Evidence for a Need to Develop a Tropical Forage Database for Near-Infrared Spectroscopy (NIRS) Analyses

Abstract

A simple study was performed to evaluate the relationship between Near Infrared Spectroscopy (NIRS) analyses and wet chemistry analyses for tropical forages. NIRS offers an economical and rapid response, providing several key nutrient information for animal feedstuffs.

Regression analyses for crude protein (CP), neutral detergent fiber (NDF), and acid detergent fiber (ADF) showed R^2 of 0.78, 0.52, and 0.27, respectively. Regression analyses for major minerals (calcium, phosphorus, potassium, and magnesium) between the two methods for tropical forages showed poor relationships; R^2 were 0.19, 0.45, 0.002, and 0.67, respectively. This short communication discusses the results and provide possible explanations for the discrepancies. It also explores the potential of a solution to address the crucial need for a broad database for tropical forages using NIRS technology.

Beef cattle on kikuyu pastures at the Mealani Research Station, Waimea, Hawai'i Island.

Introduction

Several laboratories (Stalling, 2011) across the nation offer efficient forage analyses using near infrared reflectance spectroscopy (NIRS). NIRS technology can provide an accurate and rapid "turn-around time" for feed analyses when samples are properly handled (Western Dairy Inc., 2004). Some laboratories offer the option of using two different databases: *local* – generally only C3 forage database for the NIRS, or *global* – a combined C3/C4 database. These laboratories have a vast database for temperate (C3) forages but a more limited database for tropical (C4) forages. One possible explanation is that alfalfa hay, rye grass, timothy hay, and other common forages for the North America ruminant industry are all C3 forages.

Rapid response, coupled with very reasonable prices for analyses, make the NIRS the favored choice. For large livestock operations, e.g., dairies or feedlot, rapid responses to feed analyses at economical prices are crucial to ration balancing to meet production needs. However, some caution that, while the NIRS provides good precision analyses, wet chemistry provides more accurate data. NIRS uses infrared light reflection of an array of spectrum, thus allowing for better evaluation of large molecule versus smaller molecules, e.g., minerals (de Ondarza and Ward, 2013).

The accuracy of NIRS-based analyses compared to traditional wet chemical analyses (the AOAO method) for tropical forages should be evaluated, given the existing database. Accurate calibration has been suggested by de Ondarza and Ward (2013) and Stalling (2011). Hence, this study's objective was to examine the relationship analyses for the following nutrient compositions: crude protein (CP), neutral detergent fiber (NDF), acid detergent fiber (ADF), and major minerals (calcium, phosphorus, potassium, magnesium) for tropical forages by a service laboratory.

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Materials and Methods

Forage samples (N=40), *Saccharum officinarum*, commonly known as sugarcane, were harvested and dried at 65ºC for 3 days. The dried samples were then ground using a Thomas Wiley mini mill (model 4). The ground sample was then divided into 2 portions and placed into Ziploc plastic bags. The labelled samples were shipped for analysis by NIRS and wet chemistry (Dairy One, 730 Warren Road, Ithaca, New York 14850; http://dairyone.com/). A special request was made to use the global database for the NIR analyses. The results were then compared by simple regression analysis or by correlation coefficient for the two methods of analyses. The data from these methods of forage analyses were then compared using a regression (R-squared) coefficient.

Results and Discussion

Figure 1 shows the laboratory analyses for CP (%) by wet chemistry and NIRS. The R-square value between the two methods for this nutrient is R^2=0.78. By most standards, this is interpreted as a poor prediction.

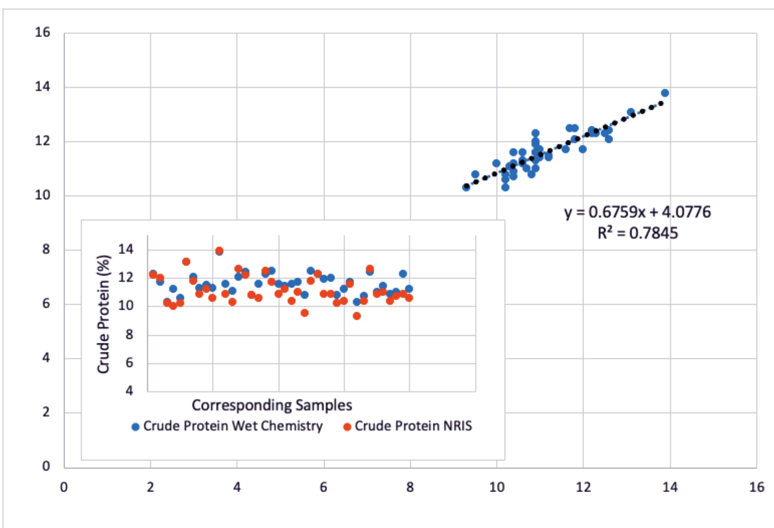

Figure 1. Relationship of crude protein (CP) values of sugarcane (*Saccharum officinarum*) (n=40), by wet chemistry and NIRS from commercial laboratory analysis (correlation = 0.89, regression analysis (RSQ) = 0.78). The inset graph shows the corresponding raw CP (%) value.

One would like to see R^2 over 0.95 (de Ondarza and Ward, 2013). An earlier report (Van Suan, 2013) had suggested that NIRS has better accuracy for large molecule analyses, e.g., protein and fiber. The poor relationship between the two methods within the same laboratory suggests a need for proper calibration, per de Ondarza and Ward (2013).

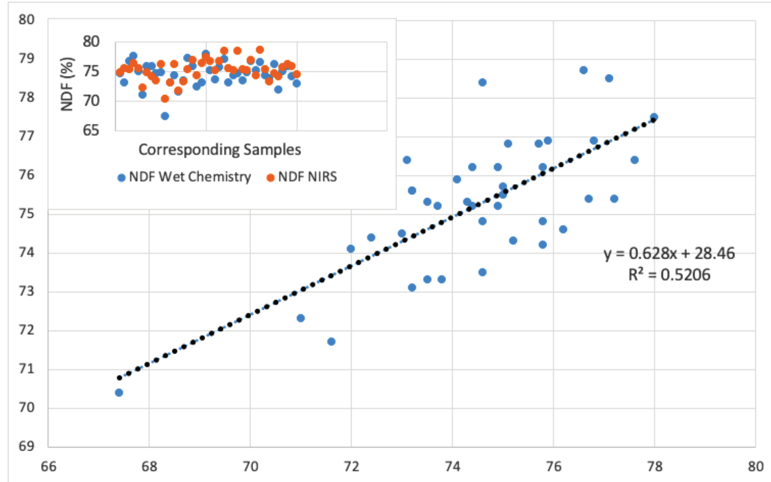

Figure 2. Relationship of neutral detergent fiber (NDF) vales of sugarcane (*Saccharum officinarum*) by wet chemistry and NIRS from commercial laboratory analysis (regression analysis (RSQ) = 0.52). The inset graph shows the corresponding values of the samples for wet chemistry and NIRS.

Figure 2 shows the analyses for NDF by the two methods; the R^2 for this nutrient is 0.52. Figure 3 shows the analyses for ADF between wet chemistry and NIRS technology. The regression analyses showed R^2=0.27. These poor predictions of NDF and ADF values raise some concerns, for they are important indicators of forage quality. Initial studies introducing the use of NIRS for forage analyses show high R^2 for CP, NDF, and ADF (Jones, et al., 1987, Mentink, et al., 2006). One possible reason for this is the database (quantity) used in the NIRS system in simulating the prediction. The forages we sent in were C4 grasses. The amount of ruminant livestock operations using C4 grasses may be limited for North America, given that the majority of dairies and cattle are found in temperate zones. Stalling (2011) cautioned the use of NIRS for unique forages.

Table 1 presents the values for calcium, phosphorus, potassium and magnesium, the correlation coefficient and the regression analyses, respectively. There was no relationship between the NIRS and wet chemistry. Stalling (2009, 2011) alluded that NRIS is generally better for predicting larger compounds (protein and fibers) in forages versus smaller compounds, such as minerals. Similarly, Van Saun (2013) and de Ondarza and Ward (2013) indicated that NRIS has poor accuracy in determining mineral values. Jones et al., (1987) showed a good relationship between NRIS and wet chemistry for calcium, R^2=0.89. This was not observed with our data. We showed poor R^2 values for all major minerals; this is in agreement with Jones (1987) for potassium, phosphorus, and magnesium.

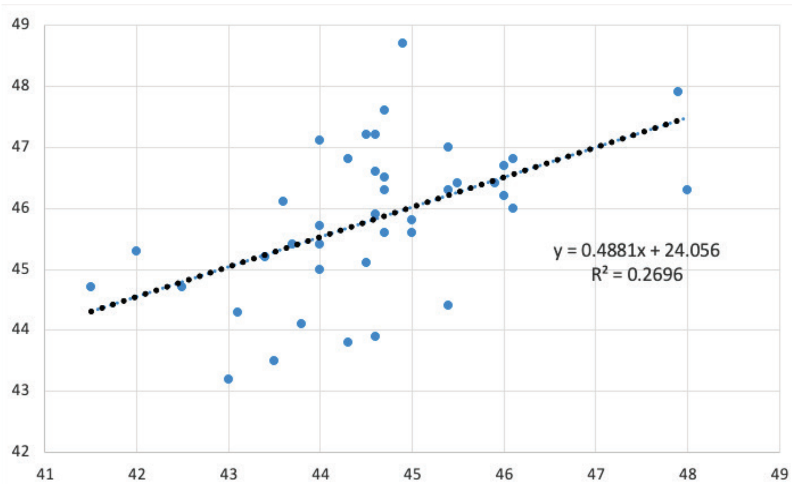

Figure 3. Relationship of acid detergent fiber (ADF) values of sugarcane (*Saccharum officinarum*) (n=40) by wet chemistry and NIRS from commercial laboratory analysis (regression analysis (RSQ) = 0.27).

Tropical forages, such as guinea grass (Megathyrsus maximus), napier grass (Pennisetum purpureum), etc. are known to have high silica content and often times have trichomes on their stems. Lee et al., (2014) highlighted some of the undesirable characteristics found in tropical forages. These elements may interfere with the light spectroscopy. Their ability to reflect light has been well documented (Schaller et al., 2013 and Mershon, et al., 2015). It has also been shown that it is possible to use NIRS to determine the plant silicon content with accuracy (Smis, et al., 2014). Hence, this simple study suggests there is a need to calibrate the NIRS for tropical forages and feeds analyses.

Table 1. Comparison of mineral values analyzed by NIRS and wet chemistry for sugarcane (*Saccharum officinarum*).

		Wet Chemistry		NIRS			
Minerals	**No. of Samples**	**Mean**	**SD**	**Mean**	**SD**	**Correlation**	**RSQ**
Calcium	40	0.22	0.05	0.39	0.08	0.31	0.19
Phosphorus	40	0.28	0.04	0.27	0.03	0.034	0.45
Potassium	40	2.16	0.38	2.36	0.21	0.0009	0.002
Magnesium	40	0.26	0.05	0.33	0.04	0.50	0.67

The ability of C4 grasses to provide high yields makes them a crucial feed source to many small holder farmers who have limited land. Forages are simple to grow, perennial, easy to manage, and are a ready source of feed for ruminants. Developing a robust tropical database and having NIRS calibrated properly is invaluable, as rapid nutrient composition of feeds is vital to meet the demands for growth and desirable performances of livestock production in the tropics.

One possible solution is to form a consortium of countries, especially those nations in Southeast Asia, South Asia, the Pacific, Africa, and Australia to develop a robust database via wet chemistry analyses. It is unlikely that a robust database would be generated in North America, given that most sources of feed are of temperate origin. The database collected by this consortium could then be used to calibrate NIRS instruments to predict nutrient composition for tropical feedstuffs; especially tropical grasses and legumes. The database would include species, age of harvest, season (e.g., wet vs dry), date, height of plant above ground, and other appropriate criteria. Once developed, the prediction equations could be shared to enhance forage production for wildlife and livestock.

Countries in Asia have a growing demand for animal protein (Lee and Hansen, 2019, AHDB and Lamb, 2018). There already exist a tremendous interest to build the ruminant livestock sector in these countries to alleviate poverty in rural districts, reduce imports, reduce outflow of currency in trade, and increase food security. The slow responses for feed analyses lead to an inability to meet the nutrient demands of ruminants, and can lead to poor production and the increased risk of diseases due to nutritional stress.

Finally, one cannot ignore the potential of grasses in assisting in the sequestering of atmospheric carbon in an era of climate change (Conrad et al., 2017; Savory, A. 2013). A robust database of different species of grasses across regions and seasons could yield huge benefits in managing our resources and reduce the carbon footprint.

Summary

The data from this small study suggest a need to develop a robust database for tropical forages which could use the NIRS method for nutrient prediction of tropical forages. Such a database would be helpful in assisting proper nutritional needs for ruminants in the tropics.

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References

AHDB and Lamb. 2018. Asia continues to drive global beef demand. http://beefandlamb.ahdb.org.uk/market-intelligence-news/asia-continues-to-drive-global-beef-demand/

Conrad, K.A, Dalal, R.C., Dalzell, S.A., Allen, D.E., and Menzines, M.W. 2017. The sequestration and turnover of soil organic carbon in sub-tropical leucaena-grass pastures. Sci. Direct 248:38-47. https://www.researchgate.net/publication/318768318_The_sequestration_and_turnover_of_soil_organic_carbon_in_subtropical_leucaena-grass_pastures

de Ondarza, M.B. and Ward, R. 2013. Accurate analysis:NIRS versus wet chemistry. https://www.foragelab.com/Media/Accurate%20analysis%20NIRS%20versus%20wet%20chemistry.pdf

Jones, G.M., Wade, N.S., Barker, J.P. and Ranck, E.M. 1987. Use of near infrared reflectance spectroscopy for forage testing. J.Dairy Sci. 70:1086-1091. https://www.journalofdairyscience.org/article/S0022-0302(87)80115-7/pdf

Lee, C.N., G.K. Fukumoto, N. Nakahata, and R. Ogoshi. 2014. Sugarcane crosses as potential forages for ruminants: Selection Criteria. https://www.ctahr.hawaii.edu/oc/freepubs/pdf/PRM-6.pdf

Lee, T. and Hansen, J. 2019. South East Asia's growing meat demand and its implications of feedstuff imports. Source: the United States Dept. of Agriculture Economic Resource Service. https://www.ers.usda.gov/amber-waves/2019/april/southeast-asia-s-growing-meat-demand-and-its-implications-for-feedstuffs-imports/

Mentink, R.L., Hoffman, P.C. and Bauman, L.M. 2006. Utility of Near-Infrared Reflectance Spectroscopy to predict nutrient composition and in vitro digestibility of total mixed rations. https://pdfs.semanticscholar.org/e448/fd9f15038ac0ec6105ca7d5a9fcd955dbd5d.pdf

Mershon, J.P., Becker, M. and Bickford, C.P. 2015. Linkage between trichome morphology and leaf optical properties in New Zealand alpine Pachycladon. New Zealand J. Botany 53(3):175-182. https://www.tandfonline.com/doi/full/10.1080/0028825X.2015.1042486

Savory, A. 2013. How to fight desertification and fight climate change. Ted Talk. https://www.ted.com/talks/allan_savory_how_to_fight_desertification_and_reverse_climate_change?language=en

Schaller, J., Brackhage, C. Baucker, E. and Dudel, E.G. 2013. UV screening of grasses by plant silica layer. J. Biosciences 38(2):413-416. https://www.researchgate.net/publication/236674849_UV-screening_of_grasses_by_plant_silica_layer

Smis, A., Murguzur, F.J.A., Struyf, E., Soininen, E.M., Jusdado, J.G.H., Merie, P., and Brathen, K.A. 2014. Determination of plant silicon content with near infrared reflectance spectroscopy. Frontiers in Plant Sci. 5(496):1-9. https://pdfs.semanticscholar.org/a6f5/6db953e534b8f65e62e838aa475f817726ae.pdf

Stalling, C.C. 2009. The basic of forage testing. Virginia Cooperative Extension pub. 404-300. https://www.pubs.ext.vt.edu/content/dam/pubs_ext_vt_edu/404/404-300/404-300_pdf.pdf

Stalling, C.C. 2011. Feed analysis for dairy producers. https://www.vtdairy.dasc.vt.edu/content/dam/vtdairy_dasc_vt_edu/documents/cow-college/2011-cc/14-stallings-paper.pdf

Western Dairy Science Inc. NIR or wet chemistry. Source: Dairy production primer-feeds and feeding management. (2004). http://www.dairyweb.ca/Resources/DPPF/DPP_Feeding_014.pdf

Van Suan, R.J. (2013) Determining forage quality: understanding feed analysis. https://extension.psu.edu/determining-forage-quality-understanding-feed-analysis

Dairy heifers grazing on guinea grass pastures in ʻŌʻōkala, Hawaiʻi Island.