Performance Comparison of Moisture Sensor Technologies for Forage Crops

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Abstract

The measurement of forage moisture is an important input for making management decisions, especially whether the forage material is at proper moisture to harvest and store. Additionally, site specific moisture measurements would be beneficial in creating yield maps of forage crops. The measurement of moisture in forages is currently time consuming and can be inaccurate if drying time and temperature are not properly controlled. The aim of this research was to investigate different moisture sensing technologies that could be used to measure moisture while harvesting.

The primary measurement technologies investigated for measuring moisture were conductance, capacitance, microwave, and near infrared. Conductance technology measures the electrical resistance of the forage and correlates resistance to the amount of moisture present. Capacitance technology measures the difference in dielectric properties of forage and uses the large difference between water's dielectric constant and solid material to estimate the moisture content. Microwave technology measures change in electromagnetic waves or fields during transmittance of waves or fields through the material. Near infrared reflectance (NIR) technology analyzes the amount of absorption of infrared light by a material at various wavelengths.

Testing of different technologies was carried out by testing statically or dynamically. Crops included dry alfalfa hay, wilted alfalfa haylage or whole-plant corn silage.

Testing of conductance technology was carried out using commercially available hay and forage testing equipment. In dry hay material, sensors were mounted in the bale chute of a small-square baler and hand probes were also used to statically analyze material. A conductance sensor was also mounted in the transition chute of a self propelled forage harvester to measure moisture in wet material. At times, conductance sensors produced encouraging results; however, the major conclusion from the data for both wet and dry materials was that conductance sensors produced too much scatter to be considered successful.

The capacitance sensor used primarily in the food and aggregate industry was adapted for testing both wet and dry material. The sensor was tested statically and dynamically. A definite relation with density was seen, and because of this density was used as a factor along with sensor output in all regression equations. However, even with the addition of a density factor the data still provided unacceptable results during testing with high amounts of scatter.

Near infrared (NIR) technology was tested, however the primary testing was done with a filter-wheel based sensor and limited amounts of static testing were completed with diode array based sensors. The majority of NIR testing was done on wet material. Dynamic testing of a filter-wheel based NIR sensor showed inconsistent results, problems with gumming of material over the sensing zone, and a lack of wavelength control. Filter-wheel based NIR results were not acceptable and contained large amounts of scatter. During lab testing of diode array sensors it was determined that the optimal wavelength range for monitoring moisture was between 1000-1600 nm. The results produced in this wavelength were acceptable with minimal amounts of scatter in the data.

Both reflectance and transmission based microwave systems were tested on dry hay. Attempts were made at testing wet material; however, drifting of the signal hampered data collection. During testing of dry hay material it was found that a transmission based system did have some sensitivity to moisture, however, error was found when the signal would deviate from the intended path to take the path of least resistance. By using a reflectance based system the signal was more contained and more accurate results were obtained. Both in static and dynamic situation acceptable results were found with the reflectance based technology with minimal amounts of scatter.

The data collected shows that the best current solution for monitoring moisture in wet material is a diode array based NIR sensor. The current unit used for testing needs to be ruggadized for dynamic testing and additional testing over a larger variety of crops will prove if the results found are repeatable. In dry hay, the reflectance based microwave system produced the only acceptable results and possibly the incorporation of temperature compensation will help improve the results for future testing. Both of these systems provide encouraging results, however, these systems are expensive. Conductance technology is low cost and for this reason should continue to be investigated.