Density Independent and Temperature Compensated Moisture Prediction Model for Agricultural Products Using Impedance Analyzer: A Review

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Abstract— *Agricultural products play an essential role in stabilizing the country economy. Third largest sector of Indian economy is agricultural products. In agricultural products the important factor for post harvesting, processing, storage and transport, is moisture, which affect their quality. In modern agriculture fast, non-destructive and reliable sensing technique for determination of moisture content in agricultural crops is required to prevent the losses and to improve efficiency of production. Various techniques are available for moisture sensing in agricultural products and better results have been achieved with use for these techniques. The performance of developed method for moisture sensing is comparable with that of commercial moisture meter. The most reliable solution for measuring the moisture content of agricultural products and non-destructive method is use of bulk density dielectric function. This paper reviews the area of moisture determination methods for various agricultural products and summarizing the various electrical methods for moisture determination.*

Keywords— Agricultural products, bulk density, impedance analyzer Moisture content, permittivity.

I. INTRODUCTION

Moisture content of various agricultural products is one of the most important parameter to be considered while making the decision of quality of product and durability of product. Moisture content determination mainly refers the water presence in the agricultural products. Moisture content is mainly related to the weight loss after drying the products. Storage time is also under consideration also affected by the moisture content. Moisture level is inversely related to storage time because of the reason that moisture is greater than that storage time is lesser moisture level is high then spoilage of the agricultural products.

Several methods of measuring moisture play an important role in agricultural products. Chemical spectroscopic methods and other methods are used in laboratory for moisture analysis. Each mechanism has its own advantage and disadvantages and all are being continually studied, modified and improved. This paper reviews existing and in-development procedures and technologies.

II. METHODS OF MOISTURE DETERMINSTION

Moisture content of agricultural products can be obtained by direct and indirect methods. Direct method of moisture measure the amount of water by removing it with the help of standard method air oven method and vacuum oven method. Direct methods are formulated to obtain accurate value for calibration purposes and often are used as reference methods. However, these suffer from the demerits being offline, time consuming and destructive as well. General moisture measurement methods and instrumentation

I. Direct Method
II. Indirect Method

Direct method of moisture determination based on measurement of weight of sample. The methods oven and microwave oven used to determine moisture content from the sample. The direct methods are used as a reference method.

Indirect method measure the moisture content using electronic instrument that uses grains electrical characteristics. Resistive and capacitive type moisture meters are most commonly used in indirect methods.

III. TECHNIQUES OF TEMPERATURE COMPENSATION AND DENSITY INDEPENDENCE MOISTURE MEASUREMENT

Moisture measurement can be make density independent with the help of a new density independent function reported in literature. This new density independent function determines the relationship of bulk density and two component of complex permittivity [1]. The new density independent calibration functions accounts the energy distribution and integrates effect of both temperature and frequency. Researchers reported calibration equation for bulk density and moisture determination at different temperatures and frequencies. The accuracy of determination of both entity depends on accuracy with which ε' and ε" are determined [2]. Several equations for calibration based on measurements taken 1.5GHz for various densities, temperature and moisture contents. Bulk density of grain cannot be determined, but moisture content determination for independent of bulk density of material and temperature for compensation can be done. Attenuation and phase shift were considered as a function of moisture content. One researcher revealed that density independent and temperature compensated determination were obtained with 15.2 GHz measurement on shelled corn [3]. The calibration exclusively dependent on content of water and relatively independent of both bulk density and material type. For the attenuation and phase measurements function required for moisture measurement of different agricultural products like wheat, oats soybean at frequency 9 GHz . Electrical property of materials which required calibration function is expressed in terms of relative complex permittivity and this suggested method is more flexible to measure ε' and ε'' accurately [4]. Cereal grains permittivity at radio frequencies are useful in fast and nondestructive moisture content measurement because of high corrections that exist between the dielectric properties of grain and amount of water present in the grain at any frequency are dependent on frequency, temperature and bulk density variables taken in to account for reliable moisture content sensing technique [5]. Nondestructive, fast, reliable moisture content measurements in cereal grains for improvement in efficiency of production of source of food, prevention of losses agricultural crops is important in modern agriculture and relative complex permittivity measurement, dielectric properties have their advantages at microwave frequencies that include density independent moisture content measurements[6]. Three sensing electrodes which are electrically separated that were used as a fringing field sensor, as a parallel plate sensor. [7]. Multichannel ring electrodes used to measure the electrical properties of various zones of bread. They found resistance variation bread crumb as an exponential equation with moisture content [8]. Four steel electrodes and an LCR meter were used for the measurement of resistance, reactance and capacitance. They found low level of correlation coefficient in between the moisture ranges from 1.2% to 80 % wet basis [9].

IV. ELECTRICAL PROPERTIES MEASUREMENT BY LCR METER

The material that correlates with factors of the quality of product i.e. ripeness and moisture content Measured the dielectric constant and loss factor. Capacitive sensor is mainly used for moisture content determination [10]. At the final stage the moisture content of tea leaves, drying plays an essential role in product quality and durability. The two methods for this propose are weight method and human taster. They found these methods are not suitable for online monitoring of MC of tea leaves [11]. Three temperature correction functions were evaluated and main goal of the method to provide equivalent moisture prediction without any calibration development. Temperature measurement require high and low moisture levels to confirm that a quadratic and linear moisture dependent to establish for correction coefficient more precisely [12]. Non-destructive measurement of moisture by using capacitive sensor in nuts and grain.

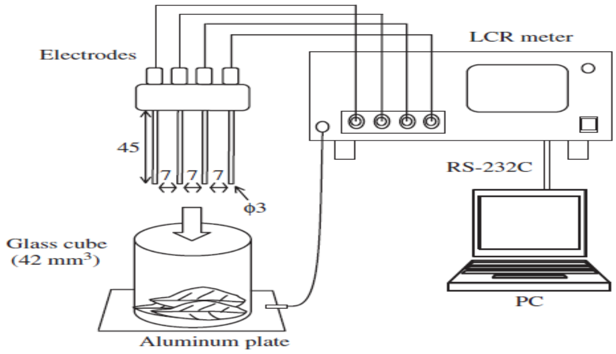

Fig.1: LCR Meter

This electronic circuit could be useful tool and economical in marketing and drying processing of peanuts [13]. Grain moisture measurement may be predicted by measuring the dielectric constant that is mostly conditional on the moisture content of all the frequencies. Dielectric constant changed as homographic function with variation in moisture content [14]. From investigations a nondestructive impedance spectroscopic technique, is made with the help of probe of two terminals and precise LCR meter as shown in fig. 1. The ratio in middle of raw and ripe mango, measured 1 KHz frequency. Optimum frequency selected for repeatability and dependability [15]. Bulk density determination of granular materials from dielectric properties measurement at microwave frequencies that bulk density is used to created calibration at frequency 7 GHz for seed over wide ranges of temperature and moisture content [16]. Measurement values of current and voltage are used for the impedance at each zone and electrical impedance behavior of bread loaf at crumb and crust investigated during storage time. This technique can be fine-tuned to meet the requirement of moisture content determination of other bread products through software [17]. Dielectric properties of peanut hulls pellets can be used for development of rapid and non-destructive sensors. They observed variations in permittivity due to temperature moisture content and density. They develop the calibration method for rapid and nondestructive technique for moisture content determination of peanut hull pallets [18].

A fast and simple FTNIR technique to moisture content prediction in green tea granules was developed with single calibration model. The measurement can be done in short period of Time (approximately 5 to 10s). Industries can be directly adopt this technique for measurement of moisture content in green tea leaves at different stages of drying and during storage without preserving the tea leaves [19]. To determine NIR reflectance spectroscopy could be a useful tool for the moisture concentration analysis in shell peanuts that requires sample preparation. Partial least square regression analysis was obtained calibrations. NIR spectroscopy would result in large saving in time, processing, and labor during drying, and storage of peanuts [20].

For storage and processing of tea moisture content sensing is necessary because it affects the quality and durability of the product. Oven method is time consuming technique. To overcome this problem moisture content measurement of oolong tea by equilibrium relative humidity technique used [21].Density-independent moisture content measurements can be applied on wheat within certain density ranges. Both Static and dynamic tests on wheat yielded the good results for density independent determination [22]. Values of loss factors and dielectric constants are presented graphically for different products, i.e. grains, poultry products fruits and vegetables [23]. Oilseeds and cereal grains permittivity varies with the frequency of electric field applied, and their temperatures, and bulk densities varies with the moisture content. [24]. Researcher found the high correlation between moisture content and dielectric constant for each sample and was fitted data to quadratic trend line [25]. Various factors such as frequency, moisture content, bulk density, temperature of food materials affect dielectric properties. Dielectric properties analysis and on-line measurement of food materials are portable, fast and inexpensive [26]. The impedance of carrot samples at the end of the drying process reached higher values in comparison when samples had higher moisture content with the beginning of drying [27]. The loss factor and dielectric constant related to the moisture content, temperature, and bulk density of wheat straw and the electric field frequency. The dielectric properties i.e. temperature, and bulk density are recognized, and measured moisture content of straw [28]. Moisture content is an essential parameter in peanuts to be determined and observed at various parameters in the peanut industry and it is possible to evaluate the MC of a small sample of in shell Peanuts from phase angle and impedance determine by using a low cost impedance meter [29]. Two essential factors are moisture content and frequency. Temperature and bulk density impact the value of dielectric properties. If increase in frequency then decrease in moisture content [30]. Two semi oval isolated copper plates and keithly C-V analyzer used for capacitance measuring instrument, which has capability of measuring capacitance at two frequencies of 100 KHz and 1 MHz. they carried out experiments on five field crops of sorghum, maize capsular bean sunflower and white bean. They determine the coefficient were higher at 100 KHz than at 1 MHz [31].

V. ELECTRICAL MEASUREMENT TECHNIQUES

The electrical methods of moisture measurement are considerable interest because of their inherent features over other techniques. The variations in dielectric properties with change in temperature moisture content, density, frequency and graphical belonging to grain and soybeans as a function as measurement of moisture content. The aim of research was to improvement in product quality by improving seeds, keep nutritional value and to control insects in grains. [32]. Impedance analyser, open-ended coaxial-line probe, and suitable sample temperature control equipment dielectric properties of samples of chickpea flour as a function of moisture, frequency and temperature were measured with an Greater impact on permittivity, temperature and moisture content is high and then lower temperatures and moisture content. [33].

1. Open ended Coaxial Line Probe- Open ended coaxial line probe have loss factor and dielectric constant with in surface and an impedance analyzer on outer surfaces. They divided loss factor and dielectric constant, soluble solid content are correlated [34]. For the determination of complex permittivity and moisture content and dielectric properties of oil palm fruit open ended coaxial sensors isused. [35].

2. Transmission Line Technique- This technique measure both transmission and reflection. This technique is more accurate then coaxial probe method and having narrow frequency range. Sample preparation is more typical and nondestructive, automated determination ofthis technique and time consuming method. By this technique dielectric properties can be easily obtained [36].

3. Time Domain Spectroscopy/ Reflectometry- During storage, processing, harvesting, and trading are controlled by its moisture content for maintaining quality of agricultural products. The method offers fast, water content of soils with minimal soil-specific calibration in a wide range. It is usually essential to determine the electrical properties under the extreme conditions of interest to acquired reliable data [37].

Table 1 Comparision of Different Electrical Measurement Techniques [34],[35],[36],[37],[38]

S.No.	Technique used	Merits	Demerits
1.	Open-ended coaxial probes	This method is easy to measure the dielectric properties of semi-solid foods and high loss liquid and vegetables and fresh fruits. Sample preparation is not needed.	This method is not free of error due to the reason of variation in density.
2.	Transmission line technique	This technique is more precise and delicate than the above method. Viscous-fluid type and Liquids foods can be determined and easily acquired the results.	Sample preparation is also time consuming and much difficult.
3.	Resonators and transmission Line	The method resister to all solid and liquid materials.	Preparation of sample of solid materials is difficult and not acquired good result.
4.	Time domain spectroscopy/ reflectometry	The measurement is very fast and highly precise, with a few percent errors and sample size utilize in this technique is very small and the substance to be determined must be same and exceptional tools for advanced research electromagnetic energy and materials over a wide range of frequency.	These techniques are very costly.
5.	Free space transmission techniques	Particular Sample preparation not needed, therefore they are especially suitable for in homogeneous dielectrics. They may be easily recommended in industrial applications for and control and continuous monitoring e.g., density and moisture content determination. Precise determination of the permittivity over a wide frequency range can be attained.	

4. Resonator and Transmission Line- To determine permittivity with the use of microwave resonator. The resonator is usually calibrating material whose dielectric properties are known. This method is used for all liquids and solids [36].

5. **Free Space Microwave Technique-** The free space microwave technique for low moisture content determination of green tea leaves. The maximum moisture content determined by this method is 32%. By using this method phase shift at the frequencies 9 GHz and 12GHz and the method provides low moisture content determination of green tea without knowledge of thickness and density. The mean value of error and maximum error in moisture content ranges from 6% to 32% on dry basis are 3.7% and 1.2% [38].

VI. IMPEDANCE ANALYZERTECHNIQUES

Moisture content of single kernel of corn, by determination of pecan kernel halves and single in-shell pecan nuts can change in capacitance and dissipation factor using parallel plate capacitor system at 1 MHz and 5 MHz frequencies. 4129 LF Hewlett-Packard impedance analyzer was used to determine the dissipation factor and capacitance. The technique appeared useful for practical applications and provided a basis for development of practical instrument for single grain moisture measurement [39]. The technique was used on hard red winter wheat, using parallel plate capacitor arrangement and 4129A LF Hewlett-Packard impedance analyzer was used to capacitance measurement at frequencies 1MHz and 10MHz. The permittivity variations were found and relation to measure moisture content independent to density variations [40].

VII. CONCLUSION

This article reviews those different electrical properties with different measurement techniques. Various factors like frequency, temperature, moisture content, bulk density, protein content affect the dielectric properties of material. Electrical method is non-destructive, cost effective, reliable, accurate moisture sensing in grains. The complex impedance determination at two radio frequencies with apply of a density independent function to produce valid moisture content on varying densities of static bulk sample. This technique is well work in controlled laboratory environment, not used in fields because the device is very sensitive.

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