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Development of a microwave sensor application for online detection of corn silage dry matter content

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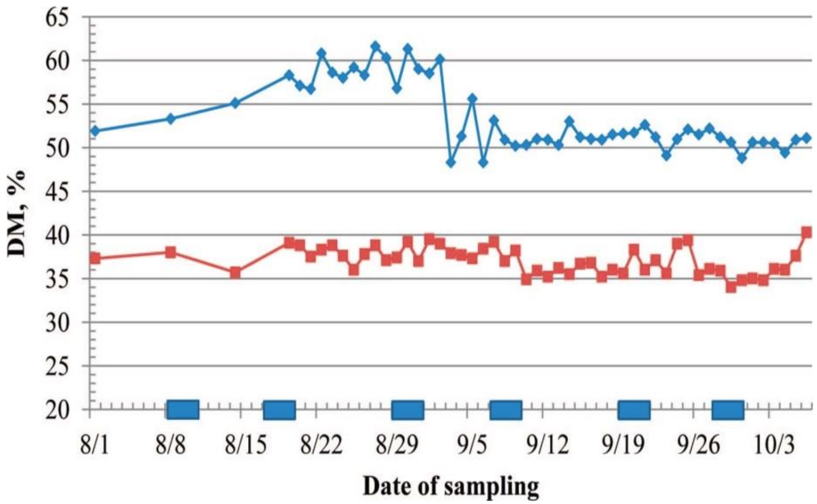
Background (1)

- ✓ Dry matter intake (DMI) establishes the amount of nutrients available to an animal for health and production *(NRC, 2001)*

- ✓ Rations are formulated on a dry matter basis, however ingredients are included in the Total Mixed Ration (TMR) on an as-fed basis

- ✓ Dry matter content of silages often undergoes transient changes (e.g. due to rainfall event on uncovered silos, fermentation patterns)



Concentrations of DM in alfalfa (blue line with diamonds) and corn (red line with squares). McBeth L.R. et al., 2013

Background (2)

- ✓ Transient (1- to 3-d) decrease in silage dry matter of 3 to 8 percentage units decreased short-term DMI and milk production *(Boyd and Mertens, 2011)*

- ✓ 8-percentage unit decrease in silage dry matter concentration (caused by water addition) determined a 0,9- to 2,6-kg decrease in milk yield *(Mertenes and Berzaghi, 2009)*

- ✓ A 10-percentage unit decrease in silage DM over short-term bouts had only minor effects on DMI, milk yield, and composition *(McBeth L.R. et al., 2013)*

Aim of the project

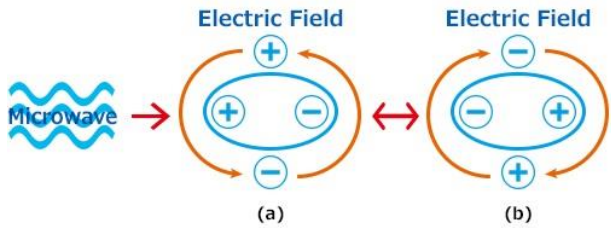
Development of a microwave sensor application for online detection of corn silage dry matter content

Precision Livestock Unifeed System project: development of different sensory systems to be embedded on the mixing wagon for the optimization of TMR production (ID: 145923 CUP: E77H16001570009)

Materials & methods (1)

Sensor

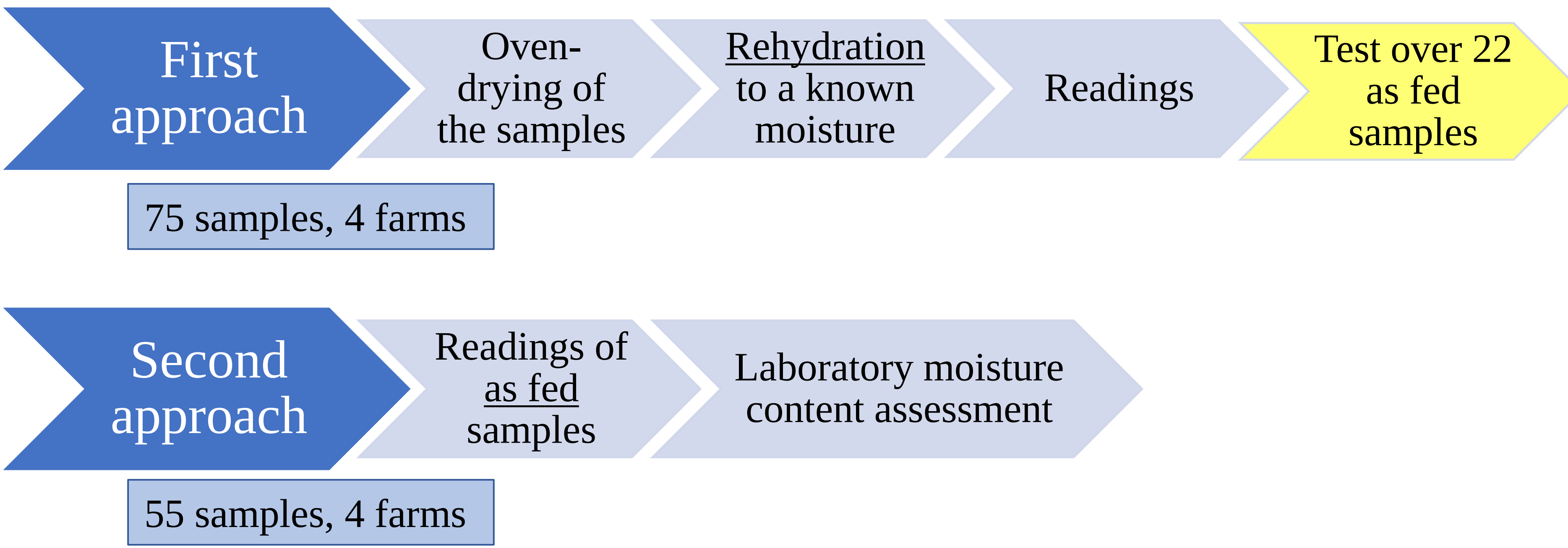
- ✓ Borrowed from concrete industry
- ✓ Microwave technology → When the material to be measured is irradiated by microwaves, water molecules are stimulated to vibrate and a certain amount of energy is absorbed (microwave attenuation)



- ✓ $Quotient = \frac{emitted\ energy}{reflected\ energy}$
- ✓ Linear response

Materials & methods (2)

The calibration of the sensor requires to associate the observed *Quotient* value with the real moisture of the sample → Static conditions



4 readings (*Q1*, *Q2*, *Q3* and *Q4*) for each samples, achieved by the rotation of the sample over the probe

Materials & methods (3)

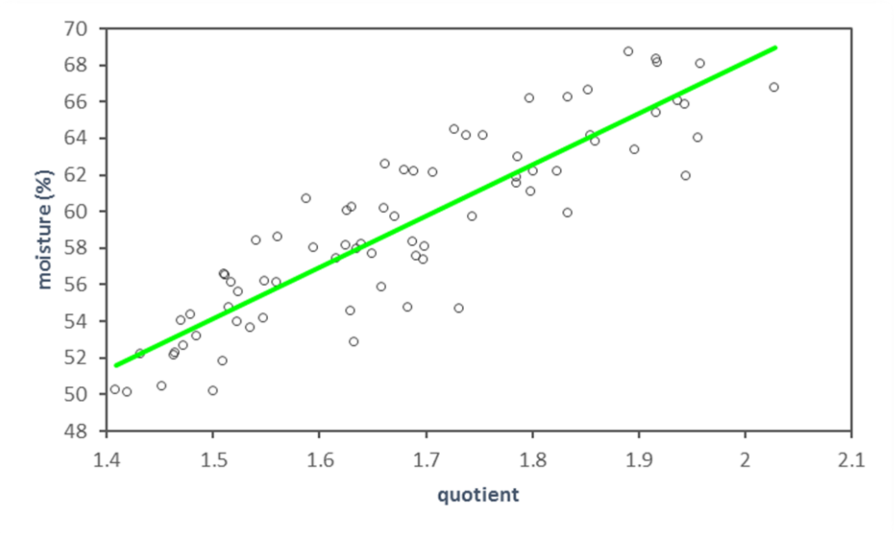
Statistical analysis

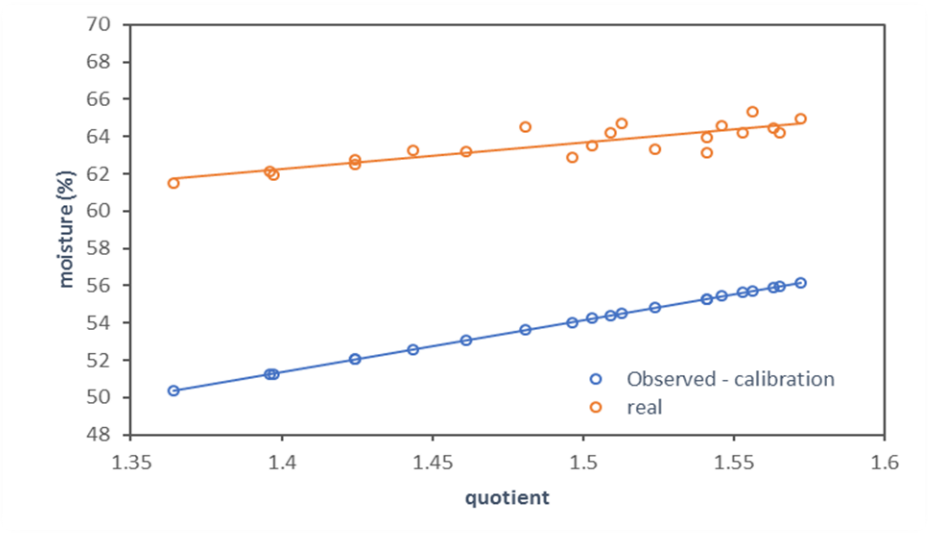
- ✓ Linear, logarithmic and polynomial regression analysis
- ✓ Validation with bootstrap
- ✓ Cluster analysis

RStudio®

Results (1)

First approach: rehydrated corn silage samples





Good correlation between *Quotient* and moisture content (R^2=0.79)

Test of the calibration over as fed material

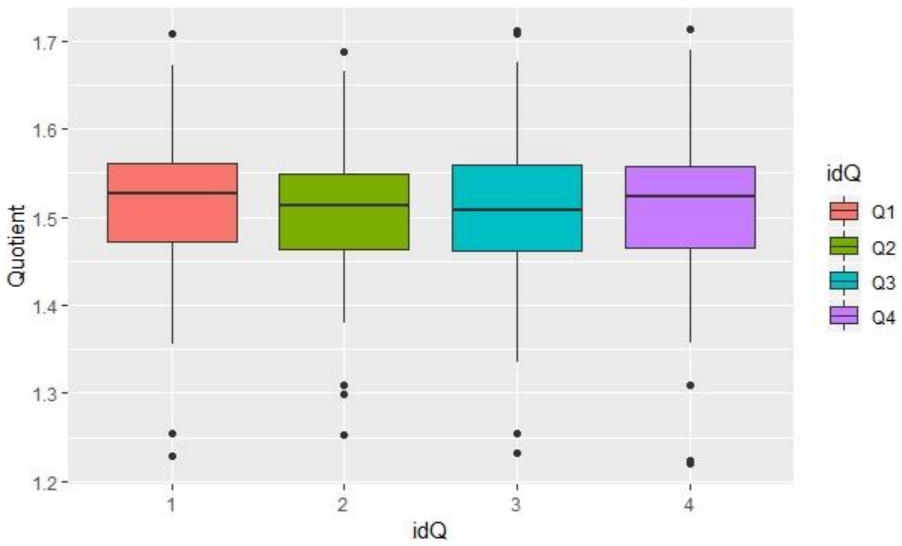
- Great discrepancy between observed and expected moisture (Δ=9.60±1.04)
- Statically significant difference in the slope of the curves

water was not completely absorbed due to the cellular breakdown? → Calibration over as fed samples

Results (2)

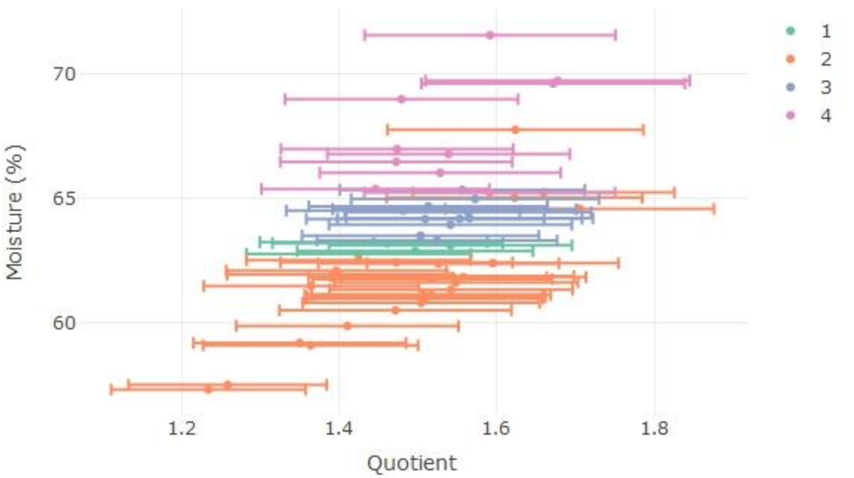
As fed corn silage samples

No statistical differences were evidenced for the mean of *Q1*, *Q2*, *Q3* and *Q4* across samples (t test: p=0,6847)



The instrument works properly and a single reading can be assumed as reliable

Volatility of *Quotient* for a given moisture



Bartlett's test evidenced significant differences (p<0.001)

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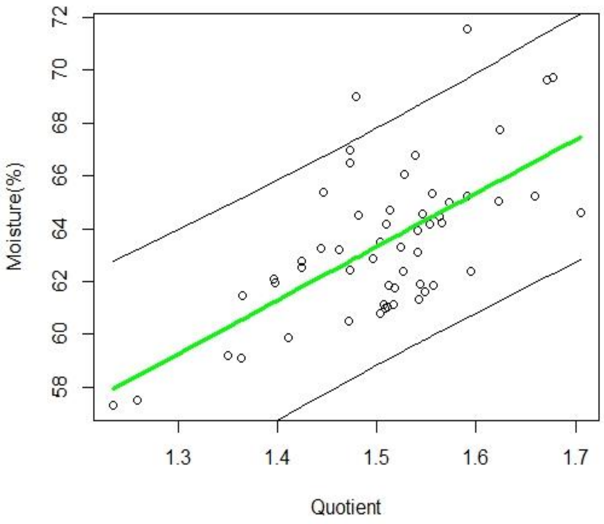
Missing information

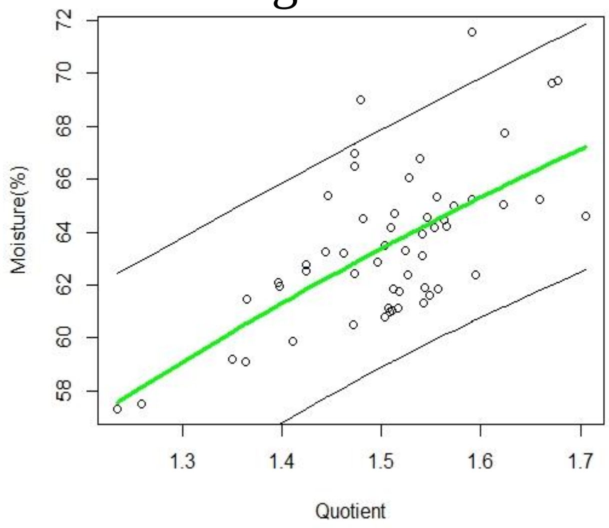
Results (3)

Calibration

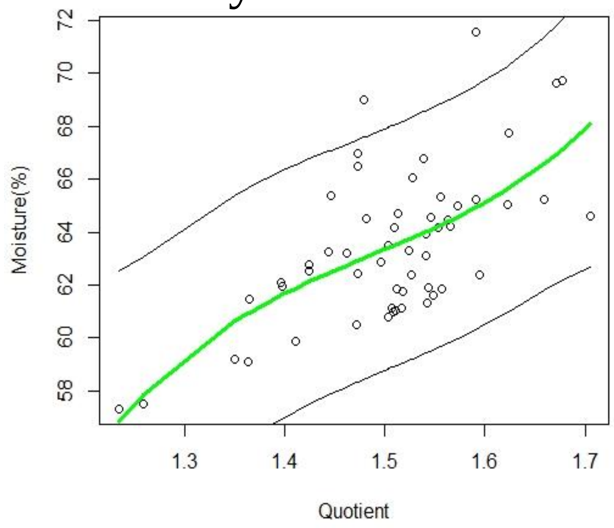
Linear model



Log-model



Polynomial model



	LINEAR	**LOG**	**POLYNOMIAL**
Adj R^2	0.4099	0.4109	0.3964
RMSE	2.177	2.175	1.006

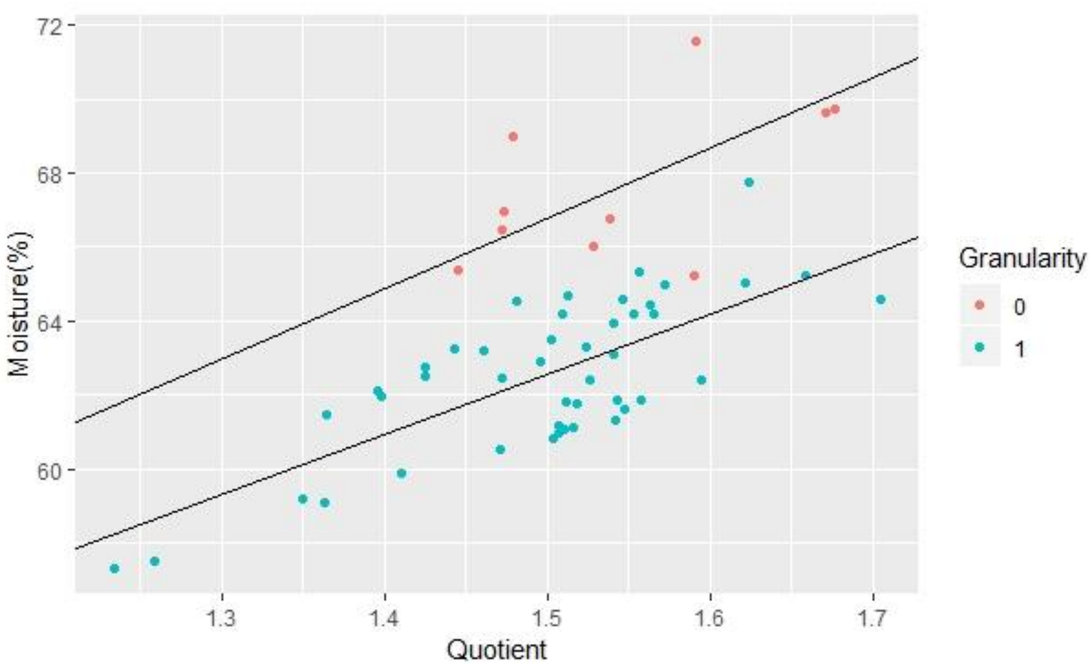
Results confirmed by bootstrap

But, when using the Log-model, rather than the linear model, the obtained gain in terms of RMSE is <1% → the choice of the Log model is not justified

Results (4)

The linear model has a low R^2 (0.4099) → Missing information → Hp: **Granulometry**

Proxy variable for granulometry (corn silage)



Improved R^2

This hypothesis is corroborated by obtained data from <u>high moisture corn</u>

↓

- ✓ No statistically significant difference of volatility of *Quotient* for a given moisture
- ✓ No clustering

Conclusions

1. Identification and study of possible variables that can influence sensor readings:
    - ✓ Granulometry → variability of corn silage granulometry among (Penn State Particle separator/Retsch) and consequent definition of classes (fine, medium, coarse)
    - ✓ Specific weight
    - ✓ Other?
2. Calibrations for other silages (e.g. high moisture corn and grass silage) - on going

↓

Implementation of the sensor on the cutter-mixer wagon and test in dynamic conditions

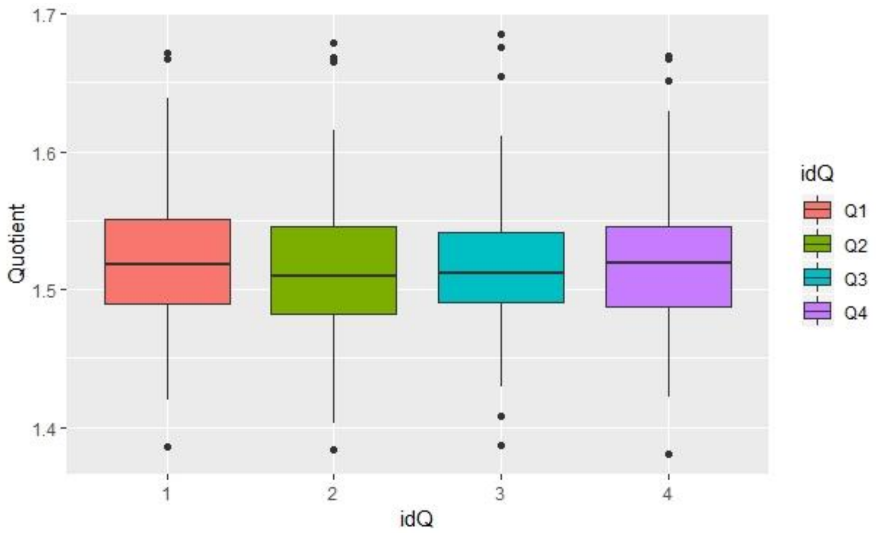
Acknowledgments

Project co-funded in the framework of POR FESR Lombardia 2014-2020 (Axis I, Objective 1.b.1)

Thank you for your attention

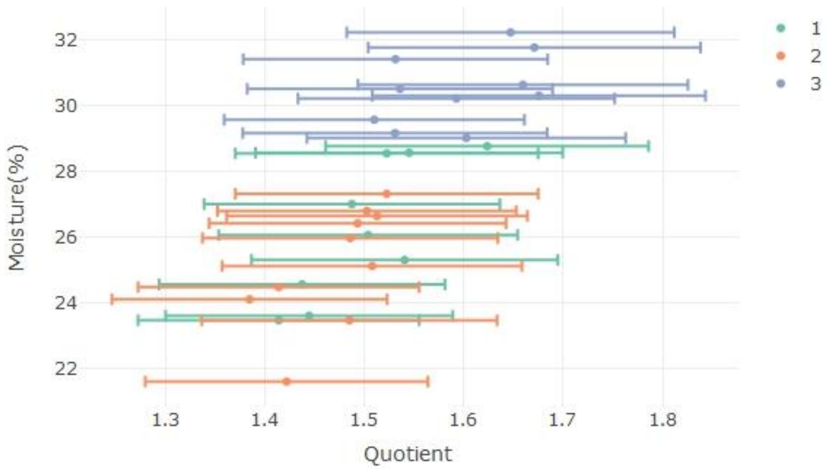
Results (5)

High Moisture Corn



As well as for corn silage, no statistical differences were evidenced for the mean of *Q1*, *Q2*, *Q3* and *Q4* across samples

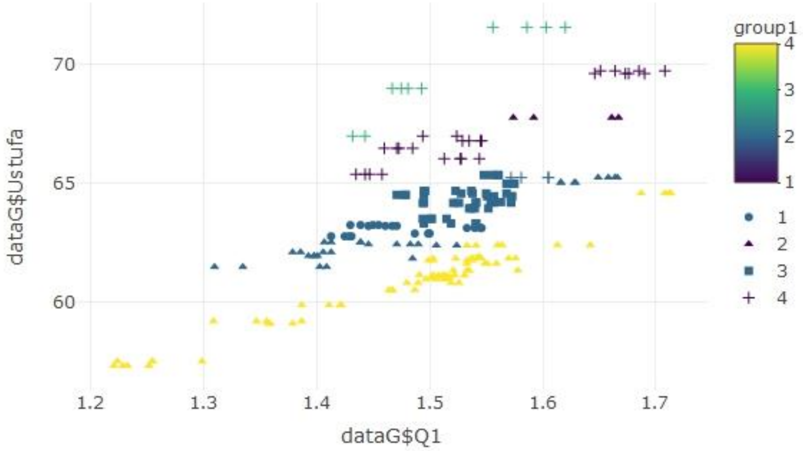
Volatility of *Quotient* for a given moisture



Bartlett's test evidenced NO significant differences

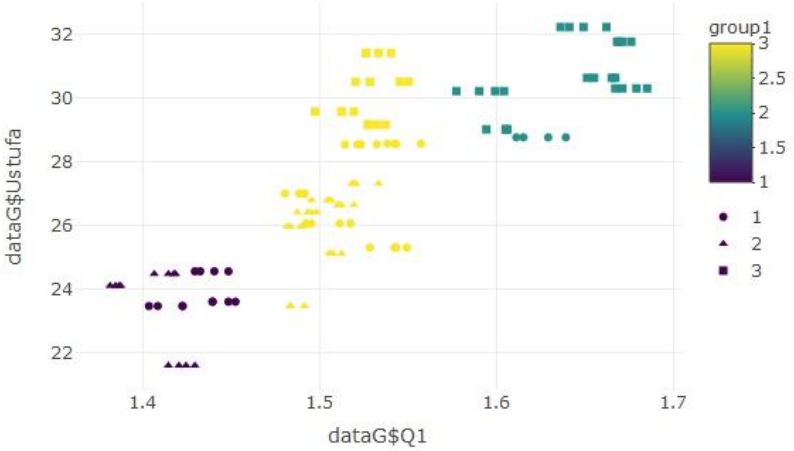
Results (6)

Corn silage



Evident clustering

High Moisture corn



NO clustering

Results (7)

20 kg corn silage as fed/cow (32% DM – 68% moisture) ⟶ 6,4 kg DM

SE of the calibration (linear model) = ±2,2

Moisture read by the sensor

(+)

68 + 2,2 = 70,2 (=29,8 DM)

Kg (as fed) = 6,4*100/29,8 = 21,5

21,5 – 20 = 1,5 → we are giving 1,5 kg as fed more then expected

Considering the real moisture (32% DM)it means:
1,5*32/100 = 0,48 kg DM more then expected

↓

6,4+0,48=6,88 kg DM / cow

Err% = 0,48/6,4*100 = 7,5

(-)

68 – 2,2 = 65,8 (=34,2 DM)

Kg (as fed) = 6,4*100/34,2 = 18,7

20 – 18,7 = 1,5 → we are giving 1,3 kg as fed less then expected

Considering the real moisture (32% DM)it means:
1,3*32/100 = 0,42 kg DM less then expected

↓

6,4-0,42= 5,98 kg DM / cow

Err% =0,42/6,4*100 = 6,6