A Review on Moisture Measurement Technique in Agricultural Silos

M S M Abdullah¹, M H F Rahiman¹, A Zakaria¹, L M Kamarudin¹ and L Mohamed

¹Centre of Excellence for Advanced Sensor Technology (CEASTech), Universiti Malaysia Perlis, Pauh Putra Campus, 02600 Arau, Perlis, Malaysia.

Email: hafiz@unimap.edu.my

Abstract. Moisture content (MC) is that the weight of water contained in paddy and other grains expressed in percent. Moisture content is typically mentioned the wet basis which means the whole weight of the grain including the water (MCwb). Accurate MC testing is very important in managing and selling paddy and rice because depending on the aim rice has completely different ideal MC. Inaccurate MC measurements lead to lower head rice once milled at wrong moisture content, additional drying cost and loss of quality if paddy is dried too much, spoilage if the grain is just too wet in storage, additional drying cost and harvesting loss if paddy is harvested wetter than necessary and Weight loss (loss in profit) if grain is sold too dry. This paper intends to review the available techniques of moisture content measurements, its principles and sources of inaccuracies. Relevant properties of cereal grain also are studied with their impact on moisture content, temperature, density and humidity. There are several ways of grain moisture detection such as drying technique, resistance technique, capacitance technique, microwave technique, neutron technique, V/F Conversion, Fttir spectroscopic technique and Microcontroller technique. Current MC of grains are based- on sampling and individual single point measurement, so far, there is no available overall measurement of MC in silo, but by using tomography method can measurement MC in whole silo and investigate the efficiency and accuracy of localization of moisture distributions sensing in agricultural silo by using Gaussian algorithm.

1. Introduction

Moisture content (MC) typically refers to the wet basis, which suggests the entire weight of the grain, together with the water (MCwb). Accurate MC testing is incredibly necessary in managing and marketing paddy and rice as a result of counting on the aim rice has totally completely different ideal MC. Inaccurate MC measurements cause additional drying value and harvest loss if paddy is harvested wetter than necessary, spoilage if the grain is simply too wet is storage, additional is drying worth and loss of quality, if paddy is dried too, so much, lower head rice once milled at wrong moisture content and weight loss (loss in profit) if grain is sold too dry. MC of grain can measure by using either primary method, based on weight measurements like the (a) oven method or (b) infrared moisture balance or secondary method, using an electronic instrument that uses electrical characteristics of the grain. As moisture content measurements are done manually and this is the biggest problem in grain storage due to inefficient and not well distributed in moisture content reading and lead to false measurement, in turn, damaging the grain due to excessive moisture. To maintain grain quality throughout storage, grain
should be protected against the expansion and reproduction of fungi, insects and mites[1]. Storage
temperatures below 15C will forestall insect development and mite and fungi growth[2]. temperature in
storage is one in all the most necessary factors that verify grain storage quality[3].

The MC of stored rice grain changes according to the weather which affects MC in the silo with poor
aeration, this could lead to moisture build-up within the storage overtime and the moisture might be
unevenly distributed. Paddy drying technique embrace ancient and mechanical systems with variable
technological quality and capacities for either farm or industrial level, High MC level throughout storage
will lead to grain discoloration, increase the likelihood of attack from pests and encourage the
development of molds[4]. Table 1 show the moisture content for safe storage.

Table 1. Grain should be dried to a specific MC counting on storage period[5].

| Required MC for safe level storage | Storage period | Potential problems                      |
|-----------------------------------|----------------|----------------------------------------|
| 9% or less                        | <1 year        | Loss of germination                    |
| 12% or less                       | Storage of farmer’s seeds | Loss of germination                    |
| 13% or less                       | 8-12 months    | Insect damage                          |
| 14% or less                       | Weeks to a few months | Moisture adsorption, discoloration, respiration loss insect damage, Mold | ?

Ecological conditions like uneven temperature dissemination and wet wind current will make higher
wet substance create over the keep grains. The RH inside the air shut a grain test at a particular
temperature (T) relies upon the wet substance of the grains [6]. it’s along these lines important to
appropriately live and the executives the natural conditions for finding out the standard of the grains, keep
up an upper hand inside the nourishment technique exchange, and certification sustenance security[7].

MC measurements are done manually, and this is the biggest problem in grain storage due to inefficient
and not well distributed in MC reading and lead to false measurement, in turn, damaging the grain due
to excessive moisture. Thus, this study aims to investigate the efficiency and accuracy of localization of
moisture distributions sensing in agricultural silo using tomography approach. The advantages of
tomography lower cost, safety, easy handling, and high speed performance are important reasons why
this type of tomography is chosen particularly within the method industry and medical area[8]. The
correlation between multiple RF attenuation information can be gathered and analyzed using
tomography method to locate the moisture distribution in the silo. This would benefit the agricultural
sector in securing the food storage for the country and reduces damages of grain in the silos.

2. Methods of Measurement
There are several ways of grain moisture detection, as well as drying technique, resistance technique,
capacitance technique, microwave technique, Electrical moisture meter technique, Wi-Wheat technique,
Smart detector Network System technique, FTIR spectroscopic technique, Microwave technique,
Microcontroller technique, neutron technique, V/F Conversion and Radio-frequency (RF) technique.

2.1. Capacitive moisture detection technique
Developed quickly however the measuring value isn't only sensitive to temperature, however
additionally terribly sensitive to the grain flow rate and grain compactness within the drier and lots of
different factors in grain moisture measuring. And this technique is limited to the detector re-calibration
once very long time use[9][10].
2.2. **Wi-Wheat method**

Presented a non-destructive and economic wheat moisture detection system with artefact wireless local area network. The experiment validates the practicability of wheat moisture detection by victimization channel state information (CSI) amplitude and phase difference data. Data pre-processing, feature extraction and support vector machine (SVM) classification are enforced for CSI process module, However Wi Wheat achieved higher classification accuracy for line of sight and non-line of sight eventualities[11].

2.3. **DeepWMD technique**

A profound LSTM organize fundamentally based framework for multi-class wheat wet location. They utilized two Wi-Fi devices(5 GHz), while one is prepared in light of the fact that the transmitter and furthermore the inverse as the collector, framework misused CSI [12] abundance and stage refinement information from exchange products Wi-Fi gadgets for wheat MC detection, System accomplished high-exactness multi-class wheat wetness recognition in numerous indoor stockpiling environment [12], however the measuring device is complicated, high in price, unavailable to measure the whole silo, unavailable outdoor and need repeat steps more than just once.

2.4. **Smart detector Network System supported ZigBee Technology**

To observe Grain Depot is planned to monitor grains in storage depots. The harm of grains is controlled by observation the parameters like temperature, humidity and light that influence the storage of grains. The optimum temperature for the insects is 25°C to 32°C, Grain harm by fungi once the grain is keep at MC content below 14% and also the temperature is less than 20°C and higher than 40°C respectively, accurate measurements for parameters like, temperature, humidity and light[13], however this method available for various laboratory experiments and affected by surrounding environment.

2.5. **FTIR spectroscopic technique (Fourier Transform Is Required)**

An accurate, efficient and non-destructive techniques which might be used for multi-component analysis. These techniques can even be used for continuous on-line measurements. FTIR needs no external calibration, operation is incredibly easy and this method has most optical throughput with accrued sensitivity[14], However, technique will fail due to very localized and not represent whole grain in the silo.

2.6. **Microcontroller technique**

Based system for safe grain stockpiling in an exceedingly silo system which will monitor temperature and RH, live MC non-damagingly, and the management stockpiling condition to a protected level, system utilized Arduino software programming. The created CS was made out of Mega2560 (as the microcontroller), SHT21 sensors (temperature and RH), GSM SIM900A module, and data feller safeguard (V1.0 Deep-Robot). These deliberate parameters were wont to initiate and off the fan and warmer to oversee or keep up the capacity condition to a protected dimension, however framework could keep up and manage the capacity surroundings to safe dimension conditions [15][17], however, the temperature was very important for storage however, RH was thus high that the grain MC is laid low with the relative humidity (RH) of the storage surroundings.

2.7. **Microwave method**

Microwave wetness meters are developed specifically for oat grains. Okabe et al portray a microwave meter to be utilized with rice and wheat, operational at 9.4 GHz and uphold the lessening of the microwave motion by the grain test, that was set among sending and receiving horn antennas. The according precision was ±0.5% dampness content over the range from 10 to 30th. A microwave wetness meter for wheat, rye, grain, and oats, operational on the construction of a 9.35 gigahertz wave engendering through the grain and intended for nonstop wetness perception applications. Microwave movement at frequencies 9 GHz give preferred standpoint to solid assurance of grain test wetness content in either group or on-line application [18]. At these frequencies, varieties among grain tests in material properties on account of not meddle with solid discovery of the amount of water inside the grain
[19], estimating with microwave thunderous cavities of the resounding recurrence move and changes in hole transmission losses due the presence of a part inside the pit will offer size free and shape-autonomous estimation of the moisture content of single kernels[16][17].

2.8. Microwave moisture meter method
For estimate the relationships between wetness density inside the grain and so the attenuation and section shift, A model grain wetness meter consisting of a 10.5 GHz oscillator, patch array antennas, isolator, detector and electronic voltmeter provided a constant of determination, microwave is extremely effective for activity the moisture content of grain and will be pliant for fast, accurate, non-destructive on-line wet measurements on flowing grain [22]. However, the measurement device is complex and high in worth. However, it is affected by heat.

2.9. Relative humidity (RH) technique
May be measured using electronic meters, or perhaps a lot of inexpensively using indicator paper that changes colour response to RF. This method provides a spreadsheet to convert RF to MC for several common seeds and commodities. This technique may be used in the sector for quickly estimating seed or commodity moisture content to determine whether any drying is required or is suitable for storage, milling or different uses. Although the colour scale can distinguish only differences of 10 to 20% in RH, this is sufficient to estimate grain moisture content to at intervals or so a 1% within the range from 40 to 60% RH. At the extremes (80% RH), the conditions are clearly excellent or very poor for storage, therefore precision in conversion to moisture content is less necessary in those RH regions[18].

2.10. Radio-frequency (RF) technique
Basically, principles are represented for practice (RF) (including high frequencies and microwaves) material properties, or permittivity, of grain for detecting status material properties, or permittivity, of grain for detecting status through their relationship with wet substance. Radio frequencies are useful in quick and non-ruinous detecting of status content gratitude to high relationships that exist at any recurrence between the material properties of grain thus the amount of water blessing at interims the grain. The greater part of those dielectric-type status meters uses frequencies at interims the range between with respect to 1-20 MHz. Another methodology. All through that weakening and area move were thought of as elements of status content, grain mass thickness, and temperature, uncovered that temperature compensated, and thickness free status content judgments were gotten with 15.2 GHz estimations on shelled corn. [23].

2.11. A density-independent
Perform of the granular material permittivity offers guarantee for an all-inclusive institutionalization for detecting condition substance of granular or particulate materials. The procedures of thickness autonomous condition detecting by high-recurrence and microwave estimations give guarantee to advancement of instruments for brilliant use in perception MC of grain and completely very surprising materials on-line for strategy the board and the board.[19].

3. Design and Tomography method
Based on the principle of RF sensor, the diagram of detection circuit can be described as: RF sensor get the received signal strength indication each sensor by using 20 ESP8266 sensor then send data to cloud. It is shown in Fig.1.

![Fig.1 The design diagram of system](image_url)
The hardware of system is designed based on RF sensor, system has 20 ESP8266 sensor each sensor get data from 19 sensor then push it to cloud this part goes with all sensor after all sensor push data to cloud MATLAB analyse data to get tomography image.

Current MC of grains are based on sampling and individual single point measurement, so far, there is no available overall measurement of MC in silo. The MC of stored rice grain changes according to the weather which affects MC in the silo. With poor aeration, this could lead to moisture build-up within the silo overtime and the moisture might be unevenly distributed. In this condition, conventional measurement of MC will fail due to very localized and not represent whole grain in the silo. RF sensor network signals are known to have some level of sensitivity towards moisture. This characteristic can be exploited to locate the source of the moisture in the form of tomogram (moisture distribution map). To reconstruct the map, some information is required to be collected form the RF sensor network and suitable reconstruction can be studied. This project will focus on modelling RF sensor network communication to act as the sensor for sensing the moisture content in rice grain. A novel tomography project will be proposed to cater for the uneven moisture distribution in the silo. This tomography approach (RF sensor network) is possibly giving a full spectrum of MC reading inside the silo. System cover all silo by using mesh network each sensor become sender and receiver to get data in every place inside silo. By using gaussian algorithm to analyses data to localization of moisture distribution and get several image reconstruction algorithms for mapping the moisture in the silos. In Linear Back Projection algorithm (LBP), the concentration profile is generated by combining the projection information from every device with its computed sensitivity maps, the image reconstructed by LBP lands up in blurring the image that ends up in high AE in each live taken, This blurring image is due to the character of back-projection technique [20].

4. Comparison of measurement of moisture content (MC) strategies
Several methods have reported the values of the parameters used in drying their material likewise because the accuracy of the moisture content determination based on a typical test. These methods are given in Table.2. As can be seen, the electromagnetic Imaging technique has been used for an oversized of grains, with a large range of sample masses, applied, drying durations and initial MC.

Table.2 Measurement the moisture content by several method.

| No | Methods of measurement | Setup of the system | Description |
|----|------------------------|---------------------|-------------|
| 1  | Electromagnetic Imaging | ![Electromagnetic Imaging System](image1) | The measured data collected by an electromagnetic imaging system are used as the input to a picture reconstruction algorithm[21]. |
| 2  | Microwave Transmission at 10.5 GHz | ![Microwave Transmission System](image2) | System carried out to work out the optimum dimensions of a single patch antenna for wetness measure with antenna style [22]. |
| 3  | Microwave Dielectric at 5 to 15 GHz | ![Microwave Dielectric System](image3) | Dielectric properties of cereal grains were measured at 23°C over a variety of wet contents and over microwave frequencies from 5 to 15 GHz [17]. |
4 Electromagnetic Imaging

The setup is comprised of twenty four flux transmitter/receiver probes mounted on the inner walls of the bin. The system quantitatively pictures the insulator properties of the grain used as indirect indicators of wetness content, temperature, insect infestation[23].

5 Commodity WiFi

Wi-Wheat setup with off-the-peg laptops and native space network cards. the instance consists of associate horsepower ProBook 4411s PC with 2.1GHz Intel (R) Pentium 2 central process unit and 2GB RAM as receiver, and a Sony PCG-6S1T PC as a transmitter[12].

6 Relative Humidity and Temperature sensors

A data lumberman model TC-800D (Make: Ametropias, Mumbai) was record the temperature among the silo. The instrument had eight thermometer sensors K of a length of fifteen cm and a wire of length three m [24].
5. Conclusion

Apparently, a scientific study has not been conducted over the association of grain moisture in grains by drying to the vary varied grain wetness meters and diverse characteristics of grain that contribute to variability in insulator properties. To boot, there ought to be plenty of study conducted on the however the physical properties of grains influence the last word condition content throughout acquisition, storage and methodology. The foremost effective insulator properties and best frequency ranges ought to be designated whereas springing up with the instrument for fast condition determination, the correct choice and use of circuits are necessary on springing up with the sample holder capability for various commodities. The other necessary wishes for grain condition instrument embody the great issue concerning use, accuracy, consistency, precision, irresponsibleness and lightweight thus one will simply carry the instrument from heap to heap throughout acquisition season. Finally, there's another disadvantage that deals with the indirect techniques for activity of condition in grains that's that the “standard wetness determination method” to that all the measured electrical information should be referred. Typically, RF sensor network technique is to be considered because it is to investigate the efficiency and accuracy of localization of moisture distributions sensing in agricultural silo using tomography approach analyse data by gaussian algorithm. The correlation between multiple RF sensor network attenuation information can be gathered and analysed using tomography method to locate the moisture distribution in the silo. This would benefit the agricultural sector in securing the food storage for the country and reduces damages of grain in the silos and can measurement of moisture content in whole silo.

Acknowledgement

This research was financed by the Ministry of Education Malaysia under Transdisciplinary Research Grant Scheme (Ref: TRGS/1/2018/UNIMAP/02/4). The authors would also like to acknowledge Universiti Malaysia Perlis (UniMAP) for the facilities and technical support.

References

[1] Sun D W and Woods J L 1997 Deep-bed simulation of the cooling of stored grain with ambient air: A test bed for ventilation control strategies J. Stored Prod. Res. 33 299–312
[2] Sun D W and Woods J L 1994 Low Temperature Moisture Transfer Characteristics of Barley: Thin-Layer Models and Equilibrium Isotherms J. Agric. Eng. Res. 59 273–83
[3] Jia C, Sun D W and Cao C 2001 Computer simulation of temperature changes in a wheat storage bin J. Stored Prod. Res. 37 165–77
[4] Anon Drying - IRRI Rice Knowledge Bank
[5] Weinberg Z G, Yan Y, Chen Y, Finkelman S, Ashbell G and Navarro S 2008 The effect of moisture level on high-moisture maize (Zea mays L.) under hermetic storage conditions-in vitro studies [1] Z. G. Weinberg, Y. Yan, Y. Chen, S. Finkelman, G. Ashbell, S. Navarro, “The Eff. moisture Lev. high-moisture maize (Zea mays L.) under Hermet. storage Cond. Vitr. Stud. J. Stored Prod. Res., vol. 44, no. 2, pp. 136–144, 2008. 44 136–44
[6] Onibonoje M O and Kehinde L O A Wireless Sensor Network for Controlling the Effect of the Moisture Content in Stored Maize Grains Int. J. Eng. Res. Technol. Vol. 4 2278–0181
[7] Onibonoje M O and Jubril A 2012 Determination of Bulk Grains Moisture Content Ife J. Technol. 21 55–9
[8] Zarina S, Muji M, Abdul R, Hafiz M and Rahiman F 2013 Optical tomography : Image improvement using mixed projection of parallel and fan beam modes Measurement 46 1970–8
[9] Liu Z, Wu Z, Zhang Z, Wu W and Li H 2015 Research on online moisture detector in grain drying process based on V/F conversion Math. Probl. Eng. 2015
[10] Oommen T V 2002 On-line moisture sensing in transformers IEEE ABB Transmision Technol. Inst. 236–40
[11] Yang W, Wang X, Song A and Mao S 2018 Wi-Wheat: Contact-Free Wheat Moisture Detection with Commodity WiFi IEEE Int. Conf. Commun. 2018-May 1–6
[12] Yang W, Wang X, Cao S, Wang H and Mao S 2018 Multi-class wheat moisture detection with 5GHz Wi-Fi: A deep LSTM approach Proc. - Int. Conf. Comput. Commun. Networks, ICCCN 2018-July 1–9

[13] Kumar S, Hiremath V and K R 2012 Smart Sensor Network System based on ZigBee Technology to Monitor Grain Depot Int. J. Comput. Appl. 50 32–6

[14] Thakur R 2015 Determination of Grain Moisture Content Using Fttir Spectroscopy ME (Electrical Engineering) NITTTR, Chandigarh (INDIA) Assistant Professor Electrical Engineering Department, 34–5

[15] Daluyen D, Yaptenco K, Peralta E and Suministrado D 2019 Microcontroller-based control system for safe grain storage in silo IOP Conf. Ser. Earth Environ. Sci. 230 012020

[16] Anwar S I 2010 Determination of moisture content of bagasse of jaggery unit using microwave oven J. Eng. Sci. Technol. 5 472–8

[17] Trabelsi S and Nelson S O 2012 Microwave Dielectric Properties of Cereal Grains Am. Soc. Agric. Biol. Eng. 55 1989–96

[18] Bradford K J, Dahal P and Bello P 2016 Using Relative Humidity Indicator Paper to Measure Seed and Commodity Moisture Contents Aei 10

[19] Nelson S O, Trabelsi S and Kraszewski A W 2001 RF sensing of grain and seed moisture content IEEE Sens. J. 1 119–26

[20] Hafiz M, Rahiman F, Rahim R A and Rahim H A 2012 Image reconstruction algorithms for ultrasonic tomography Int. J. Innov. Comput. Inf. Control 8 527–38

[21] Asefi M, Jeffrey I, LoVetri J, Gilmore C, Card P and Paliwal J 2015 Grain bin monitoring via electromagnetic imaging Comput. Electron. Agric. 119 133–41

[22] Kim K, Daejeon Y and Kim M S 2005 Moisture Measurement in Grain by Free-Space Microwave Transmission at 10.5 GHz 0300

[23] Asefi M, Gilmore C, Jeffrey I, LoVetri J and Paliwal J 2017 Detection and continuous monitoring of localised high-moisture regions in a full-scale grain storage bin using electromagnetic imaging Biosyst. Eng. 163 37–49

[24] Sawant A A, Patil S C, Kalse S B and Thakor N J 2012 Effect of temperature, relative humidity and moisture content on germination percentage of wheat stored in different storage structures Agric. Eng. Int. CIGR J. 14 110–8