MWFPA Annual report: On-harvester and in-hand NIRS for managing vegetable quality

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8 February 2022

Project Objectives

1. Continue to build a calibration database for a commercially available diode array NIRS to predict tenderometer reading

2. Compare the accuracy to a low-cost handheld instrument

3. Evaluate the utility of NIRS to predict ripeness of peas in the pod and on the vine

Objective 1

M.F. Digman and W.M. Runge. The utility of a near-infrared spectrometer to predict the maturity of green peas (Pisum sativum), Computers and Electronics in Agriculture, 193, 2022.

Computers and Electronics in Agriculture 193 (2022) 106643

ELSEVIER

Contents lists available at ScienceDirect

Computers and Electronics in Agriculture

journal homepage: www.elsevier.com/locate/compag

The utility of a near-infrared spectrometer to predict the maturity of green peas (*Pisum sativum*)

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ARTICLE INFO

Keywords:
Peas
Pisum sativum
Tenderometer
Ripeness
Hardness
artificial neural network
support vector machine
near infrared reflectance spectroscopy

ABSTRACT

This work evaluated the utility of an embedded diode array near-infrared reflectance spectrometer to predict the hardness (maturity) of green peas. Partial least squares, support vector machine (SVM) and artificial neural network regression models were developed to predict tenderometer reading (TR) from near-infrared spectra over the range of maturities experienced throughout a harvest season. The SVM model achieved the best performance in an independent data set collected in a second harvest season. Here, the SVM model explained 83% of the variation in TR with a root mean standard error of prediction (RMSEP) of 4.4 TR units over a range of TR from 65 to 104. The RPD of 2.3 achieved in this study exceeds the threshold for rough screening but falls short of replacing the tenderometer for quality control.

1. Introduction

Farmers in Minnesota, Wisconsin, and Illinois grow about 60% of the U.S. green pea acres, annually worth more than $50 million in farm gate receipts (USDA, 2021; Mitchell et al., 2017). However, as consumer preferences have shifted from canned to frozen and then to fresh vegetables, the economic value generated by canned processing vegetables has declined. Today's industry is highly competitive with thin margins for processors, who focus on efficiency and automation to maintain profitability in the face of global competition.

Achieving a high yield of a high-quality product is challenging for any crop. This problem is especially challenging for peas because it is very difficult to predict pea maturity and harvest accordingly. Each year about 5% of peas in Wisconsin and Minnesota are planted but not harvested, and still more peas are harvested at early or late maturities, yielding a substandard product.

The state of technology for managing pea maturity is succession planting, pre-grading, and passing overripe fields. Succession planting and pre-grading are accepted best practices for managing pea harvest maturity. Here peas are planted on an interval to maximize the harvest window while maintaining a steady flow of high-quality peas into the processing plant. To ensure quality targets are met, a pre-grading process is utilized. Each day, crop scientists collect peas from a multitude of field sites to monitor the progression of yield and quality. The typical process includes gathering samples by hand, separating peas from the vines through a stationary viner, shelling, cleaning on a vibrating sorting table, and washing. The harvested mass and size distribution are noted, and the maturity is assessed as tenderness using a tenderometer (Studman, 2001).

A tenderometer measures the force needed to shear and press a sample of peas through a standard grid and a specific shear rate (Visscher and Lovink, 1999). The force needed to shear the samples increases with tenderness/hardness (maturity) reported as tenderometer reading (TR). Thus, this approach discounts the effect that maturity has on increasing yield.

A "digital tenderometer" based on near-infrared technology could minimize the processing steps required before predicting pea maturity. Further, a portable near-infrared spectrometer could mean that smaller, hand-shelled, or in-pod samples could be predicted in the field. A portable tenderometer would allow the crop scientist to increase the number of samples with fewer field scouts and predict pea maturity across field locations spatially.

Near-infrared spectroscopy has been utilized in predicting vegetable quality and ripeness including chemical, textural, and sensory references (for reviews see Ruiz-Altisent et al., 2010; Walsh et al., 2020a). New manufacturing techniques have enabled the development of spectrometers that can be used on farms and are less sensitive to temperature, dust, or vibrations (Yan, 2018; Bec et al., 2020). Portable spectrometers are now installed on various field equipment and have numerous hand-held options (Crocombe, 2018). Additionally, these

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https://doi.org/10.1016/j.compag.2021.106643
Received 23 June 2021; Received in revised form 4 December 2021; Accepted 20 December 2021
Available online 24 December 2021

Objective 2

- Neo-Spectra module, $2,500
- Neo-Spectra Hand-held, $6,150
- Compared to the HL 3000
  - Better wavelength range
  - Lower wavelength repeatability
  - More limited light gathering optics

Objective 2

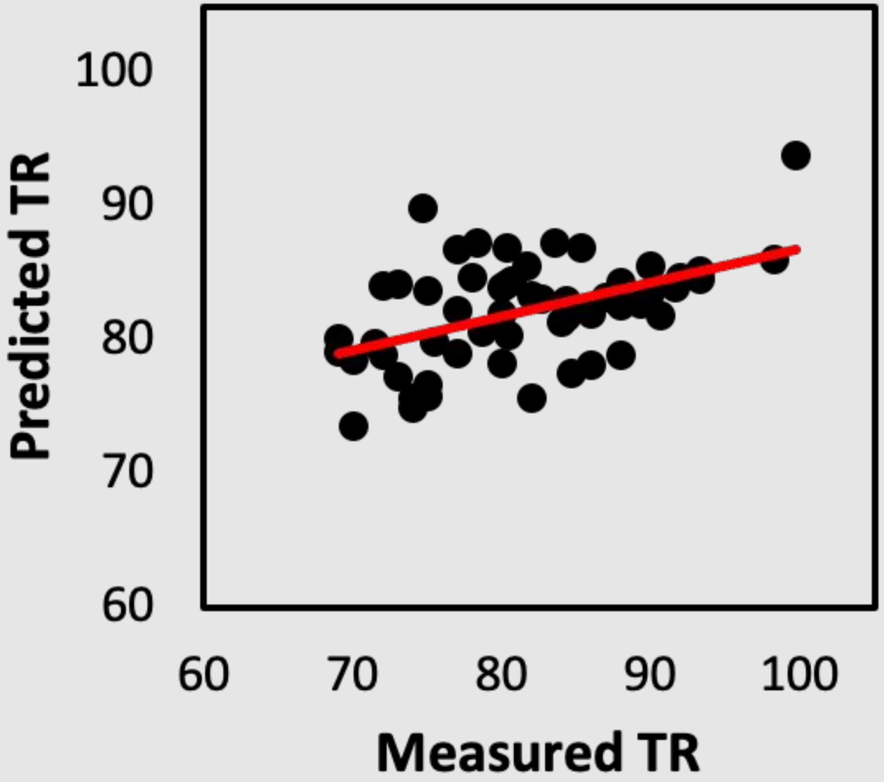
- Spectra collected over 4 days from a variety of fields and maturity levels from Seneca Foods near Hancock, WI

- Peas were shelled and washed before scanning with the NeoSpectra NIR instrument

- A white reference was scanned every five samples or every thirty minutes

Objective 2

- First technique explored - regression (PLS)
- References between days were inconsistent, 25 outliers removed from 81 samples
- Ratio of performance to deviation was about 2 - gross classification



Objective 2

- Second technique explored - classification (PLSDA)
- Samples were separated into classes based on tenderometer readings, 80<TR<100 were assumed to be “ripe”
- Classification accuracy was about 65%

		Actual	
		Ripe	Under or over ripe
Predicted	Ripe	27	16
	Under or over ripe	10	20

Next steps

- White Reference Holder – current method of setting the white reference onto the NeoSpectra scanner is inconsistent and potentially results in error in the spectra
- Sample holder – current method of setting the NeoSpectra onto a pile of peas is inconsistent and might result in gaps between peas and effecting the spectra
- Reference correction technique – A method of correcting the measured spectra to any errors in the reference (correcting each measure to 100 from the reference scan)

Funding leverage

- Team submitting a proposal to NSF NRI at the end of the month
  - Expanded scope to include UAV pregrading, on-harvester NIRS and economic analysis
  - From the RFP…

- Automated systems for planting, scouting, spraying, culturing, irrigating, and harvesting plant crops (including forests) to decrease costs, improve efficiency, or reduce inputs of water, fertilizer, or chemicals;
- Improved robotics for inspection, monitoring, culturing, sorting, and handling of plants and flowers in controlled environment facilities and nurseries, or for managing or studying (e.g., monitoring, inspecting, sorting, vaccinating, deworming) large numbers of live animals, either domestic or wild;
- Automated systems for inspection, sorting, processing, or handling of animal or plant products (including forest products) in post-harvest, processing, or meat Processing, or product distribution environments; and
- Multi-modal and rapid sensing systems for detecting defects, ripeness, physical damage, microbial contamination, size, shape, and other quality attributes of plant or animal products (including forest products), or for monitoring air or water quality.

Feedback from committee

- Performance targets?
  - Our current data would show the tenderometer repeatability is about 1.1 TR
  - For a secondary method we normally target 1.5 x ref = 1.7
- Openness to alternative technologies, parallel development
- Other accepted references outside of TR?

Thank you to Seneca Foods field and pre-grading teams!

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