrical potential value increases. This could be due to the fact that, this is the point where tightly held water molecule in the grains cells can be allowed to flow. Increase in current frequency increase the electrical potential of this variety. This occur because increase in current frequency the increases the excitements of water molecules causing to collusion among molecules therefore hinder current flow and reduce electrical potentials. For this variety any current frequency used produced similar behavioral trend on moisture.

Electrical potential values obtained in this study for NGB 01227 variety ranges from – 8.36 to – 13.64 volts. Data trend

shows that increase in moisture show a wave like fluctuations along their paths. This behaviour could be because of the present of colour pigment found in this variety. Also increase in current frequency shows similar behaviour to that of NGB 01907. Low potential values are found within 19% moisture content. This occurs due to the same reason as that of NGB 01907 too.

Analysis of variance done for data of electrical potential displayed in table 2 shows that the choice of analysis (corrected model) is significant at $p \leq 0.05$. This analysis also shows that all factors considered in this study and all its interactions were all significant at $p \leq 0.05$. Tukey HSD mean separation done shows that all levels of the three factors considered (Moisture, current frequency and variety) were statistical different from each others. This is an important factor to be considered when developing instrument that will be used to measure moisture level of sorghum grains use electrical potential values.

Table 2. Analysis of variance (ANOVA) for electrical potential of sorghum

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	1542.845 ^a	74	20.849	290.159	1.835 x 10 ⁻¹³³ *
Intercept	26059.214	1	26059.214	362666.344	1.106 x 10 ⁻²⁵⁵ *
Variety	111.291	2	55.645	774.418	8.821 x 10 ⁻⁸⁰ *
Moisture	458.904	4	114.726	1596.643	8.442 x 10 ⁻¹²² *
Current frequency	62.857	4	15.714	218.696	1.669 x 10 ⁻⁶¹ *
Variety vs. Moisture	381.546	8	47.693	663.747	5.794 x 10 ⁻¹¹³ *
Variety vs. Current frequency	36.693	8	4.587	63.831	1.818 x 10 ⁻⁴⁴ *
Moisture vs. Current frequency	176.826	16	11.052	153.806	2.239 x 10 ⁻⁸⁴ *
Variety vs. Moisture vs. Current frequency	314.728	32	9.835	136.877	2.776 x 10 ⁻⁹⁵ *
Error	10.778	150	0.072		
Total	27612.838	225			
Corrected Total	1553.623	224			

Alphabet (a) signify that R Squared = .993 (Adjusted R Squared = .990)

*Significant at $p \leq 0.05$

Regression analyses done for the three varieties are shown in Figure 3/A/B/C. The regression equations developed are:

NGB 01589

$$M = 82.866 - 36.329(\Delta V) - 3.6326(\Delta V)^2 - 0.1043(\Delta V)^3 \quad [R^2 = 0.9616] \quad (6)$$

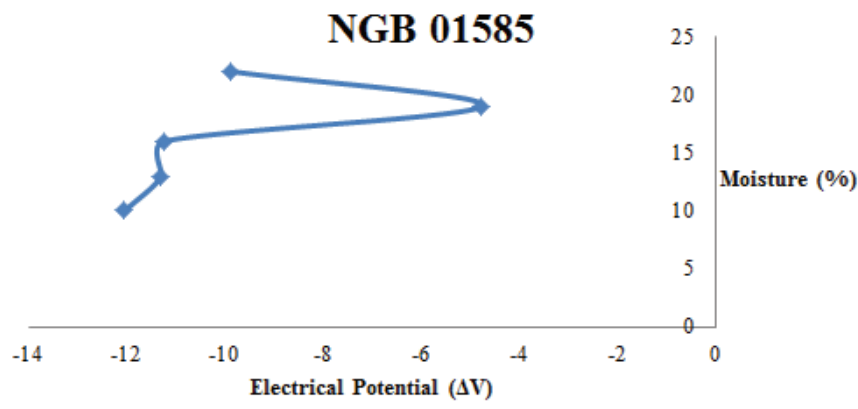


Figure 3/A. Graph of regression of moisture content on electrical potential

NGB 01907

$$M = -1348.6 - 393.93(\Delta V) - 37.226(\Delta V)^2 - 1.1527(\Delta V)^3 \quad [R^2 = 0.8885] \quad (7)$$

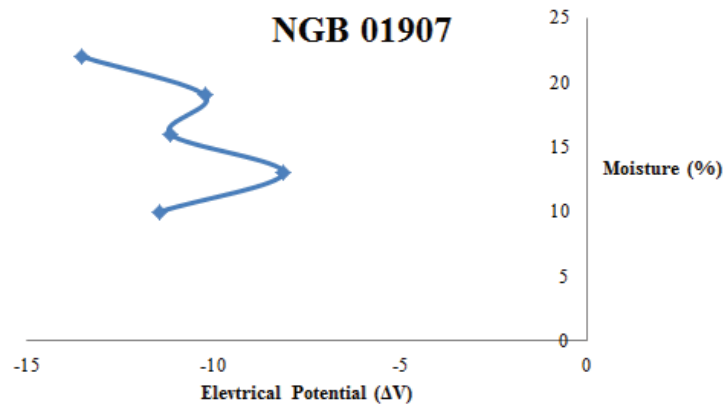


Figure 3/B. Graph of regression of moisture content on electrical potential

NGB 01227

$$M = -1910.4 - 547.9(\Delta V) - 51.477(\Delta V)^2 - 1.5975(\Delta V)^3 \quad [R^2 = 0.572]$$

(8)

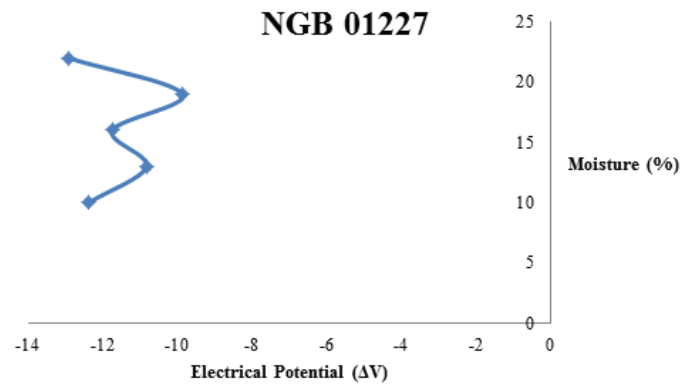


Figure 3/C. Graph of regression of moisture content on electrical potential

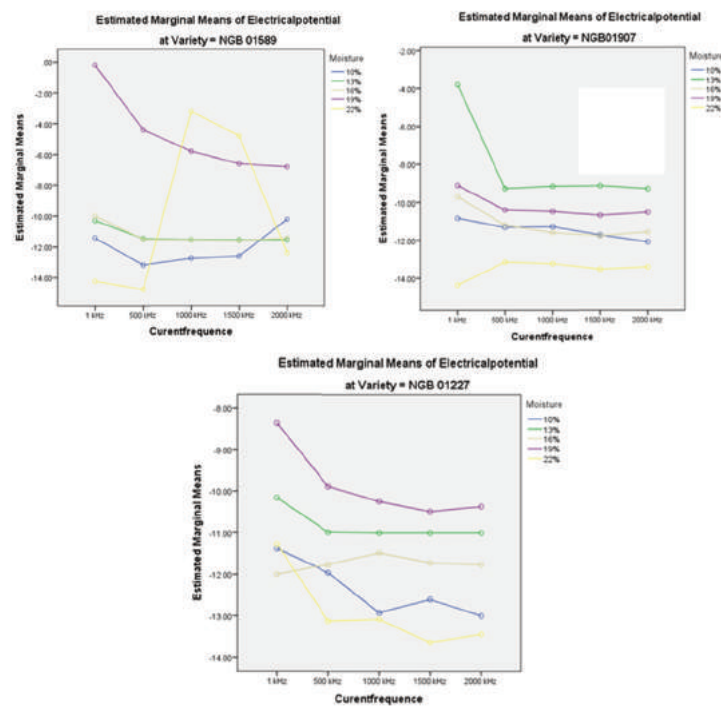


Figure 4. Graphical representation of all three factors (Moisture, current frequencies and variety) and electrical potential

An interaction graph between all factors and their interaction with the values of electrical potential are displayed in Figure 4. It shows that for NGB 01589 variety interactions occur between almost all moisture levels except 19% which has interaction only between 22%. For NGB 01907 variety interaction took place only between 16 and 10%. Interactions in NGB 01227 variety take place only between 10, 16 and 22%.

4. Conclusion

The following conclusion were drawn from this study

- Moisture, current frequency and variety with their interactions has significant effect at $p \leq 0.05$ on electrical potential of sorghum grains
- Behavioral trend between moisture and electrical potential are more visible at current frequency range of 1000 to 1500 kHz in all varieties
- Regressions equations developed shows that electrical potential values can be used to predict moisture of sorghum grains.

References

- [1] **du Plessis J.:** 2008. Sorghum production. ARC-Grain Crops Institute & South Africa Department of Agriculture. Revised edition.
- [2] **Kimber C.T.:** 2000. Origins of domesticated sorghum and its early diffusion into India and China. In 'Sorghum: Origin, History, Technology, and Production', (C. Wayne Smith and R.A. Frederiksen, eds), John Wiley & Sons, New York pp. 3-98.
- [3] **Oluwakemi A. O., Omodele I.:** 2015. The current status of cereals (maize, rice and sorghum) crops cultivation in Africa: Need for integration of advances in transgenic for sustainable crop production. *Int. J. Agric. Pol. Res.*, Vol. 3. No. 3. pp. 233-245. <http://dx.doi.org/10.15739/IJAPR035>
- [4] **Fogarassy Cs., Kovacs A.:** 2016. The Cost-Benefit Relations of the Future Environmental Related Developments Strategies in the Hungarian Energy Sector. *YBL Journal of Built Environment*, Vol. 4. No. 1. pp. 33-48. <http://dx.doi.org/10.1515/jbe-2016-0004>
- [5] **Kardjilova K., Bekov E., Hlavacova Z., Kertezs A.:** 2012. Measurement of Electrical Properties of Rapeseed Seeds with LCR Meter Good Will 8211. *International Journal of Applied Science and Technology*. Vol. 2. No. 8. pp. 35-44.
- [6] **Kondo, N. and Ogawa, Y.:** 2012. Bio-Sensing Engineering for Food Production and Product Utilization. Division of Environmental Science and Technology, Graduate School of Agriculture, Kyoto University.
- [7] **Kondo N., Mitsuji M., Noboru N.:** 2011. Agricultural Robots: Mechanisms and Practice, Kyoto University Press.
- [8] **Hlaváčová Z., Kertész Á., Staroňová L., Regrut T., Valach M., Híreš L., Petrović A., Wollner A.:** 2015. Connection between Biological Material Drying Characteristics and Electrical Properties. *Journal on Processing and Energy in Agriculture*. Vol. 19. No. 1. pp. 1-6.
- [9] **Sedighi N. T., Abedi M., Hosseini S. E.:** 2013. Effect of electric field intensity and exposing time on some physiological properties of maize seed. *Euro. J. Exp. Bio.*, Vol. 3. No. 3. pp. 126-134.
- [10] **Nelson O. E., H. S. Burr.:** 1946. Growth Correlates of Electromotive Forces in Maize Seeds. *Proceedings of The National Academy of Sciences*. Vol. 32. No. 4. pp. 73-84.
- [11] **Wheaton F. W.:** 1968. Effects of various electrical fields on seed germination. Published Retrospective Theses and Dissertations. 3521. Iowa State University. <http://dx.doi.org/10.31274/rtd-180813-928>
- [12] **Demir K. M.:** 2014. Conformity of vigor tests to determine the seed quality of safflower (*Carthamus tinctorius* L.) cultivars. *Australian Journal of Crop Science*, Vol. 8. No. 3. pp. 455-459.
- [13] **ASAE.:** 1998. ASAE S352.2 Standards, 45th Ed. DEC. 97. Moisture Measurement. Unground grain and seeds. 551. St. Joseph, Mich: ASAE
- [14] **Porsev E. G., Malozyomov B. V., Rozhkova M. V.:** 2017. Application of electric corona discharge for grain seeds treatment before sowing. *IOP Conf. Series: Earth and Environmental Science* Vol. 87. 042013. IPDME 2017. <http://dx.doi.org/10.1088/1755-1315/87/4/042013>
- [15] **Sangamithra A., Swamy G. J., Sorna P. R., Nandini K., Kannan K., Sasikala S., Suganya P.:** 2016. Moisture dependent physical properties of maize kernels. *International Food Research Journal* Vol. 23. No. 1. pp. 109-115.
- [16] **Burubai W.:** 2014. Some Electrical Properties of Melon (*Citrullus colosynthis* L) Seeds. *J Food Process Technol*, Vol. 5. No. 1. <http://dx.doi.org/10.4172/2157-7110.1000290>
- [17] **Kardjilova K., Yulian R., Zuzana H.:** 2013. Measurement of the Electrical Properties of Spelled Grains – T. Dicoccum. *International Journal of Applied Science and Technology*, Vol. 3. No. 7. pp. 118-126.
- [18] **Shyam N. J., Narsaiah K., Basediya A. L., Sharma R., Jaiswal P., Kumar R., Bhardwaj R.:** 2011. Measurement techniques and application of electrical properties for nondestructive quality evaluation of foods—a review. *J Food Sci Technol*, Vol. 48. No. 4. pp. 387–411. <http://dx.doi.org/10.1007/s13197-011-0263-x>
- [19] **Lagares M. L., Morais de Sousa M.:** 2008. Design of a Low-Cost Capacitive-Type Moisture Measurement System Embedded in Combine: Construction and Electrical Characteristics. *ABCM Symposium Series in Mechatronics*, Vol. 3. pp.493-500.
- [20] **Hlaváčová Z.:** 2003. Low frequency electric properties utilization in agriculture and food treatment. *Res. Agr. Eng.*, Vol. 49. No. 4. pp. 125–136.