Science Societies

Handheld vs. benchtop near-infrared spectrometers

How Do They Compare for Analyzing Forage Nutritive Value?

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Left: A researcher prepares samples contained in scanning cups to be scanned in a benchtop n

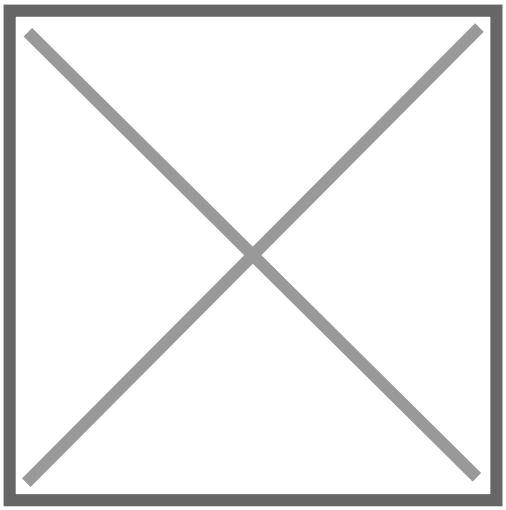
Left: A researcher prepares samples contained in scanning cups to be scanned in a benchtop near-infrared spectrometer. Right: Grass sample ready to be scanned using a handheld spectrometer. Photo on the right courtesy of Miguel Castillo.

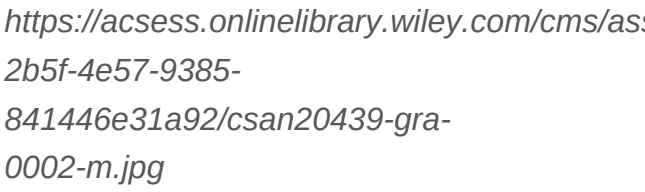
- Benchtop near-infrared spectrometers are seen as the standard of data collection and consistency because they are at a fixed location, in a controlled environment, and handled by trained personnel.
- Handheld devices with comparable characteristics that are smaller in size and lighter in weight offer versatility and flexibility in where and when measurements can be taken.

- Researchers compared two handheld devices against a benchtop model and found that the predictive power of the handheld devices was very similar to that of the benchtop device.

Rapid advances in near-infrared spectroscopy technology have helped many handheld-measuring devices enter the market. These options are becoming more affordable and easier to use, allowing for rapid determination of nutritive values in forages. However, how handheld devices stack up to traditional benchtop devices, which are seen as the guiding standard for accuracy, hasn't received much attention.

In new research in *Crop Science* (**https://doi.org/10.1002/csc2.20264**), scientists at North Carolina State University (NCSU) compared two handheld devices against a benchtop model. Their findings indicate that the low-cost handheld devices have the potential to favorably compare to the benchtop versions.

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“Limited work has been reported that compares predictions of basic estimates of nutritive value when the sample is scanned with different near-infrared spectroscopy devices, such as new handheld-type devices now available,” explains ASA and CSSA member Miguel Castillo, Associate Professor at NCSU, who co-led this research. “If successful, the handheld devices could provide the flexibility of being portable. You can take the ‘lab’ to the sample as opposed to the sample to the ‘lab,’ particularly important in remote areas. However, it is critical to understand the potential trade-offs, which is what we investigated here.”

Near-infrared spectroscopy devices work by sending a beam of light at, in this case, plant tissue. That light can be absorbed, transmitted, reflected, or scattered, depending on several factors. One of those factors is the specific chemistry of the tissue, such as vibrations that occur in the chemical bonds of oxygen, carbon, or nitrogen to hydrogen. The absorbance of these bonds can be detected and result in a unique “spectral fingerprint” of the material that received the light beam.

Benchtop devices are seen as the standard of data collection and consistency because they are at a fixed location, in a controlled environment, and handled by trained personnel. While there are many benefits to that approach, these days there are handheld devices with comparable characteristics that are smaller in size and lighter in weight, offering versatility and flexibility in where and when measurements can be taken.

“Some handheld devices are truly portable and battery-powered so that they can be taken into the field, ultimately depicting the idea of the power of a single click onsite,” Castillo says. “However, neither devices are yet widely used in the United States at the

farm level. The potential is there, but there is still some more work to do."

In their study, they explored three near-infrared spectroscopy devices with contrasting characteristics and market prices, ranging from $1,000 to $100,000, using each to determine the nutritive value of different forages. For each device and analyte, they developed a model by correlating the spectra gathered on a sample for each device to precise chemical measurements done in a lab.

In the forage they studied, switchgrass and bermudagrass, they measured dried ground samples for several important variables: crude protein, acid detergent fiber, amylase and sodium sulfite-treated neutral detergent fiber, and in vitro true dry matter digestibility. These variables are helpful to judge the quality of a forage and its ability to meet the nutritional needs of livestock. In general, Castillo notes, one wants higher crude protein, higher digestibility, and lower fiber concentrations.

Similar Predictive Power

"The results from our work indicate that low-cost handheld devices have the potential to generate comparable near-infrared spectroscopy models to benchtop-type devices for predicting the nutritive value of forages," says Castillo. "We were able to make basic estimates of nutritive value using the three devices with contrasting specifications. The predictive power of the handheld devices was very similar to the benchtop-type device."

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generate comparable near-infrared spectroscopy models to benchtop-type devices for predicting the nutritive value of forages,"

The researchers report no large differences between the devices in their study. While the best prediction models—those with the highest R^2 and lowest standard error of prediction—were from the benchtop device, the two handheld devices were very similar, they found.

There are multiple advantages of rapid and on-site assessment of forage value for both researchers and farmers although Castillo says benchtop models will likely not become obsolete as each device fulfills a necessary technological niche. For researchers, the variables in the study are also important in breeding programs to develop and release new forage cultivars. For example, near-infrared spectroscopy can be used to rapidly screen germplasm. Other uses include crop management and the ability to assess the impacts of fertilization practices.

On the farm, the technology can help producers decide on forage types to feed livestock. A producer may be purchasing bales of hay or have different types of forage at different maturity levels. Also, near-infrared spectroscopy technology could help determine moisture levels and the concentration of other nutrients to prioritize and optimize the use of forages.

Jerry Cherney, a professor at Cornell University who was not involved in this research but also studies handheld near-infrared spectroscopy devices, says a great potential benefit of the devices is the ability to estimate daily changes to the moisture content of forages to allow daily decision-making of dairy rations.

“Currently, many farmers re-balance dairy rations on a weekly basis,” Cherney explains. “There are daily changes in forage moisture in bunkers. If those changes can be accurately determined, it could improve the economics of milk production by increasing milk production, if correcting for wetter forage, or decreasing feed costs by reducing overfeeding, if correcting for drier forage.”

Research Needed to Address Remaining Challenges

Both Castillo and Cherney note that research showing the predictive power of handheld devices is useful and promising, but that challenges remain. One caveat to on-the-farm measurement by a producer is exactly the form of the sample being shot with the device. To establish valuable baseline data, both have generated models and compared devices using dry, ground, and uniform forage samples. However, a producer on a farm would likely be scanning wet, coarsely chopped material.

“There are significant day-to-day differences in forage moisture in bunkers, but the current calibrations for the handheld devices we have tested in our own separate research were not as accurate on wet, chopped material,” Cherney says. “That does not mean the instruments are not capable of being calibrated well enough to work, just that there are further steps and research needed now that we know handheld devices are capable of favorably comparing to benchtop versions.”

Castillo adds that research on this question is also underway at NCSU. Other next steps include increasing awareness of the technology among producers and

developing tools that can provide specific and easy-to-understand solutions to land and livestock managers.

“The technology for development of near-infrared spectroscopy calibration models is now more accessible and affordable,” Castillo says. “We as a team believe in the value of information to help improve the decision-making process at the farm level. We see this technology as an opportunity to create tools for on-site assessment of plant, soil, and animal responses, for big and small farms, and specifically at remote locations.”

Dig Deeper

“Comparison of Benchtop and Handheld Near-Infrared Spectroscopy Devices to Determine Forage Nutritive Value,” in *Crop Science* at **https://doi.org/10.1002/csc2.20264**. Also check out the article on p. 12 of this issue about an open-source R-package that makes handheld spectrometers easier to use (see **https://doi.org/10.1002/csan.20438**).

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