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On-Farm Sensors for Estimation of Milk Composition – Where Will These Devices & Data Fit in DHI Programs in the Future?

Steven Sievert
Chair, ICAR Measuring, Recording and Sampling Devices Subcommittee (MRSD-SC)

Current State of Sensor Technology

- Technology is Improving and Changing Rapidly and Easily Adopted by Producers
- Many Isolated Packages without Integration or Linkage
- Sensor Users Behave as a 'Community of Practices' – no True Standards or SOPs
- Validation, Maintenance, and Calibration Protocols are Missing
- There is both System Bias and Individual Sensor Bias

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Data Capture & Data Flow Challenges

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- Quality of LAN or Internet Connection at Dairy
- Many Different Versions of Software – Updates Not Installed
- Frequent Updates of Software Creating Data Field Errors
- Random or Arbitrary Data Fields Created by Dairyman
- Lack of Real-Time Connection – May Only Be Daily or Weekly
- System is Too Complex/Labour Intensive for Dairy
- Inconsistent Data Definitions
- Data Quality – Missing or Incomplete
- ID Truncation, Translation, Cross-Referencing

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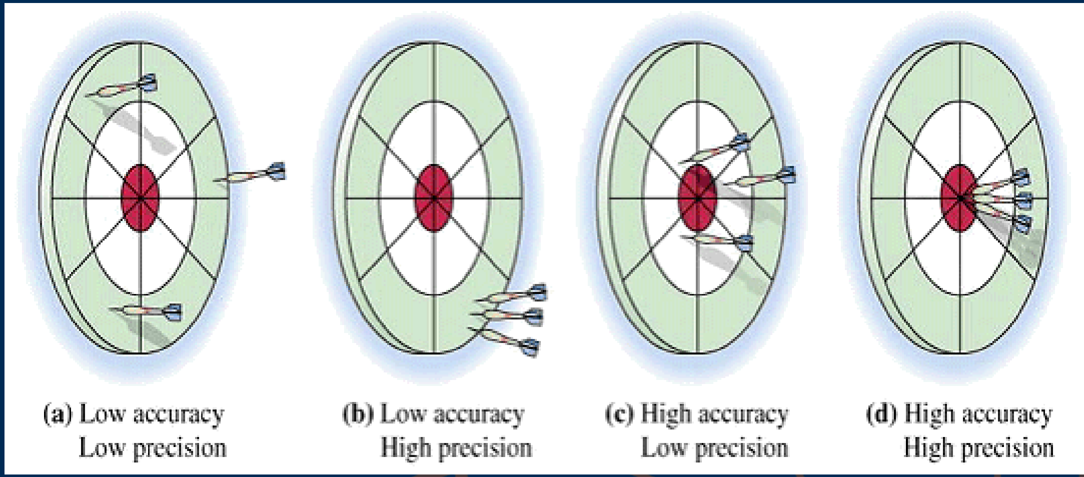
Accuracy & Precision



- Cannot simply assume that you can be less accurate in measurement just because you have more data observations
- What are the accuracy & precision compared to the “gold standard” for the industry?
- Cannot simply assume that accuracy & precision are acceptable when compared to other measures on the farm

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Accuracy & Precision of Four Fat Sensors

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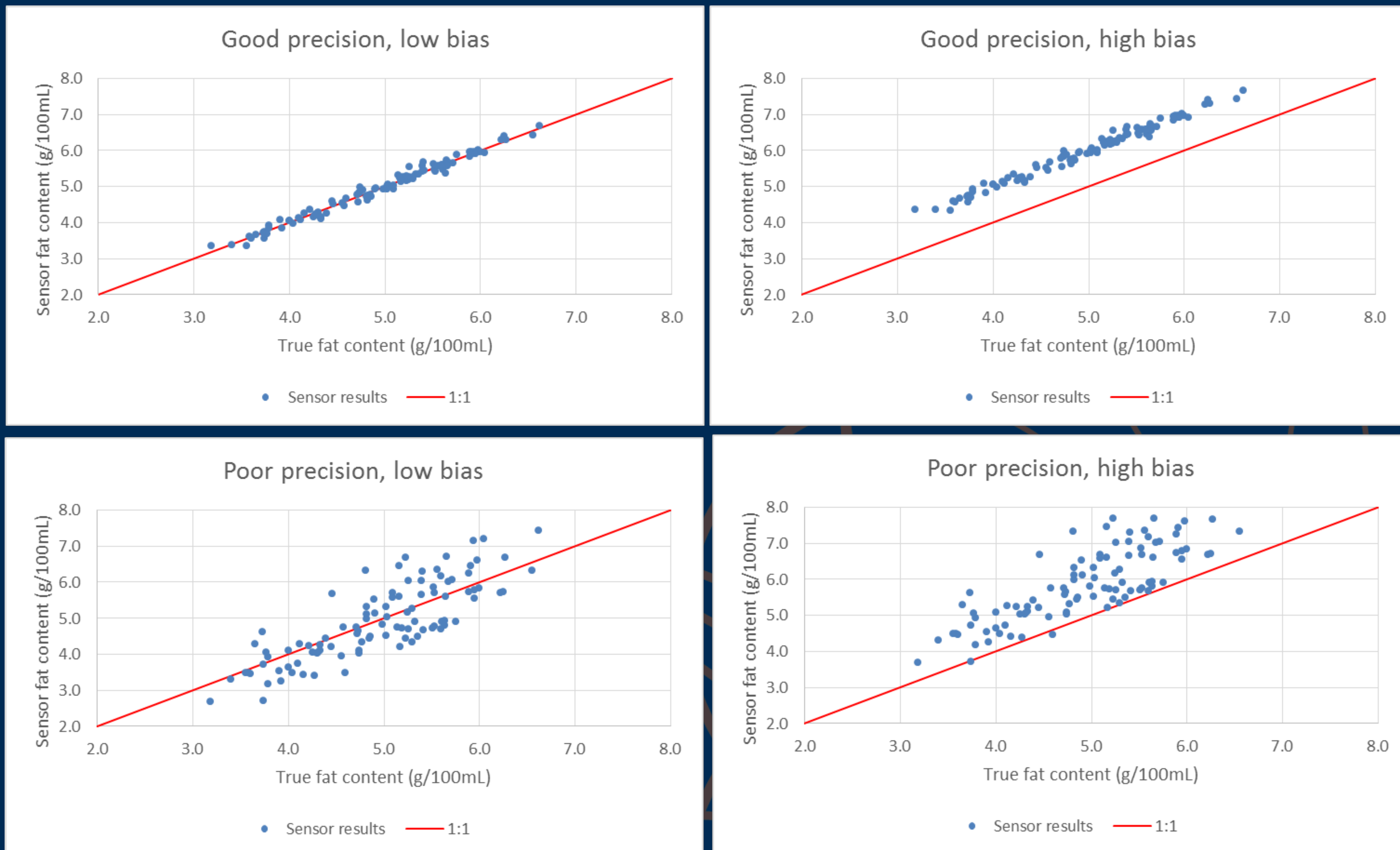

Multiple Ways to Classify Sensor Data

Management Data
- Yield
- SCC
- Milking Speed
- Feed Efficiency

Animal Health Data
- Locomotion
- Reproduction
- Disease
- BCS/Weight

Animal Welfare Data
- Activity
- Mobility
- Eating, Resting
- Heat Stress

Data for Genetic Evaluations

Different Needs for Accuracy & Precision

Data Linked to Direct Farm Payments
- Yield
- Fat, Protein
- SCC

Alarm Data
- Heat Detection
- SCC
- Locomotion
- Location

Yes/No Data
- Pregnancy
- Disease

Trend Data
- BCS/Weight
- Milk Flow/Speed
- Feed Efficiency
- Eating, Resting

Sensor Devices Bring More Challenges

- Software Updates – Is Version Control Important?
- Measured vs. Estimated vs. Displayed vs. Usable Data
- Lack of Standard Data Definitions & Practices
- Validation, Maintenance, and Calibration Protocols are Missing
- Data Connectivity, Storage, Source, and Transfer
- Managing Sensor System Bias and Individual Sensor Bias

What is the Difference?

Raw Data
vs.
Estimated Data
vs.
Displayed Data
vs.
Usable Data

- Measuring one variable & reporting another
- Handling of missing data points
- Outlier handling and exclusion
- Data smoothing
- Range of accurate measurement
- Precision of data recording
- Data transfer, custody, accessibility

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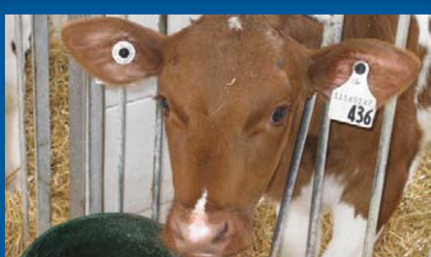
Animal ID is More Important Than Ever



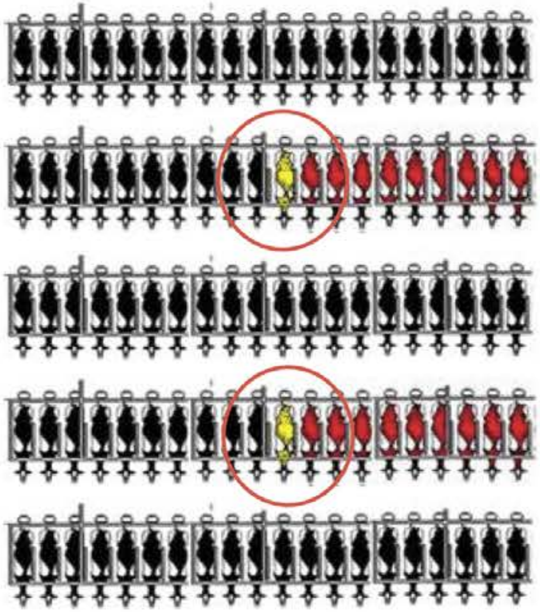
- The ‘official ID’ of an animal most likely will not be the same as ID associated with sensor measures
- Animals may have multiple IDs over their lifetime
- Animals may have multiple IDs on their body at once
- Databases will need to have protocols for ID cross-referencing and validation
- Need ICAR & DHI protocols for on-farm validation of the automatic ID system and for data transfer/custody

Reliable Data - Auto ID Systems

Example: 2x20 Parlor, ID at the entrance

ID rate 98%

- 100 cows = 5 loads
- 98% ID = 2 cows missed in 5 loads
- On average the missed cow is in mid load
  Data of 10 cows is assigned to wrong cows



RESULT: DATA RELIABILITY = 80%
20 cows out of 100 assigned with wrong data

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Challenges with the Next Generation of Devices

- We are Looking at Systems Instead of Devices
- New Systems Measure More than a Single Parameter
- System Measures One Variable and Reports Data as a Different Trait
- Reliance on Automatic ID Systems and Association with the Correct Cow
- Speed of Commerce is Faster than ICAR Testing

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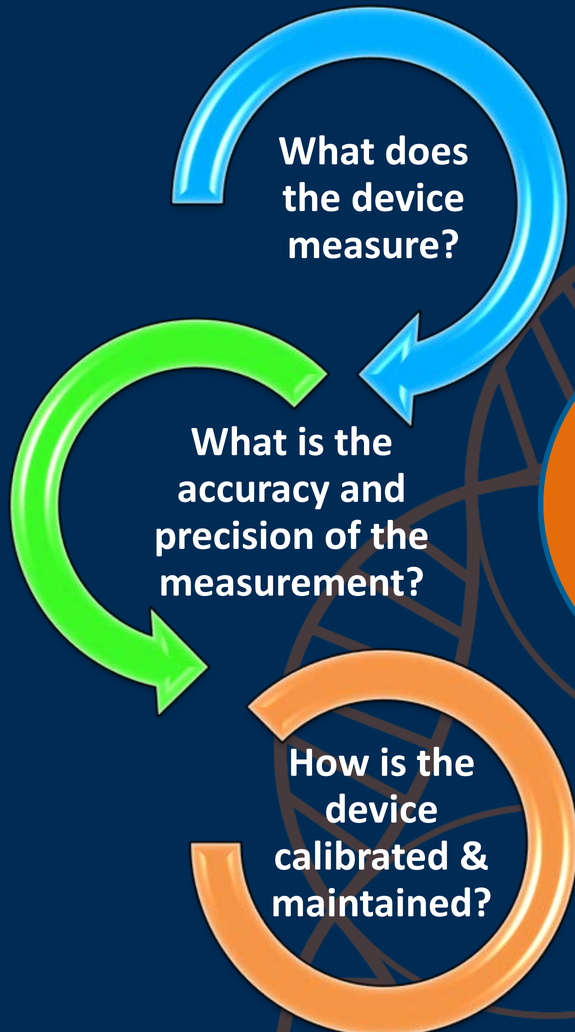
Reviewing Recording & Sampling Devices or Systems



We cannot determine suitability of data until we know and understand the measurement

What are We Measuring?

Multiple Indicators of Mastitis or Milk Quality

- Automated CMT/WMT
- Electrical conductivity
- L-lactate dehydrogenase
- N-acetyl-beta-D-glucosaminidase
- ATP luminescence
- Thermal imaging
- Visible NIR, MIR spectroscopy

Milk quality measures are affected by sampling time, temperature, milk viscosity, calibration

Afimilk
Afilab

AfiLab Features:

AfiLab automation transforms dairy farming into advanced dairy farm management.

AfiLab provides:

Milk Component Measurement

Measures fat, protein and lactose content

Quality Control Alerts

Identifies the presence of blood, allowing Afimilk to immediately discontinue milking when blood is detected

Optical Free Flow Technology

Uninterrupted measurement of milk components

- No moving parts or milk flow obstructions
- No reagents or other costs for measurement

Real Time Measurement

Analyzed data is available to the dairy manager inside the Afimilk system when the cow leaves the parlor

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Afimilk
Afilab

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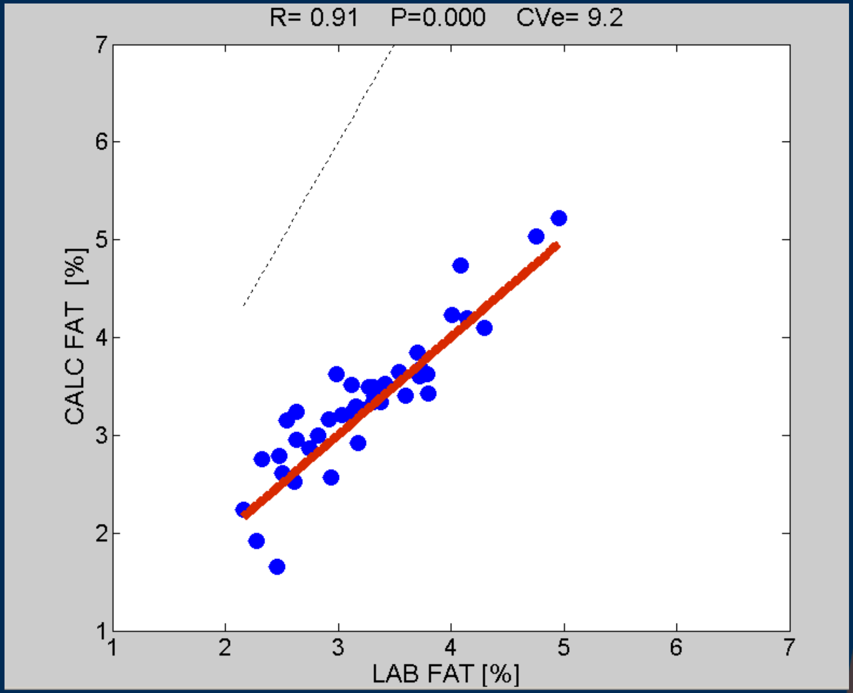
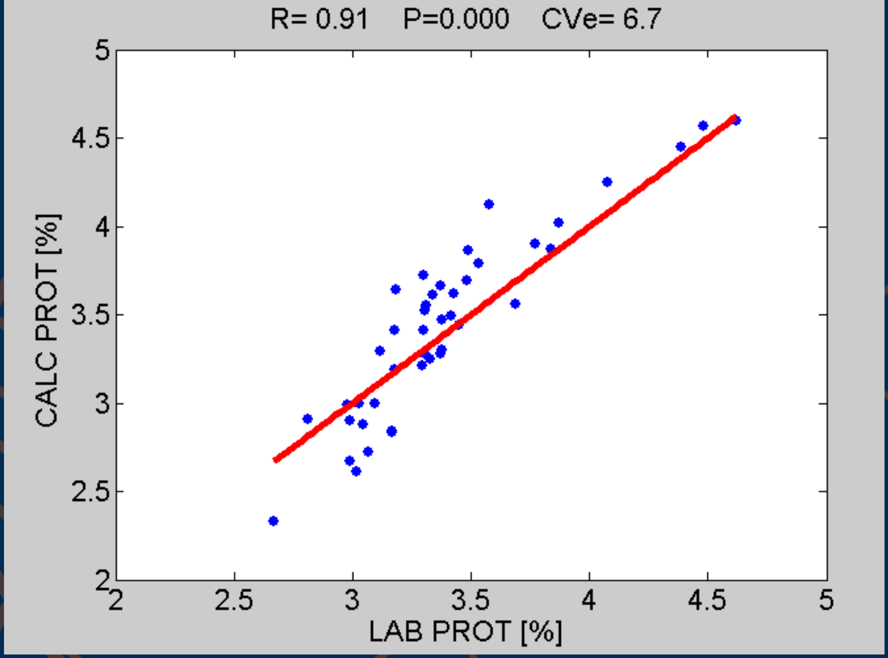


Milk Fat

Total Protein



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Afimilk
Afilab

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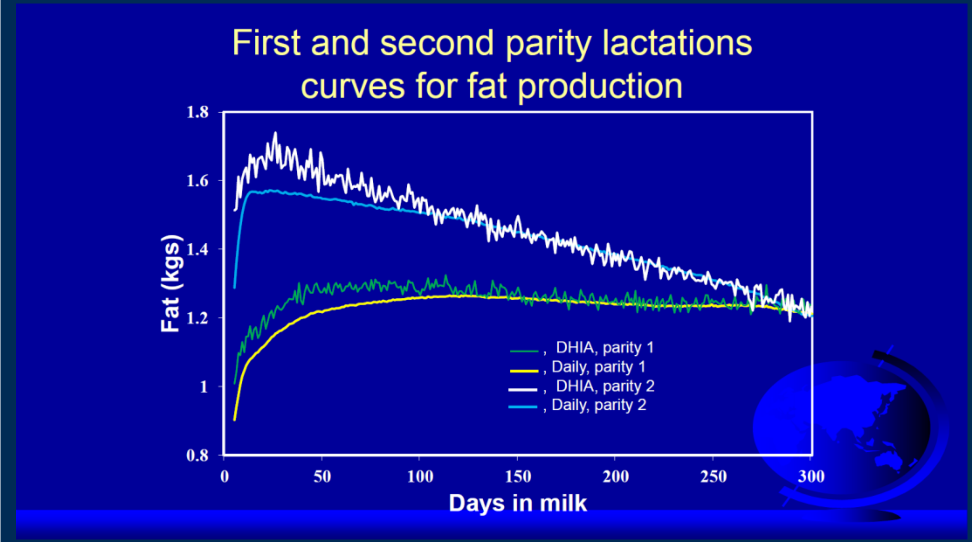

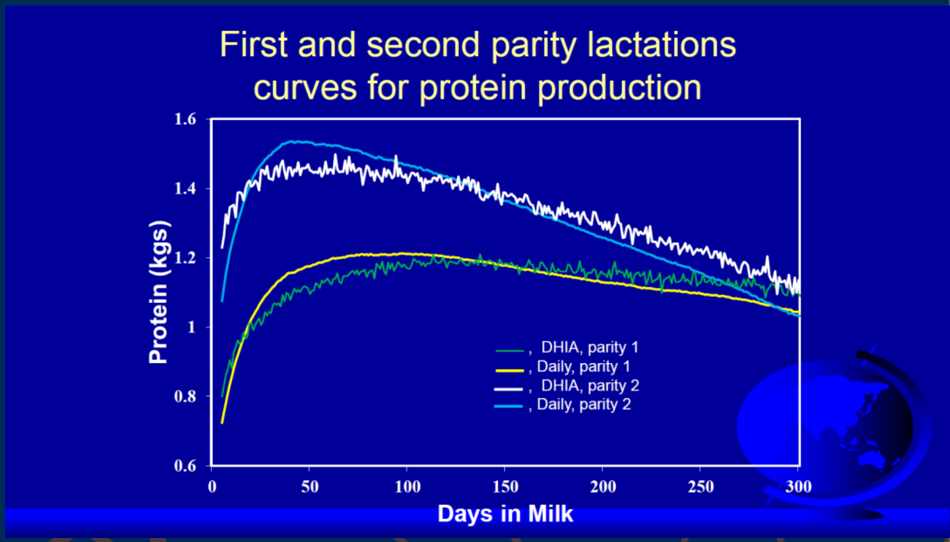

Accuracy is Not Constant

- In-line analyzer compared to DHI lab results across the entire lactation
- In this case – underestimated fat yield & overestimated protein yield in the first 125 days of lactation
- Technology is improving but cannot simply accept results because this is the ‘best we can do presently’

GEA iNTELLAB

- Estimates milk yield and flow rate – not ICAR certified
- Indicator of F-P-L using white light
- Conductivty sensor for mastitis prediction
- Raw data computed by proprietary estimates
- Assumes 100% ID accuracy

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GEA M6850
Cell Count Sensor

Network. Guidelines. Certification.

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GEA M6850 Cell Count Sensor

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- Determines cell count categories for each udder quarter individually
- Requires no additional consumables
- Evaluates the milk cell counts continuously through milking session
- How is cow SCC calculated from quarter SCC estimates when milk yield data is not available?

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Lely MQC-C Sensor

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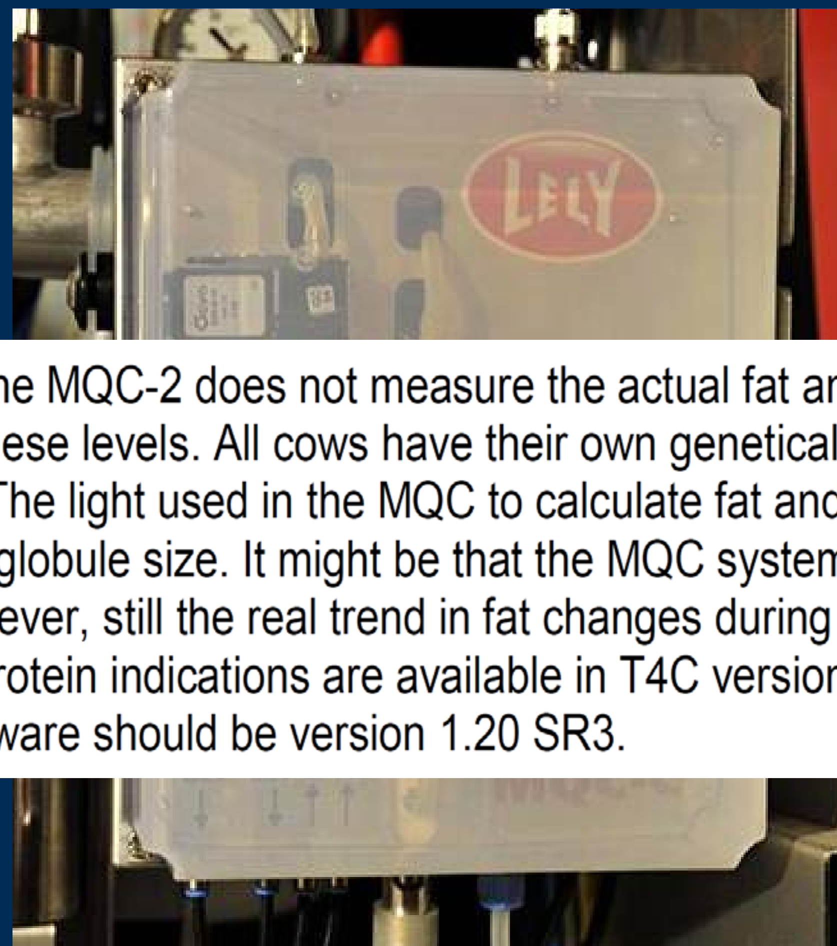
Two sensors indside providing:

SCC Estimation

Fat and Protein Indication

Lely MQC-C Sensor

Fat and Protein Indication



The term "indication" is used because the MQC-2 does not measure the actual fat and protein % in the milk, but provides an indication of these levels. All cows have their own genetically determined range of smaller or larger fat globules. The light used in the MQC to calculate fat and protein indications corresponds to a certain fat globule size. It might be that the MQC systematically differs from the analysis of the laboratory, however, still the real trend in fat changes during lactation is perfectly shown by the MQC. Fat and protein indications are available in T4C versions 3.1.0.28 and higher. On the robot, the MQC software should be version 1.20 SR3.

Lely MQC-C Sensor

Fat and Protein Indication

6.5.1 Calculation method

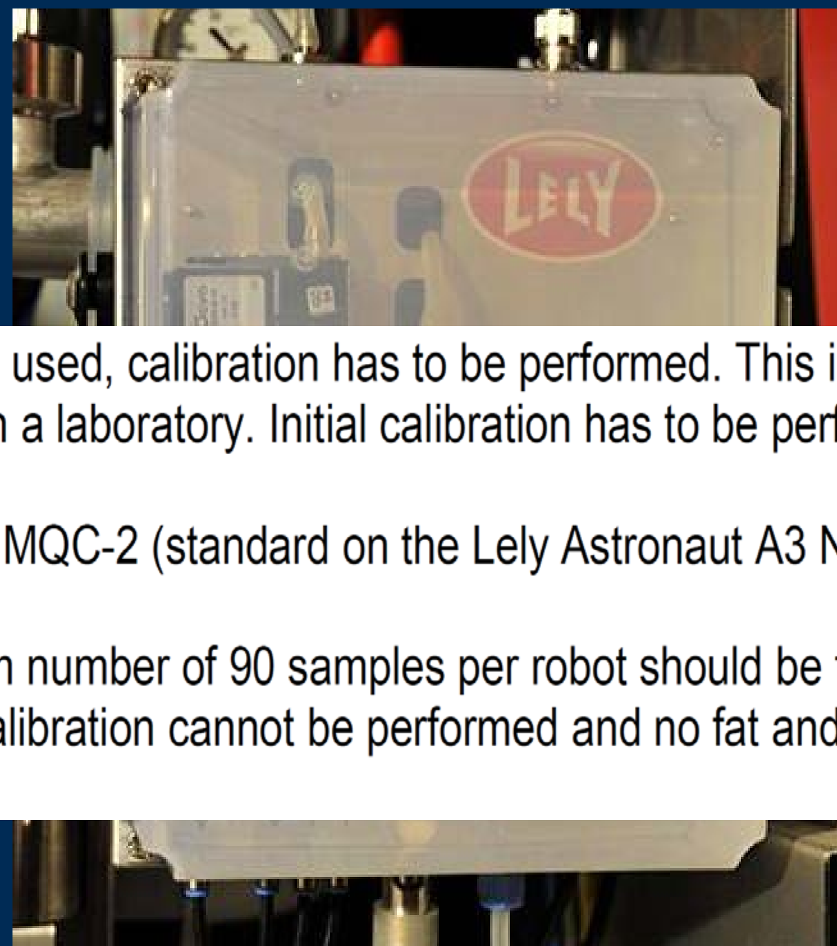
- Individual fat and protein indications are available as an average of the last 5 milkings.
- Herd averages are calculated from the individual cow data of the last milking

CellSense & MQC-C Sensors

SCC value	
> 2,000,000	●●●● (orange)
800,000 — 2,000,000	●●●● (yellow)
400,000 — 800,000	●●● (yellow)
200,000 — 400,000	●● (yellow)
< 200,000	● (green)

- Automated CMT Test
- Estimates SCC content at 45 seconds into milking
- While correlated to total milk SCC it is NOT the same
- Visual scale of probable SCC value
- Algorithm is based on calibration/adjustment based on DHI SCC values and/or adjustment to bulk tank SCC
- Each sensor has its own bias (positive or negative)

Calibration of the MQC-C Sensor

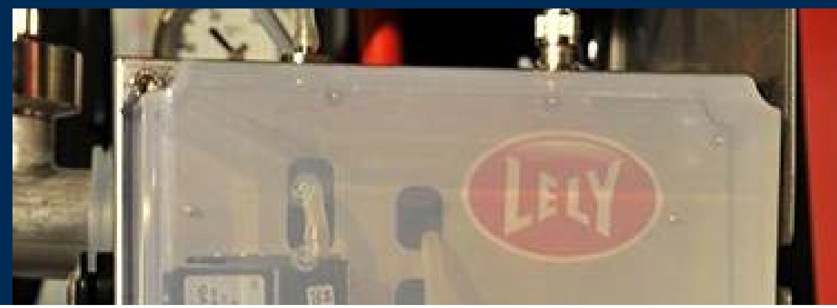


Before fat and protein indication can be used, calibration has to be performed. This is done by using the result of regular milk testing in a laboratory. Initial calibration has to be performed as follows:

1. The robotic milking system with the MQC-2 (standard on the Lely Astronaut A3 Next) should be running for at least 5 days
2. For a reliable calibration, a minimum number of 90 samples per robot should be taken. Below 60 successful samples per robot, calibration cannot be performed and no fat and protein indications will be shown in T4C.

Lely MQC-C Sensor

Calibration of the MQC-C Sensor



6.5.8 Re-calibration

- Re-calibration has to be performed every 6 months to keep accurate fat and protein indications.
- The protocol for re-calibration is identical to the initial calibration protocol.

6.5.9 Sensor replacement

- When one or two sensors of the MQC needs to be replaced, the system will use the three or two remaining sensors to calibrate the new quarter sensors automatically. This will require 500 milkings, during those 500 milkings the fat and protein results are calculated by the sensors that were kept in place. After these 500 milkings the new sensors are calibrated and the fat and protein indications are shown at cow level again.

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Lely Sensor (Denmark Comparison)

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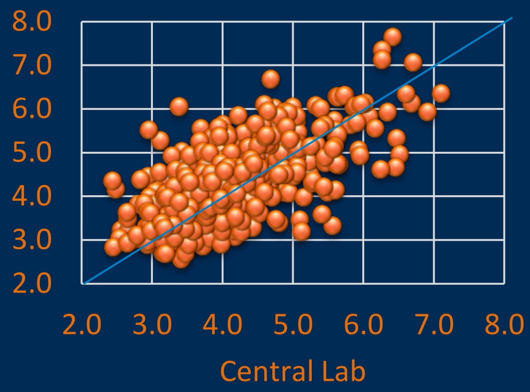
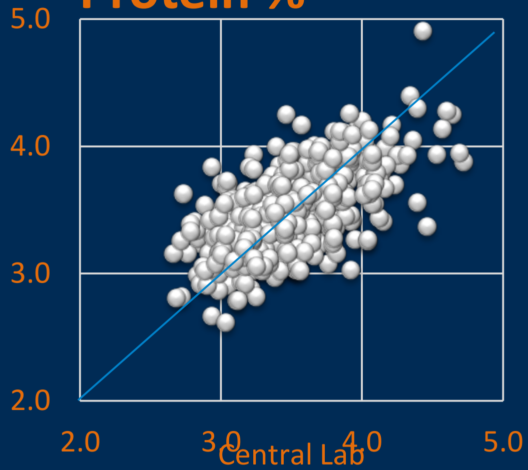
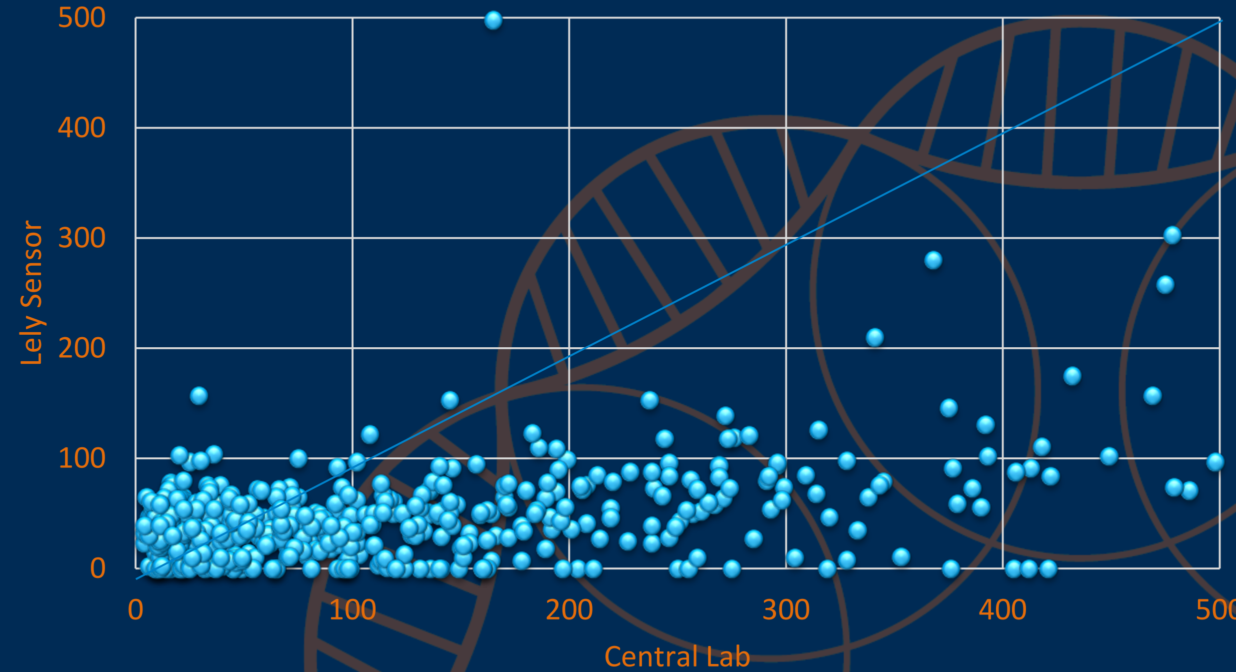
Fat %



Protein %



SCC (x1000)



- Poor relationship for SCC, moderate for fat & true protein
- One measures representative sample of total milk and the other estimates at a point during milk letdown

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Lely Sensor (Lactanet Comparison)

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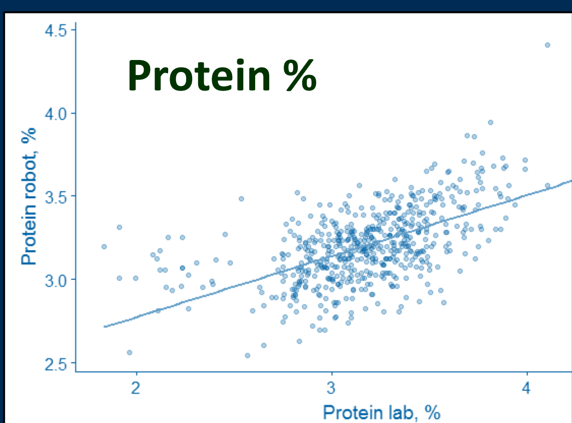

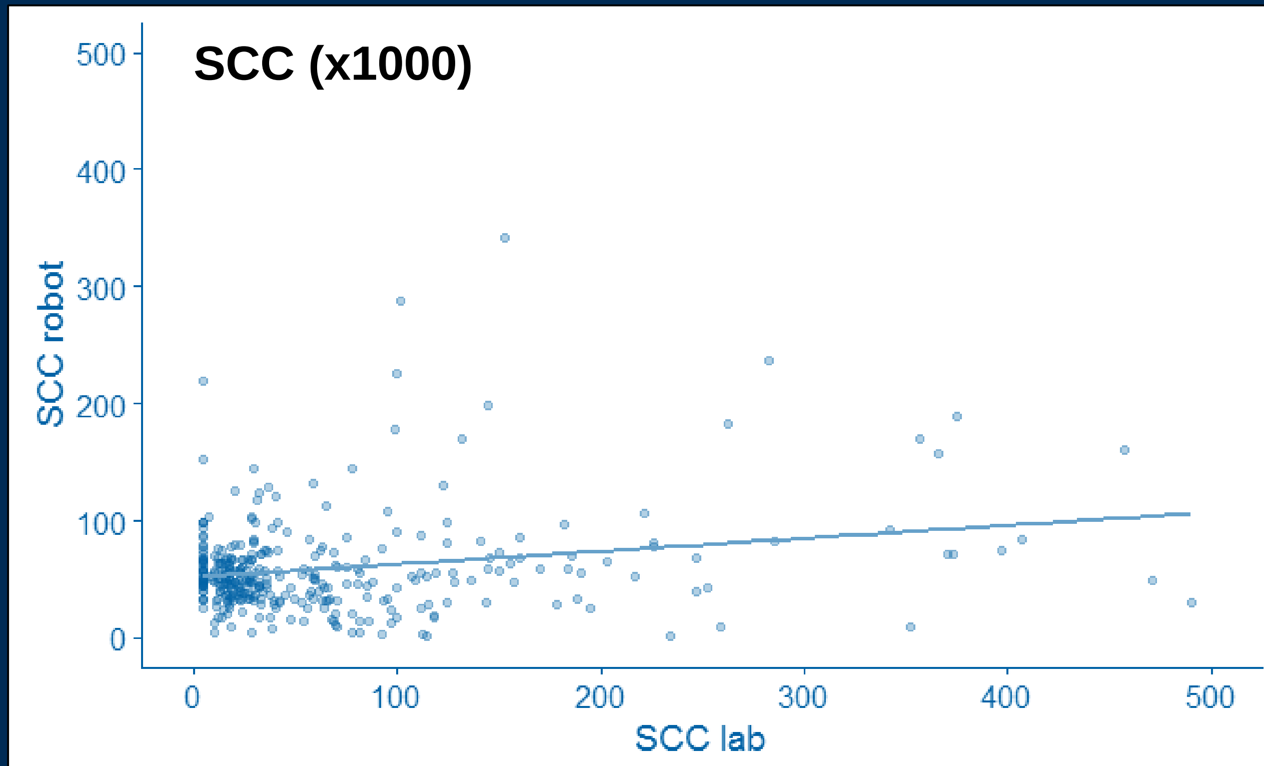

- Similar component relationships between on-farm sensors and central lab results in Quebec as in Denmark
- Environmental effects– AMS settings/adjustments, milking settings, feeding programs may have influences

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DeLaval OCC Online Cell Counter

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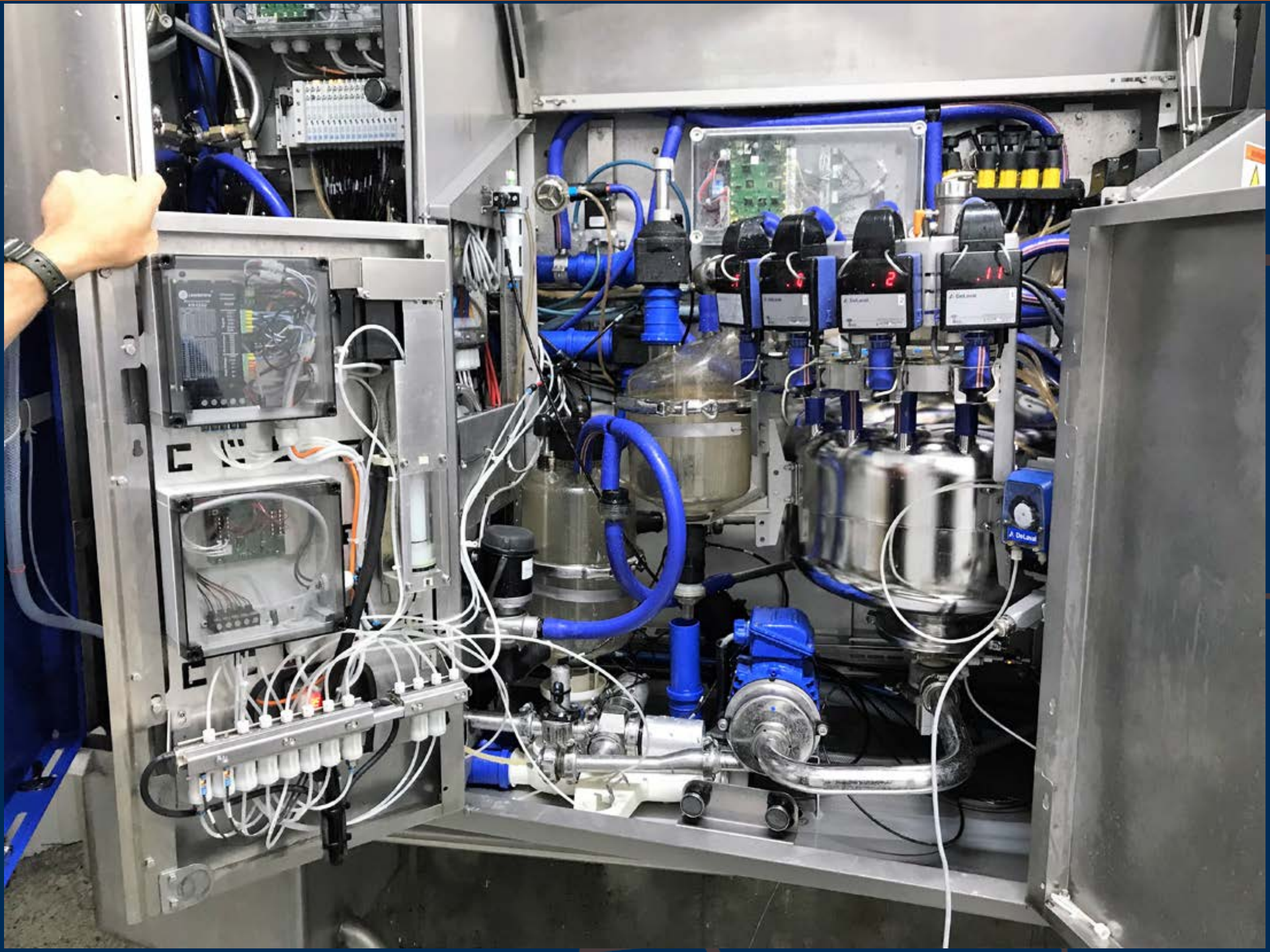

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DeLaval OCC Online Cell Counter

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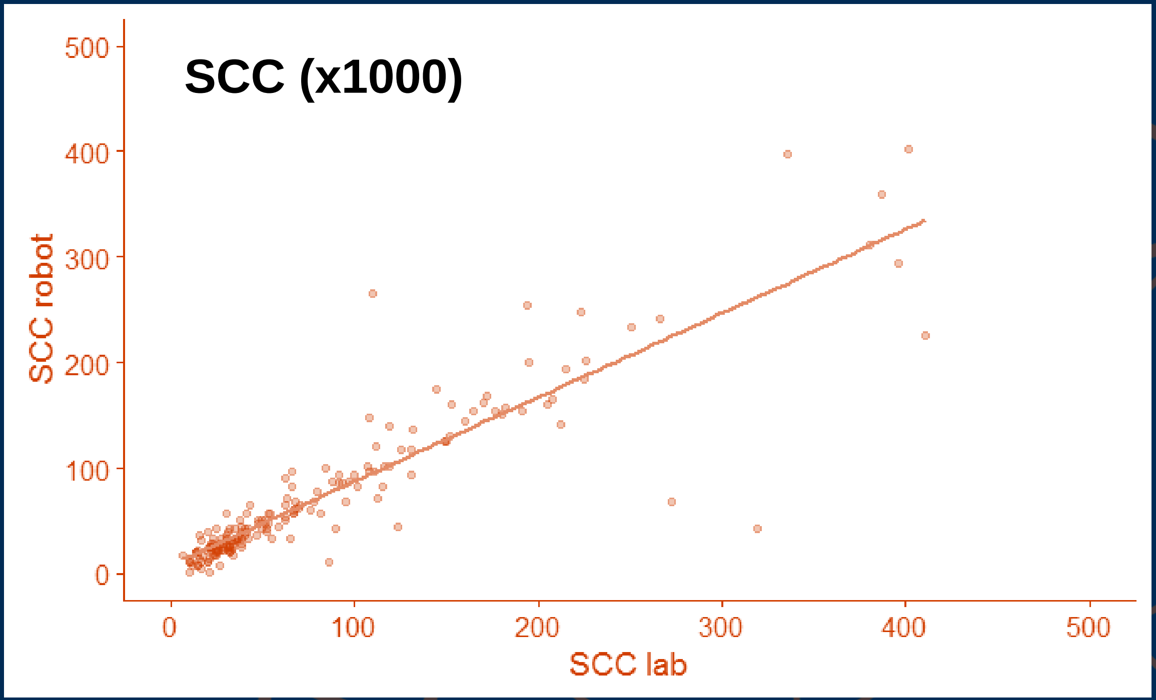
- Analysis of SCC on representative sample of entire milking
- Uses the same mixing and sampling ports as shuttles for DHI samples
- Very accurate
- Consumables – reagent and rinse solutions
- Adapted for VMS (robots) presently

Comparison of DeLaval OCC & Lactanet SCC



- Strong relationship between sensor and central lab results for SCC
- Cannot make blanket assumption by milk harvest system
- Not all robotic systems are at the same level of accuracy or precision for each component

4 DeLaval VMS dairies – preliminary data courtesy of Valacta (CA)

Soma Detect

Fat

Butterfat content is a major component of milk. It is an indicator of nutritional quality, and one or the primary factors used to determine how much farmers are paid for raw milk. Fat is an important component of milk for cheese and yogurt production.

Protein

Protein content is a major component of milk. Similar to fat, protein is an indicator of nutritional quality, and a factor used to determine raw milk prices. Protein content can be used to determine feed ratios and cow health.

Fat/Protein Ratio

Fat to protein ratios are an indicator of nutritional health. They are used as indicators of nutritional disorders such as ketosis and acidosis. Farmers may also use them to evaluate feed quality, and when making important decisions about what they feed their herd.

Our technology uses two pieces of magic working together: an incredible sensor technology with cuttin edge computer vision and deep-learning algorithms.

Progesterone

Progesterone is a hormone that changes throughout the reproductive cycle of a cow. Changes in progesterone can indicate when a cow is ready to be bred, and whether or not she is pregnant. Reproduction is key to dairy production: cows that don't produce offspring don't produce milk.

Somatic Cell Count

Somatic cell count is an indicator of udder health. They are the industry standard for milk quality and used to diagnose mastitis. Somatic cell count is regulated by the industry. Raw milk over a certain threshold will be rejected by processors.

Antibiotics

Trace amounts of antibiotics cause milk to be rejected by processors, as the milk cannot be used to make cheese or yogurt. Antibiotic contamination is not frequent, but it is a major area of concern for farmers. All milk shipments are checked for antibiotics and positive truckloads will be discarded.

Using SCC Sensors

SCC sensors are intended for mastitis management – not animal evaluations

1. Detect and monitor subclinical mastitis
2. Manage bulk tank SCC
3. Develop action list for cows to culture
4. Identify cows for selective dry cow therapy
5. Identify cows to cull

Our current data flow systems cannot distinguish sources of SCC data – the need exists to capture source of data as well as reported value

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Using F-P-L Data from On-Farm Sensors

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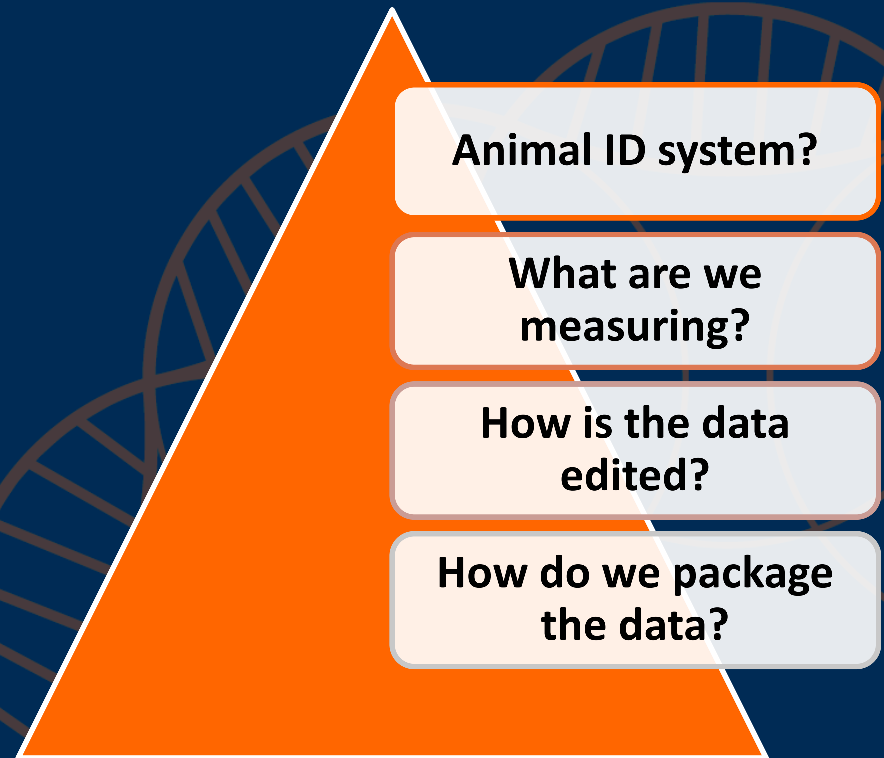
Total System Evaluation

What is Good Enough for:

Management Decisions?

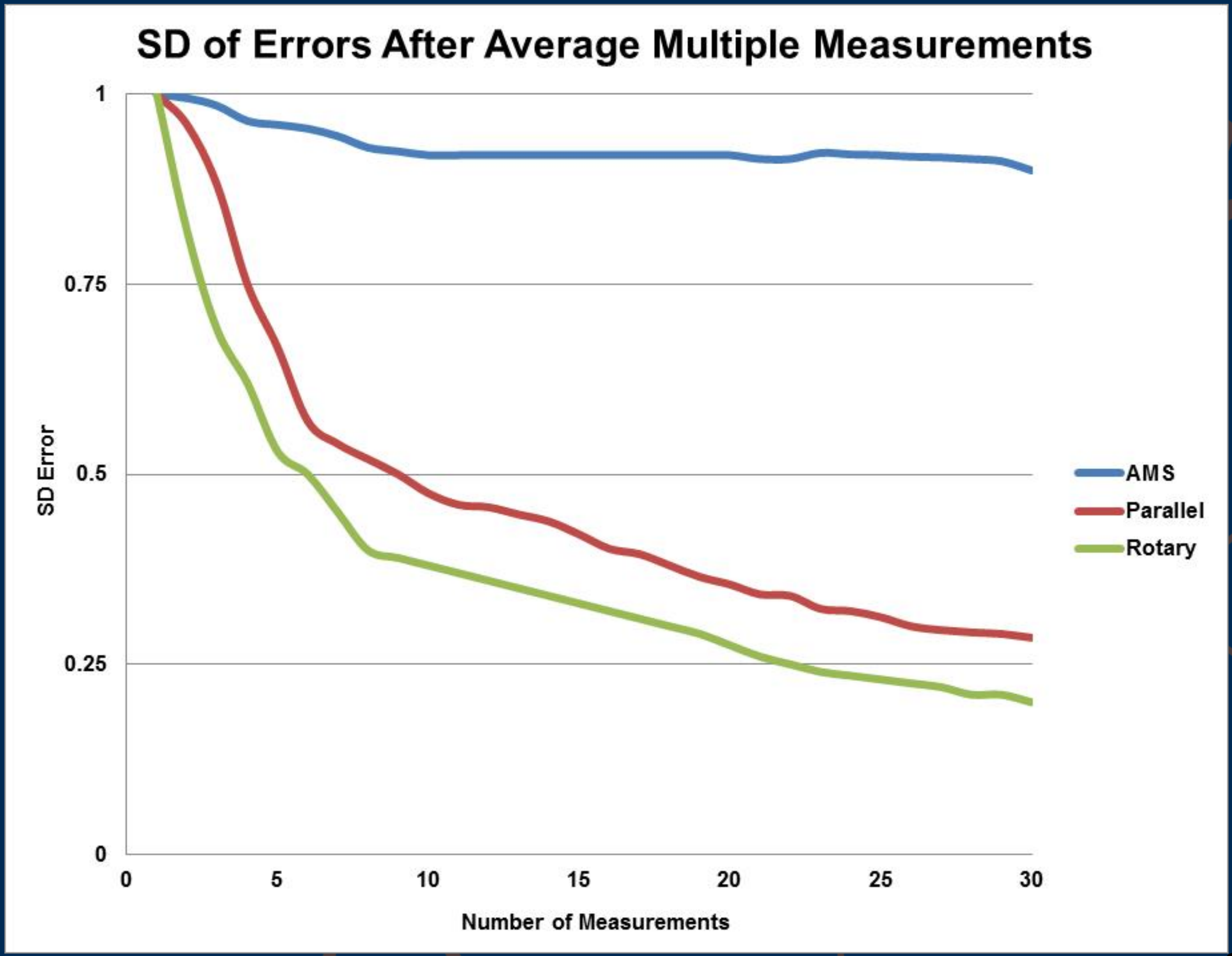
Genetic Evaluations?

Benchmarks & Research?



Cumulative Effect of Sensor Errors

More observations are not the answer in all milk parlor configurations



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Merging Multiple Streams of the Same Data

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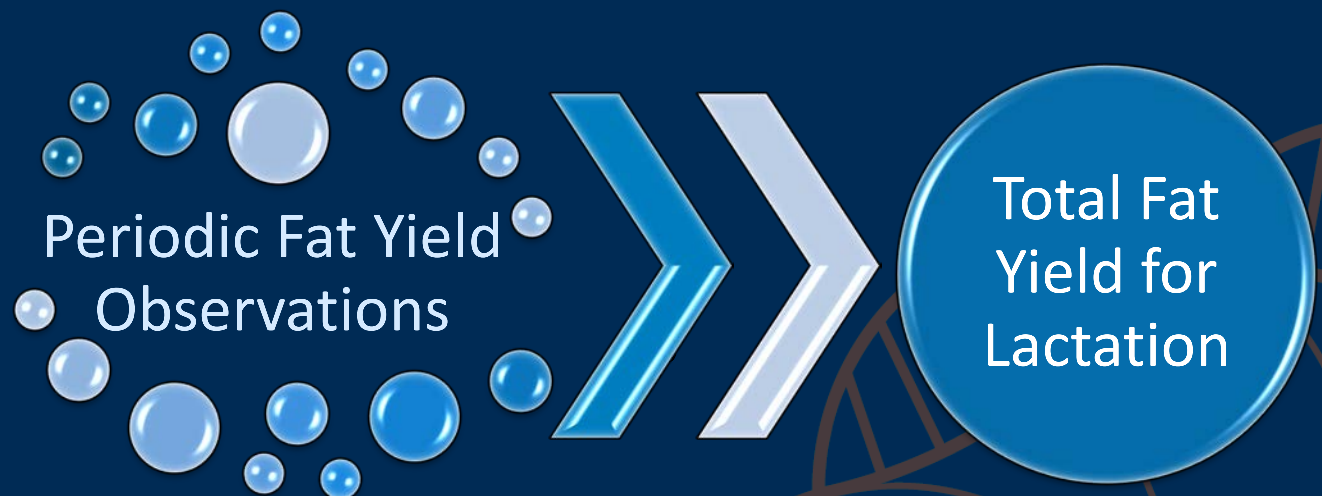

- **Producer may contribute information for the same parameter from different measuring devices**

- **Need to capture not only data point(s) but also source of the data**

How will we value each data point?

How will we value the whole record?

What information will we deliver?

How Will We Value Sensor Data?

Equivalency to Traditional Test Day Data

- Define parameters that approximate the accuracy and precision of traditional milk recording parameters like milk yield or composition

Separate Classes of Data

- Currently Supervised or Owner Sampler Test Types – will we have a test type or class for specific sensor data?

Weighting of Data

- Data collection rating system that puts relative weight on data type, collection interval, and parameters measured

Use Validated Data Directly

- New parameters may deliver data with acceptable accuracy and precision and the data is used with minimal editing

Exclusion of Certain Data

- Results from specific parameters may be deemed to be unsuitable for herd recording programs at the present time

The Future of Milk Recording

What is Needed?

- Total System Approach – Device, System, Software & Data
- Focus on Data for Management Purposes and then Assess Usability for Official Programs
- ICAR Guidelines & Protocols for Automatic Recording – Animal ID, Data Capture & Data Editing
- Innovative System Testing and Certification by ICAR
- Continuous Monitoring of Systems for Quality Assurance
- Flexibility in Data Transfer, Packaging and Delivery by DHIA
- Blend of Central Lab Milk Analysis & Sensor Estimates In DHI Programs