

Integrated Electronic Nose System for Detection of *Salmonella* Contamination in Meat

**Suranjan Panigrahi, Y. Chang,
L. Khot, J. Glower and C. Logue**

**Bio-imaging and Sensing Center
Agricultural and Biosystems Engineering
North Dakota State University, Fargo, ND**

Food Safety

- **Pathogen contamination**
(E. Coli, Salmonella)
- **Conventional techniques**
- **Rapid sensors**
 - Intelligent
 - Robust
 - Accurate



Sensors

- **NDSU multidisciplinary project**
 - **Packaged meat (beef)**



- **Intelligent quality sensors**
 - **Spoilage**
 - ***Salmonella* contamination**

Our Approach

- **Artificial olfactory sensing technique**
- **Bacterial metabolites**
 - Headspace of packaged meat
- **Artificial olfactory sensor/electronic nose**
- **Advantages**
 - Independent of sampling location

Artificial Olfactory Sensor

- Mimicking mammalian olfactory sensing system
- Array of non-specific sensors
 - Multidimensional Pattern Analysis
- Compound specific detector
- Hybrid approach
 - Increased performance
- Packaged meat (beef) contamination studies



(Confidential)

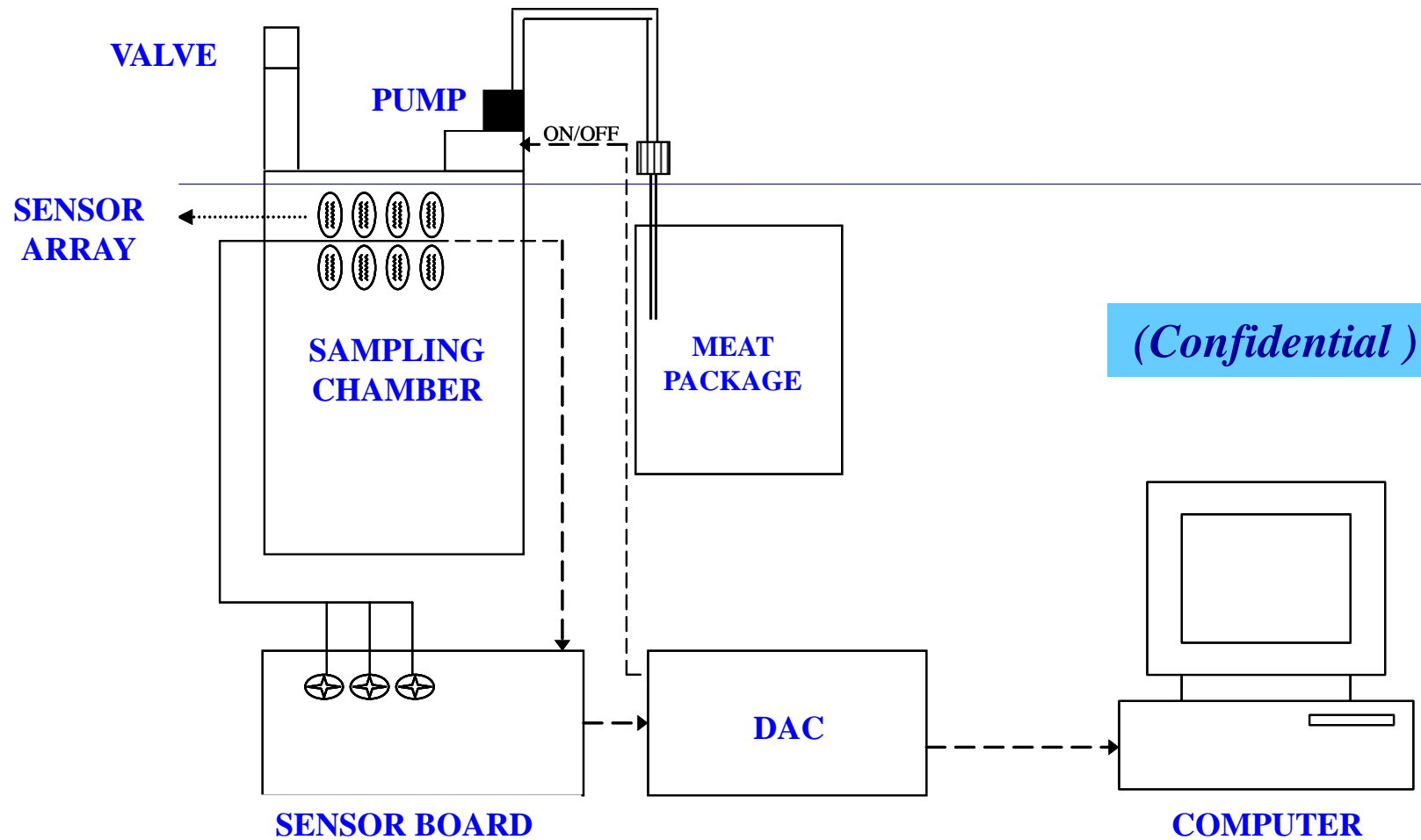
Objectives

- Develop and evaluate a novel metal oxide based solid-state **integrated sensor system (ISS)**
- Performance evaluation of ISS for discriminating *Salmonella* contaminated packaged beef using wavelet-transform based model for classification

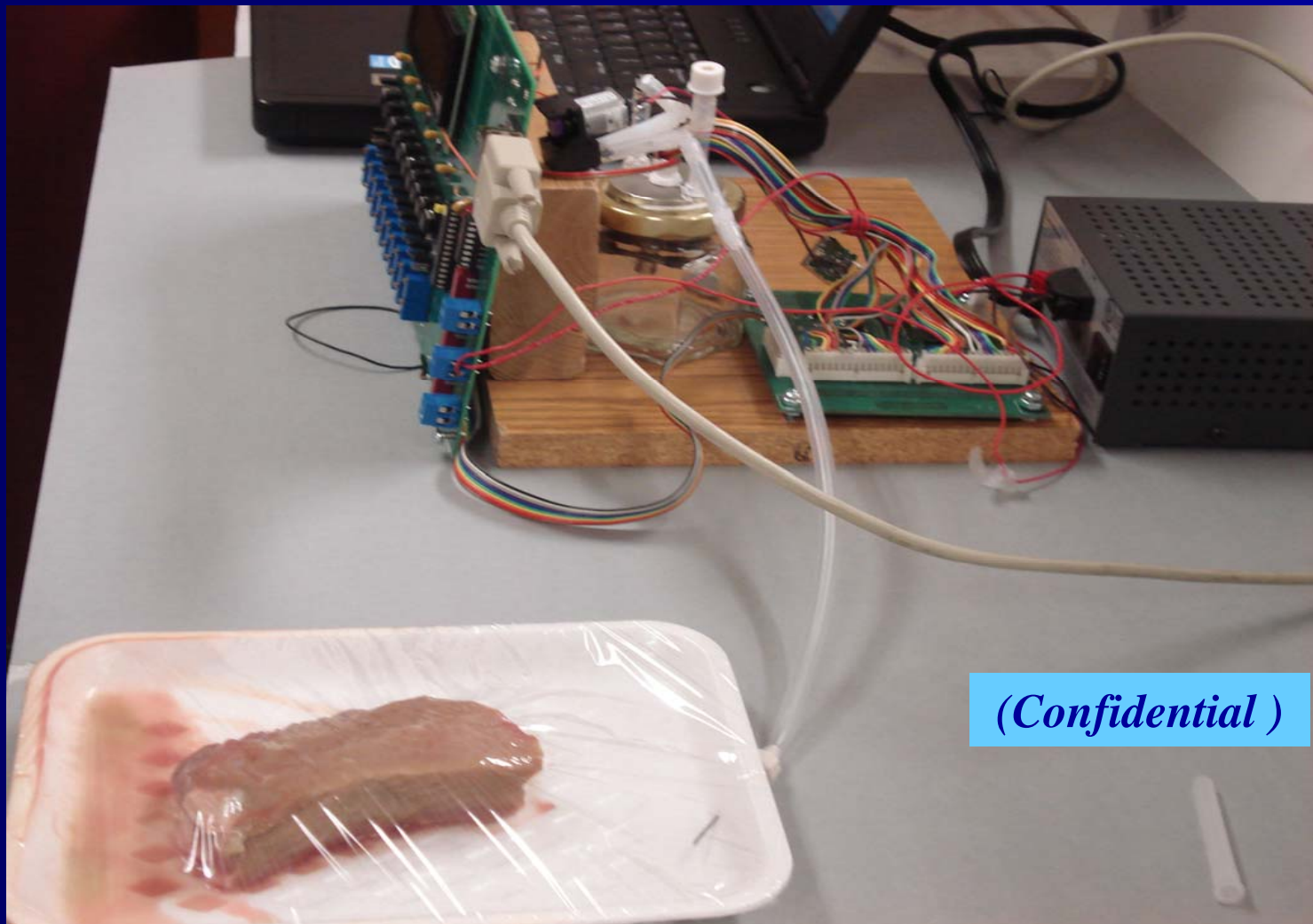
Selection of Detectors

- **Metal oxide-based solid-state detector**
 - Eight of them
 - Six of them pair (3 pair)
- **Micro controller-based**
 - Relay: DAQ (16 bit)
 - Pump
- **20° C controls (spoilage) and 20° C *Salmonella* inoculated meat packages**

System Schematic

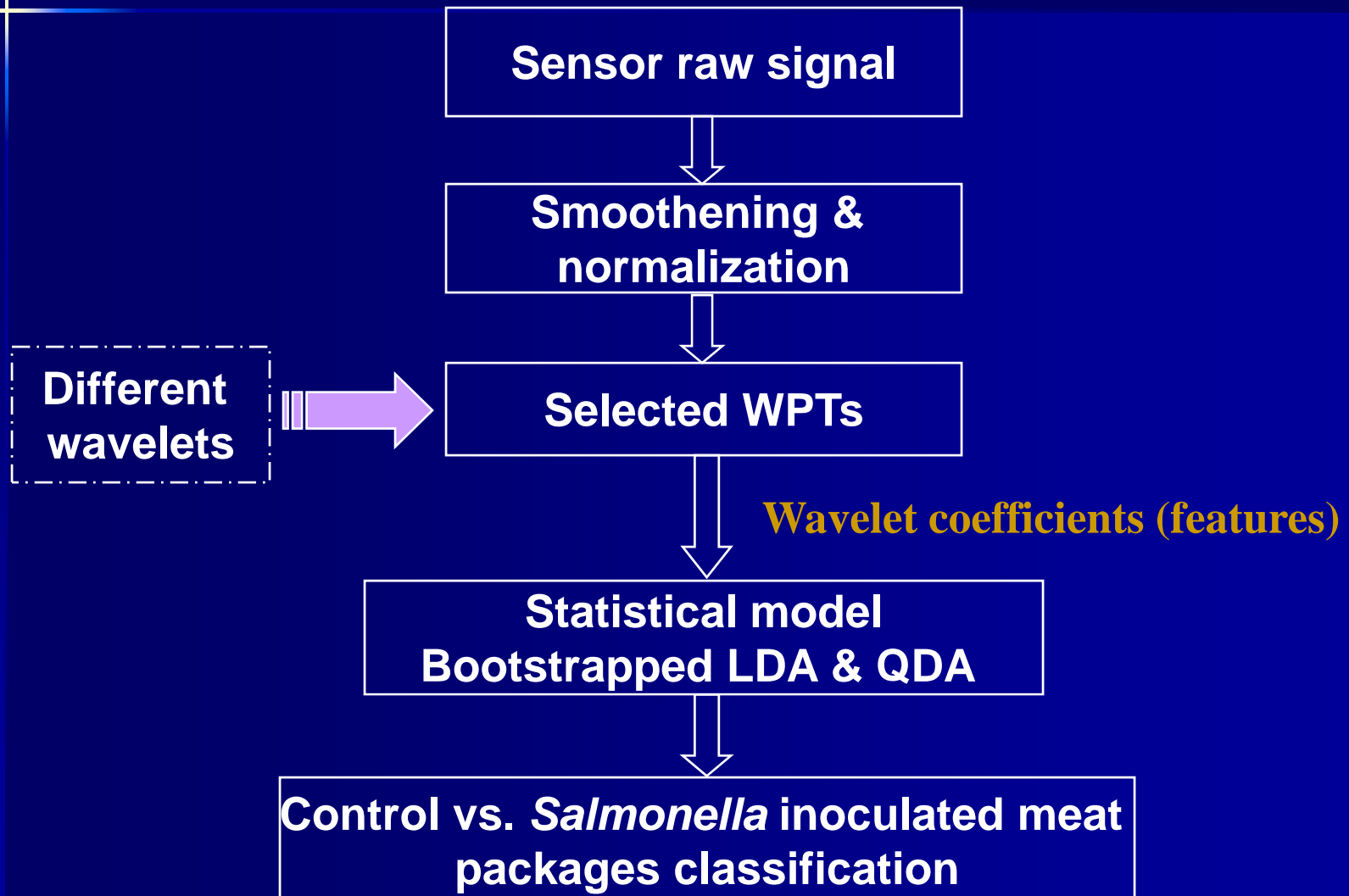


System

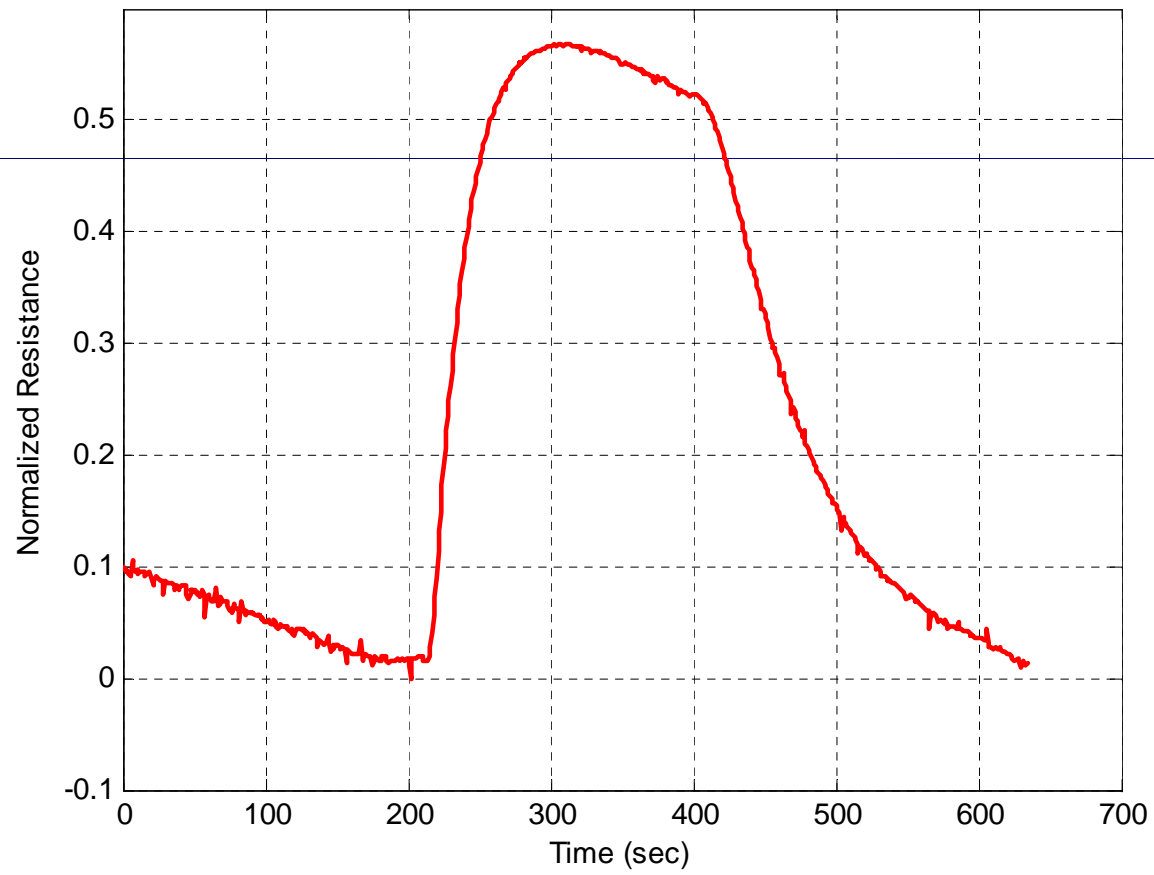


(Confidential)

Signal Analysis



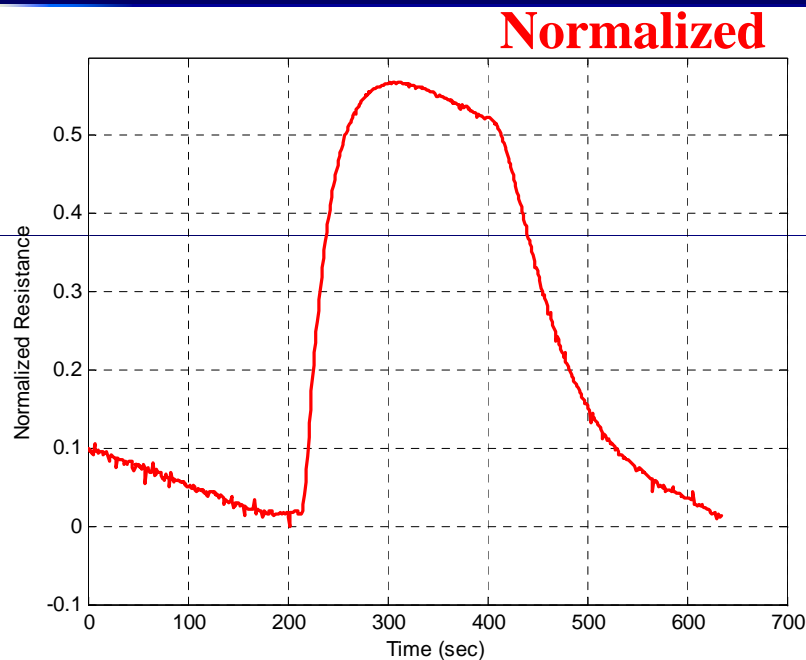
Typical Sensor Signal



Wavelet Packet Transform

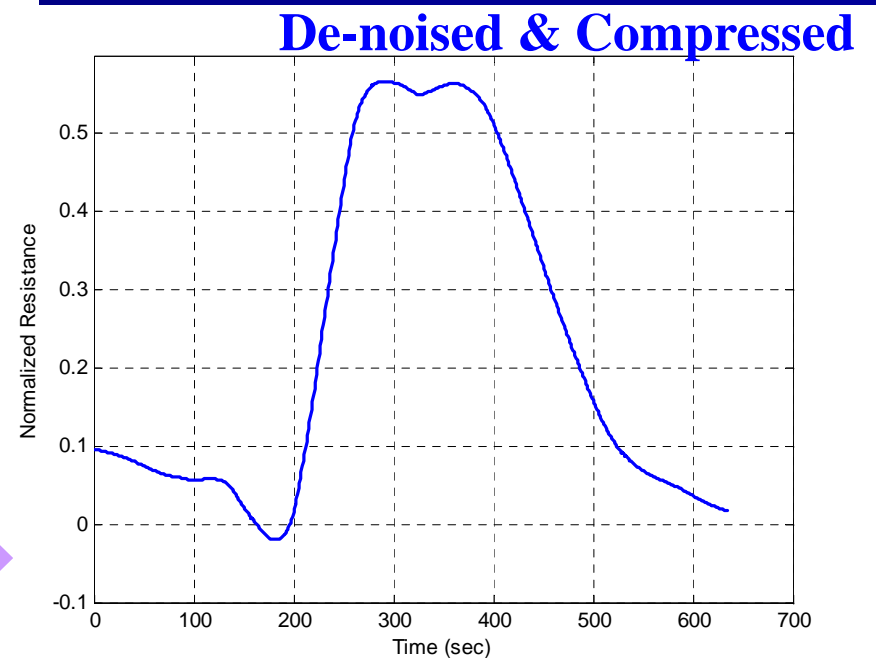
- **Powerful tool: Scaling & shifting property**
- **De-noising; Compression**
 - Dimensionality reduction
- **Small dataset (biological domain)**

Wavelet Packet Transform



L^2 energy recovery = 99.76%

Compression score = 97.12%



Signal Analysis

Bior4.4, Bior5.5 & Bior6.8
Dec. Level = 6

Extracted wavelet
coefficients

PCA

Bootstrapped
LDA & QDA

Results and Discussion

- **Two sets of experiments**
 - Each with 12 spoiled x 12 spiked samples
- **Feature extraction**
 - Bior4.4: 144 features (18 WPT coefficients x 8 sensors)
 - Bior5.5: 160 features (20 WPT coefficients x 8 sensors)
 - Bior6.8: 208 features (26 WPT coefficients x 8 sensors)

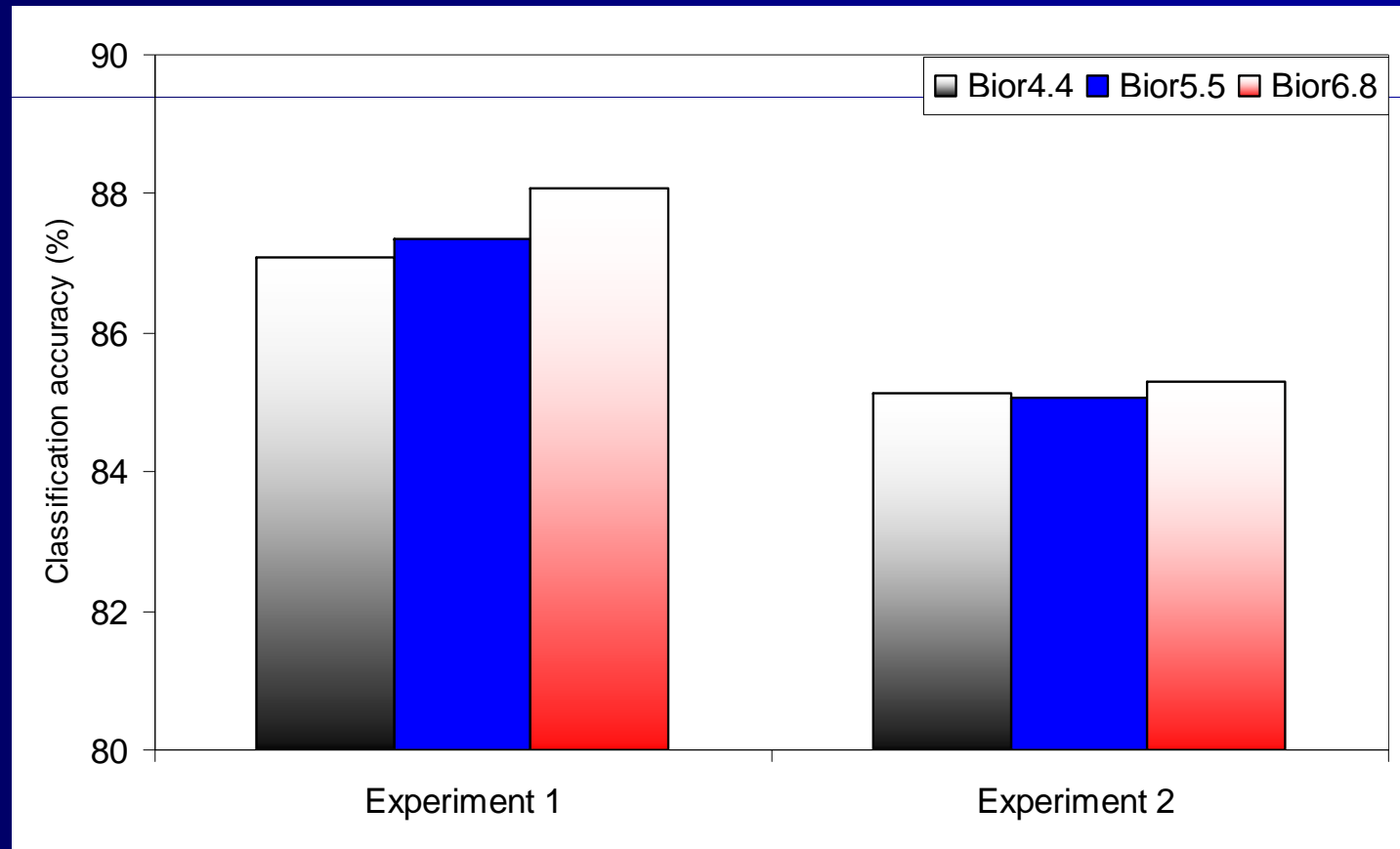
Results and Discussion

■ Bootstrapped LDA

	Experiment 1			Experiment 2		
WPT	Classification accuracy (%)			Classification accuracy (%)		
	Control	Spiked	Total	Control	Spiked	Total
Bior 4.4	88.32	77.27	82.80	83.56	84.01	83.78
Bior 5.5	88.04	76.76	82.40	83.72	83.33	83.52
Bior 6.8	88.83	77.59	83.20	84.47	82.39	83.43

Results and Discussion

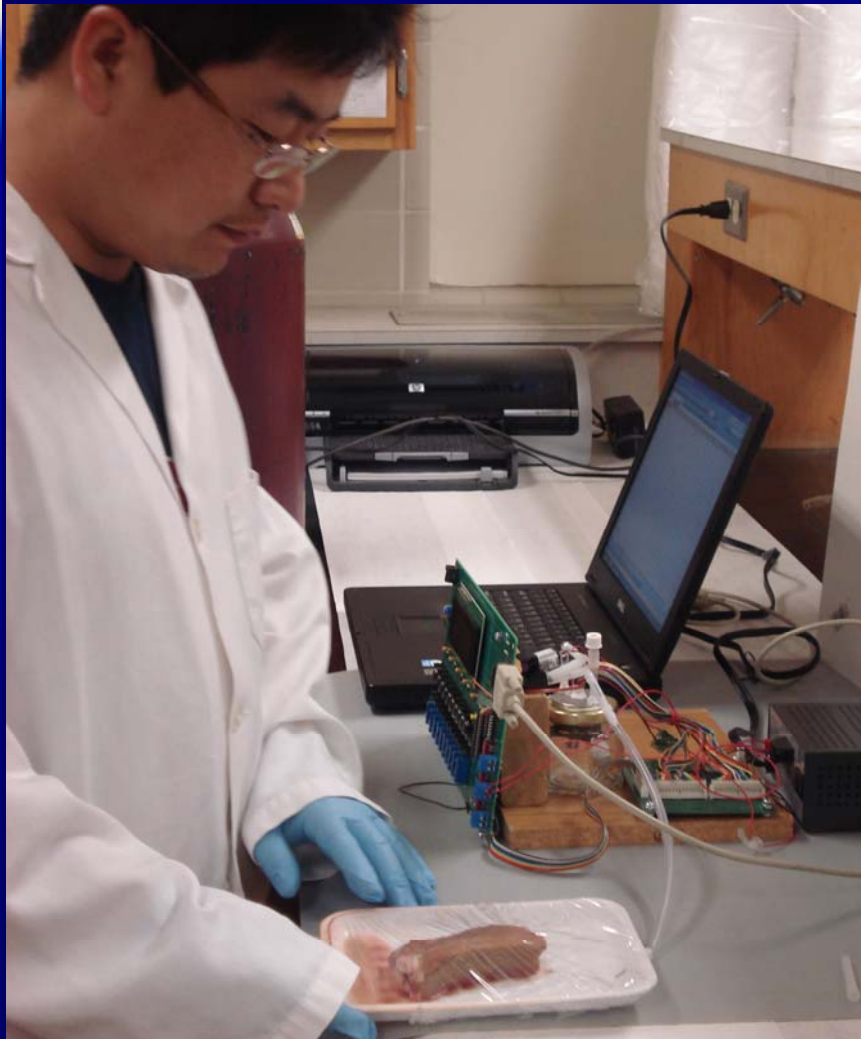
■ Bootstrapped QDA



Conclusions

- **The overall contamination classification accuracies for both datasets were $85.79 \pm 1.48\%$**
- **Total classification accuracies of LDA and QDA were found to be higher than 82% with the highest total classification accuracy of about 88%**

Current and Future work

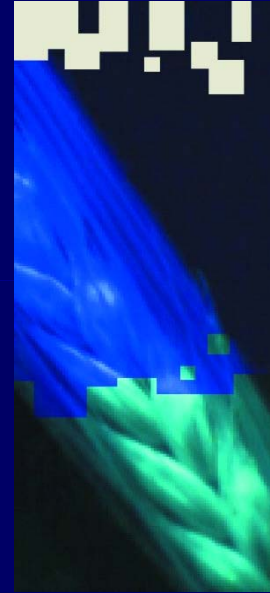


Acknowledgement

- USDA-CSRESS
- Julie Sherwood

Bio-imaging and Sensing Center

Redefining the boundaries of technology for biology and agriculture in 21st century



A multidisciplinary facility where we extend our research to find workable solutions