Int.J.Curr.Microbiol.App.Sci (2019) Special Issue-9: 85-94

International Journal of Current Microbiology and Applied Sciences
ISSN: 2319-7706 Special Issue-9 pp. 85-94
Journal homepage: http://www.ijcmas.com

Original Research Article

Development of Rapid and Novel Method for Detection of Insect Infestation during Storage of Wheat and Maize Using Dielectric and Thermal Properties

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A B S T R A C T

Effective detection of insect infestation and control will protect the grains and contain post-harvest losses. Manual sieving method is the most prevalent method to detect the level of infestation. Since human intervention is involved. This method is laborious, need skilled manpower and susceptible to variation. Which affect the insect control process this lead to much storage loss. To predict or detect the level of infestation, various advanced techniques are being explored and most of them are in the research stage. With this purview, a study has been under taken to explore the possibilities of using thermal and dielectric properties for the detection of level of infestation. The thermal properties are measured using a KD2 Pro Thermal Properties Analyzer. And an experimental compaction setup was designed and fabricated especially to measure the dielectric properties with help of LCR meter. The experimental design was made with full factorial design with 10 replications. The level of significance was evaluated with the help of multivariate ANOVA. Partial least square regression (PLS) was employed to develop a model for predicting level of insect infestation in the grains with the identified parameters. All these statistical analysis were done using SPSS.

Keywords

Dielectric properties, KD-2Pro, LCR meter, Multivariate ANOVA, Thermal properties

Introduction

India being the second largest producer of food grains produces about 277.32 million tonnes of food grain in annually. Food grains are the principal source of human food, with wheat, rice, barley, oats, millet, rye, and corn (maize) being the most widely consumed sources of grains around the word. Grains are the seeds of grasses.

Wheat (*Triticum aestivum* L) is essential component of different types of food products, all over the world. It proves to be good source of carbohydrates, B-vitamins and some minerals in vegetarian diets of major part of population of Asia and Africa. Wheat is covering about 237 million hectares annually. In 2016, 749 million tonnes wheat was produced globally and contribute for at least one-fifth of man’s calorie intake.

Maize (*Zea mays L*) is most versatile emerging crop which has wider adaptability under varied agro-climatic conditions. Globally, it is also known as queen of cereals crops due to its high genetic yield potential value amongst all the cereals crops (Brar *et al.,* 2017).

Postharvest loss (PHL), a significant issue, 3.9-6.0% cereals are lost during harvest, post-harvest operations, handling and storage in India (Nanda *et al.,* 2012). The Central Institute for Post-Harvest Engineering and Technology CIPHET, Ludhiana, Punjab, in a national level study reported losses of 4.65 to 5.99% in food grains at different post-harvest stages during 2014–15 (Jha *et al.*, 2015). This amounts to around 16 million tonnes of food grains that are lost every year. Losses in wheat and maize production are generally noticed at various stages like threshing, transport and storage. Also the attack of rodents and birds lead to losses in grain production of wheat.

Losses during storage are mainly due to attack by storage insect-pests, loss of moisture in grain, fungus infestation, rodent attack, and spillage. Since a huge amount of the wheat produce is lost during the storage of grains, various precautions need to be taken to prevent these losses. It has been estimated that between one quarter and one third of the world grain crop is lost each year during storage.

Much of this is due to insect attack. In addition, grain which is not lost is severely reduced in quality by insect damage. Many grain pests preferentially eat out grain embryos, thereby reducing the protein content of feed grain and lowering the percentage of seeds which germinate.

In general terms, these insect pests share many characteristics that are adaptive for survival in food storages. These include wide tolerance of differing environmental conditions such as temperature and relative humidity, a wider range of food habitats than many other insects, long lifespans with continuous reproductive activity, the ability to withstand long periods without food or adaptability to alternative food resources, high fecundity and the ability to rapidly increase population size, and low detectability due to cryptic behavior or relatively small size (Cox and Collins, 2002; Rees 2004; Throne, 1994).

Grain selected for different porpoises is inspected to take preventative measure to reduce quality and quantity loss that might course during storage and transport. Stored grain is affected to both external and internal damage by insect, but internal infestations are the most difficult to detect. Detection internal insects in grains are important control measures for ensuring storage longevity, seed quality and food safety. Inspecting the infestation is labour intensive and many infested kernels may be undetected where an immature insect has not emerged from the kernel. Grain inspectors at milling facilities should know the quantity of hidden insect infestation so that loads with excessive infestations can be processed or diverted for other uses.

Though many researchers were reported about measuring moisture content of food grains using electrical properties, but very limited or almost nil study were reported about using dielectric and thermal properties for detection of insect infestation in the stored grains with this purview, a research work has been planned with the following objectives:

To study the dielectric properties of stored wheat and maize at various level of infestation.

To study the thermal properties of stored wheat and maize at various level of infestation.

To develop novel methodology for detection of insect infestation in stored wheat and maize using the above properties.

Materials and Methods

Raw material selection

Freshly harvested wheat (PBW-343) from ICAR-CIPHET Abohar campus was taken for the experiment. Maize was procured from seed village of Malakpur bet, Ludhiana. The wheat and maize was pre-cleaned with sieves to separate course foreign material, ferrous particles, and dust to prepare the wheat sample. The grains were separated into two batches one for insect culturing operations and another one for thermal and dielectric properties measurement studies. The 2nd batch grains were stored safety toll the experiments ends.

Insect culturing

As discussed in chapter 2 the major stored grain insects viz. The lesser grain borer, (*Rhyzopertha dominica*), Rice weevil (*Sitophilus granarius*) and Red flour beetle (*Tribolium castaeum*) were chosen for this study. Both larvae and adults of these insects are internal feeders, causing considerable damage to grain. Due to its wide tolerance of environmental conditions, it is an economically important pest worldwide (Fields *et al.*, 1993; Osuji, 1982). The insects for this study were obtained from an already existing culture in the environmental biology and food safety laboratory, CHIPHET, Ludhiana. The selected cleared fresh grains were infested with these insects in separate batches.

Sample preparation for properties measurements

The wheat and maize grains have been used for all the experiments. The grains were cleaned manually by the removal of all foreign matters such as stones, dirt and broken seeds. Twenty samples from both wheat and maize of each 50 g in weight were taken in a container and labelled properly.

The insect were sieved out from the cultured groups from the mixture of insect group, each type were separated meticulously, finally live and sound insects were identified from each group and selected for further experiments. Lesser grain borer was selected for wheat infestations and rice weevil for maize infestation. Each 50 g of sample was infested at various levels with the selected insect as given in design of experiments.

The wheat and maize grains were divided into 20 equal samples each of 50 g. In first sample five insects were placed. In subsequent samples the number of insects was increased by 5 each time. The measurement of different thermal and dielectric properties was done with whole grains as well as grounded flour form.

Measurement of thermal properties

The thermal properties are measured using a KD2 Pro Thermal Properties Analyzer (Decagon Devices Inc., Pullman, WA). The KD2 Pro is a handheld device. The KD2 Pro is a battery-operated, menu-driven device that measures thermal conductivity and resistivity, volumetric specific heat capacity and thermal diffusivity. The dual-needle sensor measures thermal conductivity, resistivity, volumetric specific heat capacity and diffusivity. In this research thermal properties were measured by dual- needle algorithm.

Measurement of dielectric properties

The digital LCR meter (MTQ4070 India) was used for determining the dielectric properties of wheat. The meter is capable of measuring inductance, capacitance and resistance. It is adopted double A/D converter core and large-scale integrated circuits.

Experimental setup

An experimental compaction setup was designed and fabricated especially to measure the dielectric properties with help of LCR meter as shown in fig.1. A mild steel cup of 101.6 mm diameter, 101.6 mm deep and 4 mm thickness was used as a same. One end is open and another was packed with 4 mm mild steel plate of 139.7 mm diameter. A mild steel frame was attached to the base plate as shown in plate 3.4 height of frame was 212 mm 5 mm to hold the bolt-handle arrangement, movable bolt length 241.3 mm, using bolt and handle the distance between copper electrodes are adjusted accordingly, The parallel plates used in this work shown in the figure consists of a two circular copper electrodes of 101.6 mm in diameter one of the plate was glued to the bottom of the cup and another was glued to lower side of the movable Bolt as shown in fig.1 and the copper plate was separated with the help of 5 mm acrylic plate to the mild steel plate both side.

Sample was placed in the cylinder, after that the screw above was tightened enough to move maximum compaction. The wire attached to the upper and lower plates were connected to LCR metre via alligator clips. Capacitance for each sample was recorded. The same process was repeated for each sample. For the next test, sample was grounded to flour and the process was repeated for measurement each sample.

Estimation of moisture content of grounded wheat and maize with insect

50 g flour of wheat and maize with insect samples were taken for Moisture Content estimation. The Moisture Content (mc) was determined by keeping the samples in oven at 105° C for 4 hrs. The flour Moisture Content was determined by the following formula:

Where,

W1 =weight of empty petri dish

W2 =weight of petri dish +grain before drying

W3 =weight of petri dish +grain after drying

(Source-AOAC, 1990)

Design experiments and statistical method

Independent variable

Infestation level viz. 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90, 95, and 100.

Grain viz. wheat and maize.

Sample form viz. whole grain and ground flour.

Dependent variable

Thermal properties viz. thermal conductivity, volumetric specific heat, thermal diffusivity and thermal resistivity.

Dielectric properties viz. capacitance.

Moisture content

The experimental design was made with full factorial design with 10 replications. The level of significance was evaluated with the help of multivariate ANOVA. The inter dependability was estimated between moisture content and thermal properties using paired 'T' test. In order to predict the level of infestation with the identified properties, multivariate analysis has been used. Partial least square regression (PLS) was employed to develop a model for predicting level of insect infestation in the grains with the identified parameters. All these statistical analysis were done using SPSS. The graphs were made with Microsoft Excel.

Results and Discussion

Insect growth dynamics during culturing

The numbers of insects remained nearly unchanged during the first 45 days for both wheat and maize due to the winter climate. But then the number of insects rapidly increased as the infestation period increased similar results were reported by Keskin and Ozkaya (2013). The rates of debris production and damaged grain in the infested wheat samples began to rise from the third month. The reason for population stasis is that, *Sitophilus granarius, Tribolium castaeum*, *Rhyzopertha dominica* are requires 30–40 days for growth from egg to adult. Additionally, the insects could not adapt to storage conditions in the first months of storage.

Nawrocka *et al.,* (2012) also explained that the degree of damage is directly related to the infestation rate. The growth of insect was highly correlated and highly significant to the level of infestation. The insect growth was found higher in the batch number 5 where mixtures of insects were infested. The lesser grain borer is whole grain lover on the other side red flour beetle is flour loving insect; this property would have mutually helped the insects for better growth.

Change in the thermal properties of whole wheat grains with respect to insect population

The infested whole wheat grains showed significant increase in their thermal properties such as thermal conductivity, volumetric specific heat and thermal resistivity. The ANOVA has revealed that the change in thermal conductivity volumetric specific heat and thermal resistivity were highly significant ($P< 0.05$) with respect to number of insect. The thermal conductivity was ranged from 0.1732 W/mK to 0.2456 W/mK, volumetric specific heat was ranged from 1.8871 MJ/m^3K to 2.7321 MJ/m^3K and thermal resistivity was ranged from 4.4005 mK/W to 5.8464 mK/W while increasing the insect population from 5 to 100 respectively.

Change in the thermal properties of ground wheat flour with respect to insect population

The infested wheat flour showed significant increase in their thermal properties such as thermal conductivity, volumetric specific heat and thermal resistivity. The ANOVA has revealed that the change in thermal conductivity, volumetric specific heat and thermal resistivity were highly significant ($P< 0.05$) with respect to number of insect. The thermal conductivity ranged from 0.1128 W/mK to 0.1296 W/mK, volumetric specific heat range of 1.2667 MJ/m^3K – 1.4370 MJ/m^3K and thermal resistivity ranged 7.4553 mK/W – 8.8859 mK/W while increasing the insect population from 5 to 100 respectively.

Change in the thermal properties of whole maize grains with respect to insect population

The infested whole maize grains showed significant increase in their thermal properties such as thermal conductivity and volumetric specific heat, thermal diffusivity. The ANOVA has revealed that the change in thermal conductivity and volumetric specific heat were highly significant ($P< 0.05$) with respect to number of insect. The thermal conductivity was ranged from 0.2306 W/mK to 0.3391 W/mK and volumetric specific heat was ranged from2.0265 MJ/m^3K to 2.7233

MJ/m^3K while increasing the insect population from 5 to 100 respectively.

Change in the thermal properties of ground maize flour with respect to insect population

The infested maize flour showed significant increase in their thermal properties such as thermal conductivity, volumetric specific heat, thermal diffusivity, and thermal resistivity. The thermal conductivity thermal resistivity were ranged from 0.1121 W/mK to 0.1759 W/mK, volumetric specific heat was ranged from 1.2519 MJ/m^3K to 1.6401 MJ/m^3K, thermal resistivity was ranged from 6.6795 mK/W to 8.9329 mK/W and thermal diffusivity was ranged from 0.0897 mm2/sec to 0.1013 mm2/sec while increasing the insect population from 5 to 100 respectively. The ANOVA has revealed that the change in thermal conductivity, volumetric specific heat, thermal resistivity and moisture content were highly significant ($P< 0.05$) with respect to number of insect.

Change in the conductance of whole wheat grains and ground wheat flour with respect to insect population

The dielectric property i.e. conductance has been shown non-significant ($P >0.05$) changes over the level of infestation in all the samples whole wheat grains and ground wheat flour.

Fig.1 Measurement of dielectric properties with help of LCR meter (MTQ4070)

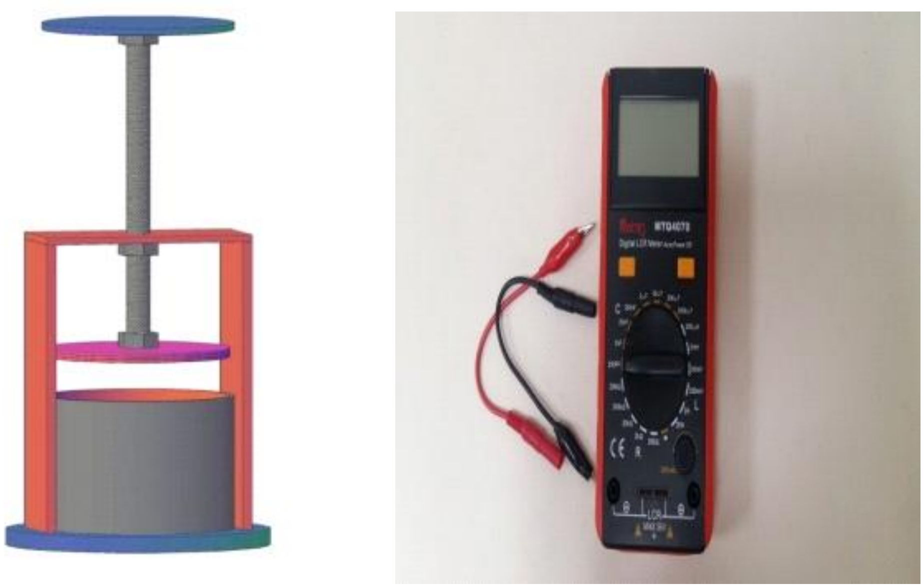

Fig.2 Variance explained by thermal properties 1. Thermal conductivity, 2. Volumetric specific heat of whole wheat grains in PLS

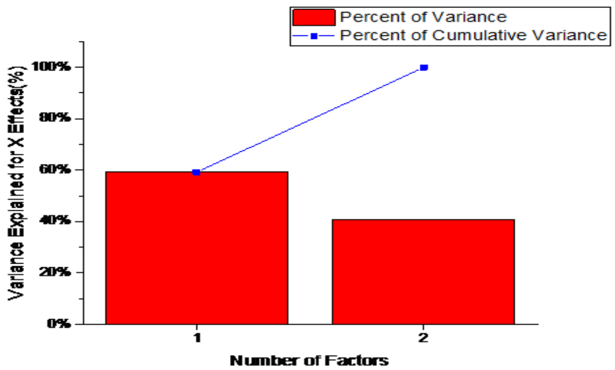

Fig.3 Variance explained by thermal properties 1. Thermal conductivity, 2. Volumetric specific heat of ground wheat flour in PLS

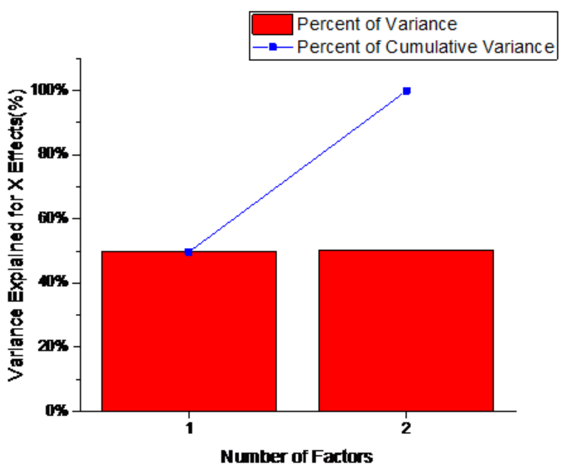

Fig.4 Variance explained by thermal properties 1. Thermal conductivity, 2. Volumetric specific heat of whole maize grains in PLS

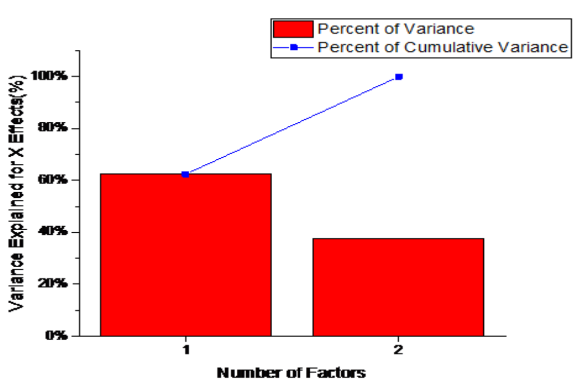

Fig.5 Variance explained by thermal properties 1. Thermal conductivity, 2. Volumetric specific heat of ground maize flour in PLS

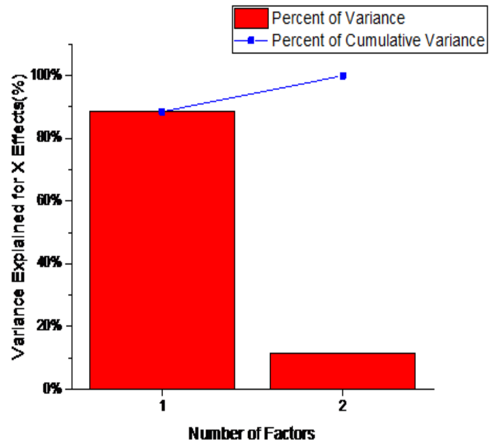

Table.1 Results of PLS regression analysis with thermal properties of whole wheat grains and level of insect infestation

	Coefficients	Per cent of Variance Explained	Per cent of Cumulative Variance Explained
Intercept	23.29989		
Thermal Conductivity	123.2098	59.22955	59.22955
Volumetric Specific Heat	2.02388	40.77045	100

Table.2 Results of PLS regression analysis with thermal properties of ground wheat flour and level of insect infestation

	Coefficients	Per cent of Variance Explained	Per cent of Cumulative Variance Explained
Intercept	96.9902		
Thermal Conductivity	-183.25	49.6899	49.68992
Volumetric Specific Heat	-246.11	50.3101	100

Table.3 Results of PLS regression analysis with thermal properties of whole maize grains and level of insect infestation

	Coefficients	Per cent of Variance Explained	Per cent of Cumulative Variance Explained
Intercept	46.55129		
Thermal Conductivity	-25.05464	62.38975	62.38975
Volumetric Specific Heat	111.74766	37.61025	100

Table.4 Results of PLS regression analysis with thermal properties of ground maize flour and level of insect infestation

	Coefficients	Percent of Variance Explained	Percent of Cumulative Variance Explained
Intercept	-27.14421		
Thermal Conductivity	-44.10163	88.52213	88.52213
Volumetric Specific Heat	60.83894	11.47787	100

Change in the conductance of whole maize grains and ground maize flour with respect to insect population

The dielectric property i.e. conductance has been shown non-significant (P >0.05) changes over the level of infestation in all the samples whole maize grains and ground maize flour.

Modelling of insect infestation for whole wheat grains and ground wheat flour

Highly significant parameters were selected i.e. thermal conductivity and volumetric specific heat for PLS analyser. Modelling of insect infestation for whole wheat grains and ground wheat flour the result obtained from PLS it could be observed that thermal conductivity has explained the level of infestation around 60 % and 50%. Then volumetric specific heat explained around 41% and 51% of level of infestation.

Modelling of insect infestation for whole maize grains and ground maize flour:

Highly significant parameters were selected i.e. thermal conductivity and volumetric specific heat for PLS analyser. Modelling of insect infestation for whole maize grains and ground maize flour the result obtained from PLS it could be observed that thermal conductivity has explained the level of infestation around 63 % and 89%. Then volumetric specific heat explained around 38% and 12% of level of infestation.

From the present study as summarized above, the following specific conclusions are drawn:

The thermal properties like thermal conductivity and volumetric specific heat values of the infested grains significantly increased with the increasing insect populations, in both wheat and maize.

The conductance had shown non-significant change with respect to insect infestation. More sensitive measuring device or compaction device may be used to get fruitful results. Since the conductance has showed non-significant results over the level of infestation, conductance properly has not been included in the modelling studies.

The significant parameters over the level of insect infestation i.e. thermal conductivity and volumetric specific heat have been considered for the PLS in order to model the infestation with respect to the measured properties. From all the modelling results, it could be concluded that thermal conductivity and volumetric specific heat can be used to develop the model for detecting level of insect infestation in wheat and maize.

References

Brar, I.S., Dixit, A.K., Khurana, R. and Gautam, A., 2017. Studies on Physical Properties of Maize (*Zea mays* L.) Seeds. *Int. J. Curr. Microbiol. App. Sci*, *6*(10), pp.963-970.

Carslaw, H.S. and J.C. Jaeger, (1959). Conduction of Heat in Solids, 2nd Edition. Oxford, London.

Cox, P.D. and Collins, L.E., 2002, Factors affecting the behaviour of beetle pests in stored grain, with particular reference to the development of lures, *Journal of Stored Products Research*, 38(2), pp. 95-115.

Fields, P.G., Van Loon, J., Dolinski, M.G., Harris, J.L., and Burkholder, W.E., 1993, The distribution of *Rhyzopertha dominica* (F.) in western Canada, *Canadian Entomologist*, 125(2), pp. 317-328.

Fontana, A. J., J. Varith, J. Ikediala, J. Reyes, and B. Wacker. 1999. Thermal properties of selected foods using a dual needle heat-pulse sensor, ASAE Paper No. 996063, St. Joseph, MI: ASAE.

Jha SN, Vishwakarma RK, Ahmad T, Rai A, Dixit AK (2015) Report on assessment of quantitative harvest and post-harvest losses of major crops and commodities in India. All India Coordinated Research Project on Post-Harvest Technology, Central Institute of Post-Harvest Engineering and Technology (CIPHET), Ludhiana, Punjab, India.

Jha, S.N., Narsaiah, K., Basediya, A.L., Sharma, R., Jaiswal, P., Kumar, R. and Bhardwaj, R., 2011. Measurement techniques and application of electrical properties for nondestructive quality evaluation of foods—a review. *Journal of food science and technology*, *48*(4), pp.387-411.

Kardjilova, K., Bekov, E., Hlavacova, Z. and Kertezs, A., 2012. Measurement of Electrical Properties of Rapeseed Seeds with LCR Meter Good Will 8211. *International Journal of Applied*, *2*(8).

Karthik, S.K., Mahesh, T., Sumanth, B. & Tanmay, M. Study of physical and engineering properties of corn (*Zea mays*). Bull. Env. Pharmacol. Life Sci, Vol 6 Special issue 1, 2017: 404-409.

Kluitenberg, G. J., J. M. Ham, and K. L. Bristow, (1993). "Error analysis of the heat pulse method for measuring soil volumetric heat capacity" Soil Sci. Soc. Am. J. 57:1444-1451.

Levinson, H. and Levinson, A., 1998, Control of stored food pests in the ancient Orient and classical antiquity, *Journal of Applied Entomology*, 122(1-5), pp. 137-144.

Mahapatra, A.K., Melton, S.L. and Isang, E.M., 2013. Effect of moisture content on thermal properties of cowpea flours. Agricultural Engineering International: CIGR Journal, 15(2), pp.251-255.

Neethirajan, S., Karunakaran, C., Jayas, D.S., and White, N.D.G., 2007, Detection techniques for stored-product insects in grain, *Journal of Stored Products Research*, 18(2), pp. 157-162.

Osuji, F.N.C., 1982, Development of the lesser grain borer, *Rhyzopertha dominica*, in maize kernels as affected by site of larval entry, *Entomologia Experimental is Et Applicata*, 31(4), pp. 391-394.

Rajendran, S., 2005, Detection of insect infestation in stored foods, *Advances in Food and Nutrition Research*, 49, p.163.

Rees, D., 2004, Insects of Stored Products, CSIRO Publishing, Collingwood, Australia.

Sangamithra, A., John, S.G., SornaPrema, R., Nandini, K., Kannan, K., Sasikala, S. and Suganya, P., 2016. Moisture dependent physical properties of maize kernels. *International Food Research Journal*, *23*(1).

Valamoti, S.M. and Buckland, P.C., 1995, An early find of *Oryzaephilus surinamensis* (L.) (Coleoptera: Silvanidae) from final Neolithic Mandalo, Macedonia, Greece, *Journal of Stored Products Research*, 31(4), pp. 307-309.