IJARCCE ISSN (O) 2278-1021, ISSN (P) 2319-5940

International Journal of Advanced Research in Computer and Communication Engineering

Impact Factor 8.102 ⁙ Peer-reviewed & Refereed journal ⁙ Vol. 14, Issue 3, March 2025

DOI: 10.17148/IJARCCE.2025.14378

Development of Optimized System for Measurement and Detection of Moisture Level in Grains.

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Abstract Moisture content plays a crucial role in determining the quality, shelf life, and market value of grains. Therefore, accurately measuring and detecting moisture levels is essential for efficient storage and processing. This study examines various methods used to determine moisture content, covering both traditional and modern techniques. Conventional methods like oven drying have been reliable for moisture measurement but often require more time and are unsuitable for real-time analysis. In contrast, advanced methods such as capacitance, microwave, and near-infrared (NIR) spectroscopy provide faster and more accurate measurements, often without damaging the grains. The study explores the principles, advantages, and limitations of each technique, focusing on their accuracy, efficiency, and cost-effectiveness. Experimental results highlight the effectiveness of non-destructive methods, which allow quick and precise evaluation without harming the grains. This emphasizes the importance of adopting modern moisture detection technologies in post-harvest management and agricultural practices to enhance food security and reduce waste in the grain supply chain. Given the impact of moisture content on grain quality, accurately and promptly detecting moisture levels is essential for farmers, grain handlers, and food processors. Modern moisture detection techniques provide real-time feedback, enabling operators to adjust storage conditions and processing parameters quickly. Capacitance-based methods measure the dielectric properties of grains, offering fast and non-invasive moisture readings. Microwave-based techniques use the interaction between microwave signals and water molecules in grains, providing high accuracy even in large quantities. Near-infrared spectroscopy (NIR) measures light absorption at specific wavelengths to estimate moisture levels, making it suitable for large-scale, continuous monitoring. The use of these advanced techniques improves post-harvest management by helping farmers and processors make better storage decisions, reduce spoilage, and maintain nutritional quality. Non-destructive methods are particularly valuable because they deliver rapid and precise results without affecting grain quality.

Keywords: USB to TTL UART Serial Converter, ADS1115, MS51FB9AE, etc.

I. INTRODUCTION

Grain moisture measurement plays a vital role in legal metrology, as it directly influences the quality, reliability, and trade value of grains in both domestic and international markets. Raw and wet grains are highly perishable and unsuitable for long-term storage, making it necessary to dry them after harvest before they can be sold or processed. Drying not only extends the shelf life of grains but also reduces their weight, which makes transportation more cost-effective and efficient.

In simple terms, when grains with high moisture content are traded, the excess moisture increases the overall weight, which means that buyers are essentially paying for water content rather than the actual grain. On the other hand, drying grains requires additional time and cost, which explains why dried grains are typically priced higher per unit weight than wet grains. This highlights the significant impact of moisture content on grain pricing, making it a key factor in both local and global trade.

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Moisture levels in grains are critical for ensuring their marketability, safety, and quality. High moisture content increases the risk of mould growth, spoilage, and pest infestations, leading to significant financial losses for suppliers and producers. Proper moisture management is essential to maintaining the nutritional value and sensory properties of grains. Therefore, accurate and timely moisture assessment is crucial for all stakeholders involved in the agricultural supply chain.

Traditional moisture measurement methods, such as oven drying, have been widely used for decades. However, these methods are often labour intensive, time-consuming, and susceptible to human error or sample manipulation. Recent advancements in technology have introduced more accurate and efficient moisture detection techniques, such as near-infrared spectroscopy (NIRS), microwave resonance, and capacitance sensors. These modern methods offer several advantages, including faster results, non-destructive testing, and the ability to measure moisture in large quantities with minimal sample preparation.

Effective moisture control is particularly important in global food supply chains, where improper drying and storage can lead to significant post-harvest losses. Beyond quality degradation, excessive moisture affects grain pricing, trade regulations, and industrial processes such as milling and biofuel production. For example, in the flour milling industry, maintaining the ideal moisture content is essential for achieving consistent product quality and milling efficiency. Similarly, in the biofuel sector, moisture levels influence energy yield and combustion efficiency during production.

Environmental factors such as temperature, humidity, and storage duration also affect the moisture balance in grains. Studies have shown that moisture migration within stored grains can lead to caking, germination losses, and biochemical changes that alter the nutritional value and processing quality of grains. Industries such as milling, brewing, and feed production rely heavily on the mechanical properties of grains, which are directly influenced by moisture levels.

While traditional moisture measurement methods like oven drying and Karl Fischer titration are known for their accuracy, they are often impractical for large-scale, real-time monitoring. To address these limitations, modern non-destructive techniques such as impedance-based sensing, microwave measurement, and NIRS have gained attention for their speed, accuracy, and automation potential. These advanced methods enable better decision-making in grain processing and storage, improving overall efficiency and reducing losses.

Managing grain moisture remains a challenge, particularly in regions with unpredictable weather patterns. Improper drying techniques can lead to moisture reabsorption, encouraging microbial activity and spoilage. Advanced storage solutions, such as controlled environment storage, aerated silos, and hermetic storage, have been proposed to address these issues. The integration of Internet of Things (IoT)-based sensors for real-time moisture monitoring is also emerging as a promising solution for intelligent grain storage management.

This study aims to provide a comprehensive overview of the impact of moisture content on grain quality, storage stability, and industrial applications. It will explore the latest advancements in moisture measurement technology and effective moisture control strategies to enhance grain handling and minimize losses. By drawing on insights from recent research, the study seeks to contribute to the development of more advanced and sustainable solutions for moisture management in the grain industry.

II. RELATED WORK

The measurement of grain moisture content has evolved significantly over time. Traditional methods, such as the oven-drying technique and Karl Fischer titration, have been widely used due to their accuracy [1]. However, these methods are often labour-intensive, time-consuming, and unsuitable for large-scale, real-time monitoring.

Numerous studies have examined how excessive moisture in stored grains contributes to mould growth, biochemical deterioration, and pest infestations. Investigated how environmental factors such as temperature and humidity influence moisture migration within stored grains, leading to caking and germination losses [2]. Similarly, research by analysed the biochemical changes in high-moisture grains, showing that increased moisture accelerates.

To overcome these limitations, researchers have explored modern moisture detection methods, including near-infrared spectroscopy (NIRS), microwave resonance, and capacitance-based sensors. NIRS, for example, provides rapid and non-destructive moisture analysis based on the absorption of infrared light at specific wavelengths. Microwave-based sensing techniques leverage the interaction between microwaves and water molecules to estimate moisture content with high precision, even in bulk storage conditions. Impedance-based sensors, which measure changes in electrical conductivity relative to moisture levels, have also gained attention for their accuracy and efficiency' [3].

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Storage conditions play a crucial role in maintaining the optimal moisture content of grains. Various studies have explored advanced storage solutions to prevent moisture-related spoilage. Suggested the use of aerated silos and hermetic storage techniques to minimize moisture absorption and fungal growth. Additionally, controlled-environment storage systems, which regulate temperature and humidity, have been found effective in preserving grain quality over extended periods.

Beyond its impact on quality and storage, grain moisture content has significant economic implications. Research has shown that high-moisture grains lead to increased transportation costs and weight discrepancies in trade [5]. Additionally, the milling industry requires precise moisture control to maintain efficiency and consistency in flour production. The biofuel sector is also affected, as excessive moisture in feedstock reduces combustion efficiency and energy output.

III. METHODOLOGY

The working principle of the resistive moisture detection system is based on measuring the dielectric properties of grains using two electrode rods. These rods act as conductive probes, detecting variations in moisture levels. The ADS1115 ADC (Analog-to-Digital Converter) converts the analog signals from the electrodes into digital values, which are then processed by the MS51FB9AE microcontroller. The processed data is transmitted via a USB to TTL UART Serial Converter, enabling real-time communication with an external device such as a PC or display unit.

❖ Block Diagram

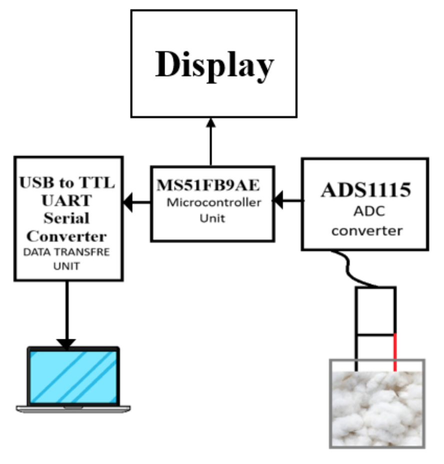

Fig. 1. Block Diagram of system

❖ Data Collection & Signal Processing:

1. The electrode rods generate a small electrical field inside the grain sample.
2. The ADS1115 ADC captures voltage differences affected by the moisture content of the grain.
3. The MS51FB9AE microcontroller receives the data, filters noise, and applies calibration formulas to determine moisture levels accurately.

❖ Algorithm Development:

To ensure precise moisture measurement, the system relies on calibration with pre-stored reference data for different grain types.

1. Regression Models: Linear or polynomial regression models convert ADC values into moisture percentages.
2. Error Correction: Advanced algorithms adjust for variations in grain type and environmental conditions, improving overall accuracy.

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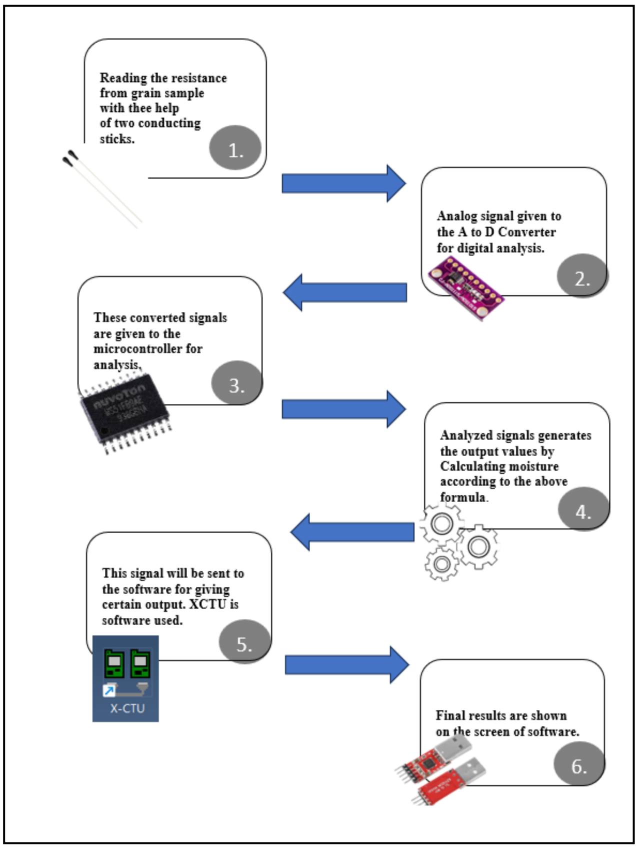

❖ System Integration:

The system is designed for efficient real-time data processing and display.

1. The USB to TTL UART module enables smooth data transfer to a PC or external monitoring device.
2. A graphical user interface (GUI), such as a PC software program or mobile app, visually presents moisture level readings, making it user-friendly.

❖ Testing & Validation:

1. The accuracy of the moisture meter is compared with standard moisture measurement devices to fine-tune calibration.
2. The system is tested with various grain types (rice, wheat, corn) under different humidity conditions to ensure reliability.

❖ Deployment & User Operation:

To use the system, the user inserts the electrode rods into the grain sample and connects the device to a PC via USB-TTL UART.

1. The microcontroller processes the data and transmits the moisture percentage for display.
2. Regular software updates can further improve the precision of moisture measurements over time.

❖ Formula for calculating moisture:

In moisture detection using resistivity, the relationship between the resistivity of a material and its moisture content can typically be modelled through a mathematical formula. This formula is often derived from experimental data and can vary depending on the material and method used for measurement.

One common formula for moisture content based on resistivity is:

$$\rho = A \cdot (M)^{B}$$

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- ρ = resistivity of the material (measured in ohm-meters)
- M = moisture content (expressed as a fraction or percentage, often in weight or volume)
- A and B = empirical constants that are determined based on the material being tested (through experiments).

❖ Method for getting readings:

Readings are taken from the grains using two conducting rods. These rods act as sensors to measure the electrical properties of the grains, which vary based on their moisture content. The collected signals are in analog form and must be converted into digital signals for further processing. This conversion is performed using the ADS1115, a high-precision 16-bit analog-to-digital converter (ADC). The ADS1115 captures the analog signals from the conducting rods and converts them into corresponding digital values.

Once the signals are digitized, they are transmitted to a microcontroller for analysis and calculations. The microcontroller used in this system is the MS51FB9AE, a product of Nuvoton Technology, belonging to the 51 series of 8051-compatible microcontrollers. This microcontroller processes the digital data and calculates the moisture content of the grains based on a predefined formula.

After performing the necessary calculations, the microcontroller sends the processed data to a personal computer (PC) for further analysis and display. This data transmission is facilitated by a USB-to-TTL UART Serial Converter, which ensures seamless communication between the microcontroller and the PC.

On the PC, specialized software is used to interpret and visualize the received data. The software employed for this purpose is XCTU, which provides a user-friendly interface to display the calculated moisture values in real time. Once the data is processed and analysed, the final moisture content of the grains is displayed on the screen, allowing users to monitor and assess the grain quality efficiently.

IV. EXPECTED RESULTS

The resistive moisture measurement system is expected to provide accurate, real-time, and reliable moisture content readings for various grain types. By detecting variations in moisture levels through the electrical resistance properties of grains, the system ensures precise grain quality assessment. The measurement accuracy is anticipated to be within ±0.5% to ±1%, making it comparable to standard moisture meters. With the integration of the ADS1115 ADC and MS51FB9AE microcontroller, the system should deliver instantaneous moisture readings, enabling quick decision-making for grain storage and processing.

Data transmission is expected to be seamless and error-free with the USB-to-TTL UART Serial Converter, ensuring smooth communication between the microcontroller and the PC. The XCTU software will provide a user-friendly display interface, presenting moisture levels in real-time through graphical or numerical formats, allowing users to analyse grain conditions efficiently. The system is designed to work effectively with different grain types such as wheat, rice, and corn, ensuring consistent performance across various moisture levels and environmental conditions. One of the key advantages of this system is its ability to enhance grain storage management by preventing spoilage, mold growth, and pest infestations, thereby reducing post-harvest losses and improving food security. Additionally, the system is scalable and adaptable, with the potential for future enhancements such as IoT-based remote monitoring and advanced calibration techniques to further refine accuracy.

A notable feature of this system is its sensor-less design, which eliminates the need for specialized moisture sensors. Instead, it utilizes conductive rods for direct electrical resistance measurement, simplifying the design while maintaining high accuracy and reducing overall costs. With these expected outcomes, the proposed moisture measurement system will serve as a cost-effective, efficient, and practical solution for farmers, traders, and grain processors, ensuring better grain quality control and optimized storage practices.

V. CONCLUSION

The implementation of a resistive moisture measurement system for grains provides an efficient, accurate, and cost-effective solution for determining grain moisture content. By utilizing conductive rods as sensors, the system effectively captures the electrical properties of grains, which vary with moisture levels. The integration of the ADS1115 ADC ensures precise conversion of analog signals into digital values, while the MS51FB9AE microcontroller processes this data to calculate moisture content using predefined formulas.

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The incorporation of a USB-to-TTL UART Serial Converter allows seamless communication between the microcontroller and a PC, where XCTU software is used to interpret and display real-time moisture readings. This system not only enhances accuracy but also ensures rapid, real-time monitoring, making it highly suitable for agricultural applications.

Overall, this method offers a non-destructive, reliable, and scalable approach for moisture detection in grains, helping farmers, traders, and industries improve grain quality, optimize storage conditions, and minimize post-harvest losses. Future improvements may involve refining calibration models, integrating IoT-based monitoring, and expanding compatibility with diverse grain types to further enhance the system's effectiveness.

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