Development of an inexpensive sensor for the detection of mold in stored canola seed

Kevin Moore
Biosystems and Agricultural Engineering
Oklahoma State University

Mold in stored grain

- Mold is a primary cause of quality loss in stored grain
- Once fungi are visible there may already be extensive damage
- Mold in corn and other grains can form aflatoxin
  - Carcinogenic to humans
  - Livestock death and disease
  - Considerable research has focused on aflatoxin detection
- Primary concern for mold in stored canola is quality loss
  - Heat damage
  - Extra processing required to deodorize
  - Mites and other insects feed on mold
- Most common storage fungi for canola
  - Aspergillus glaucus
  - Aspergillus candidus
  - Penicillium spp.
  - Eurotium spp.
Methods of mold detection

- Temperature monitoring
  - Hot spots due to mold growth
  - Must be located near temperature cables
- Periodic sampling
  - Visual inspection
  - Detectable odor
    - Possible health impact
    - Subjective test
- Damage is already present when discovered

Canola quality monitoring

- Can a low-cost sensor be developed to detect mold in stored canola seed?
Electronic nose

- Well-established technology, initially developed in the 1960’s
  - Numerous technological approaches
  - Commercial devices available for purchase
- First commercial application was the Taguchi Gas Sensor in 1972
  - Metal Oxide Semiconductor (MOS)
  - Early applications in fire and carbon monoxide detectors
  - Led to formation of Figaro Engineering
    - Manufactures and sells individual sensors
    - Provides an inexpensive option for eNose development

Metal oxide semiconductors (MOS)

- When MOS is exposed to the air, free electrons at the surface bind to oxygen
  - Resistance of MOS is increased
- When a reducing gas is introduced it removes oxygen molecules from surface and frees electrons
  - Resistance of MOS is reduced
- Change in resistance can be used to detect certain gases

System development - summary

- Development of sensor array
  - Sensor selection and construction
  - Odor sampling system
- Evaluation against known mold concentrations
  - Mycological isolation and growth of a single mold species
  - Identification via PCR and DNA sequencing
  - Preparation of mold spore standard solution
    - Known concentration of mold spores per volume
  - Inoculate “clean” canola seed with known concentration of mold
  - Incubation of samples for 0, 7, 14 days
    - Control with “clean” canola seed and inoculated glass beads
  - Measure response of electronic nose to samples
- Evaluation of sensor performance
  - Multivariate statistical techniques

Sensor array

- Figaro MOS sensors
- Honeywell HIH-4030 humidity sensor
- Analog Devices TMP-36 temperature sensor
Metal oxide semiconductors (MOS)

- Figaro gas sensors – low cost and commercially available
  - Selected to provide a response from a broad range of gases
  - Metal oxide semiconductor
    - TGS 813 – sensitive to combustible gases
    - TGS 822 – sensitive to organic solvent vapors
    - TGS 2602 – sensitive to VOCs and odorous gases
    - TGS 2620 – sensitive to alcohol and organic solvent vapors

Odor sampling system

- Laboratory air supply with flow regulator
- Gas drier / activated carbon pre-filter
- Sample container
- Sensor array
- Chemically stable, low-odor materials
  - Glass sampling jars with Teflon lid liners
  - Teflon tubing and PVDF fittings
Mold isolation/purification

Evaluation of mold by PCR

- Polymerase Chain Reaction (PCR)
  - Amplifies the DNA of a target DNA sequence
  - Amount of DNA present doubles after each cycle
Mold spore standard solution

- Aspergillus chevalier
  - Member of the A. glaucus family
  - Isolated from Croplan 115W canola seed
- Physical removal of mold spores from agar plate and suspension in reagent grade water
- Determination of concentration by counting with hemocytometer

Inoculation of seeds
Statistical analysis

- Multivariate analysis of variance (MANOVA)
  - Is there a difference in sensor output for different levels of mold inoculation?
- Discriminant analysis to select classification model
  - Test linear, quadratic, and k-nearest neighbor models
- Forward stepwise selection
  - Determine if the number of sensors in the array can be reduced without sacrificing classification quality
Thank You