UNIVERSITÀ DEGLI STUDI DI PADOVA

DAFNAE
Department of Agronomy Food Natural resources Animals and Environment

Ph.D. COURSE ANIMAL & FOOD SCIENCE
UNIVERSITY OF PADOVA

Potential of milk infrared spectroscopy to discriminate farm characteristics: the INTAQT project

Ramirez Mauricio M.A., D. Giannuzzi, L. Gallo, M. Berton, A. Cecchinato, E. Sturaro

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intaqt

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Introduction

- ✓ Parmigiano-Reggiano cheese, known for its unique flavor and traditional production practices, is a globally renowned Italian cheese
- ✓ The Fourier Transform Infrared (FTIR) Spectroscopy tool is normally used for milk quality assessment
- ✓ Additionally, it can be employed to determine the fingerprint of milk for authentication purposes, certifying the area of origin or the farming system in which the milk is produced

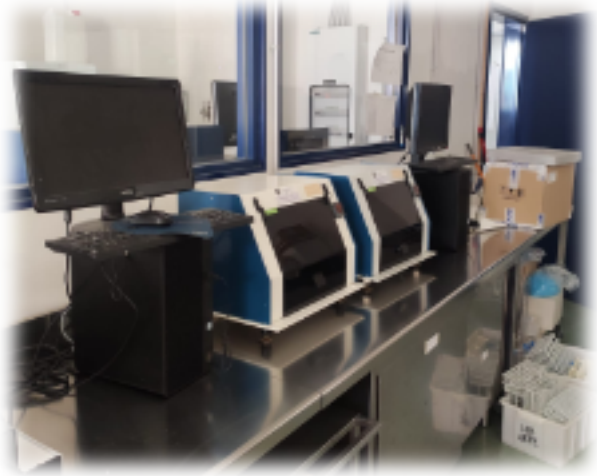
Introduction

Farm practices

Composition Analysis

The answer is in the milk

Certification



Aim

To evaluate the effectiveness of Fourier Transform Infrared (FTIR) Spectroscopy technology in bulk milk samples for discriminating dairy herds within Parmigiano Reggiano Consortium

Materials and methods

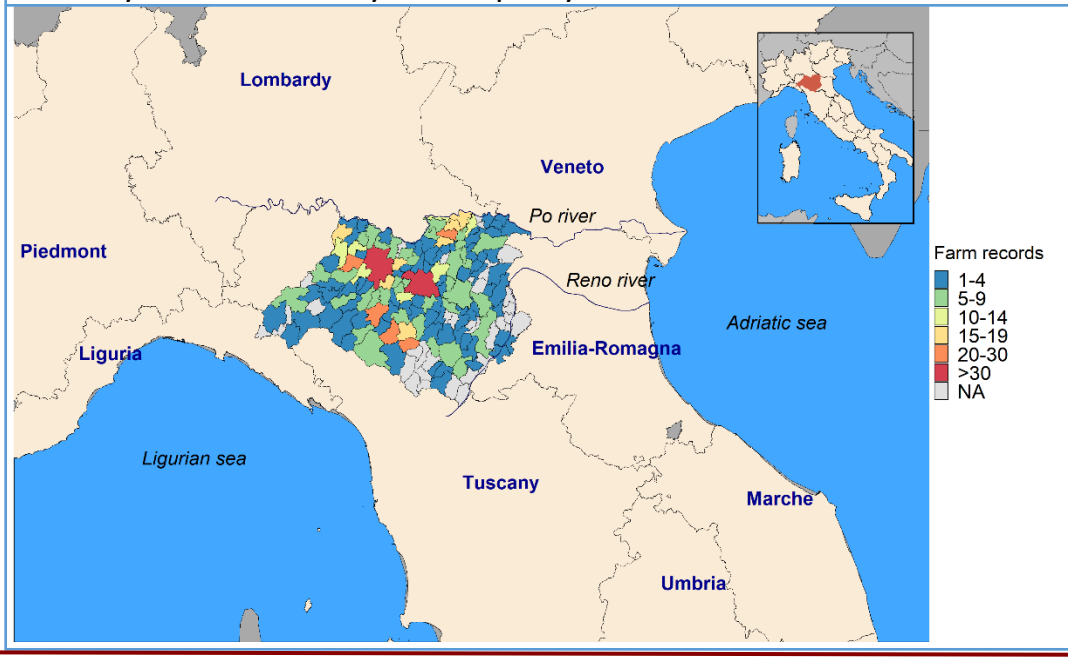
***FTIR Spectra acquisition*:**

- Obtained from the Breeders Association of Emilia Romagna Region lab (ARAER) located in Reggio Emilia, Italy (MilkoScan FT6000 milk analyzer - Foss A/S, Hillerød, Denmark)
- The spectrum covers from the short-wavelength infrared (SWIR) to the long-wavelength infrared (LWIR) regions with 1,060 spectral points from wavenumber 5,010 to 925 cm^{-1}
- From January to September 2022

***Spectra editing*:**

- Standardization (mean 0 and a SD 1)
- Mahalanobis distance (Mean ± 3 SD = outliers)
- Water regions were excluded
- Merged spectral samples with farm data, resulting in 4,631 samples from 936 farms, averaging 4.9 (±1.1) spectra per farm

Parmiggiano Reggiano area
Density farm records by municipality



Materials and methods

Farm data set (936 farms):

- Altitude: 3 classes (Plain, Hill, Mountain)
- Housing system: 2 classes (tie vs free stall)
- Feeding system: 2 classes (TMR vs traditional)
- Genetic group: 2 classes (Specialized: Holstein, Brown Swiss; not specialized: Reggiana, Modenese)
- Concentrate inclusion level in diet fed to lactating cows: 2 classes, lower (<40%) vs higher (>40%)
- Animal welfare scores (Italian CREnBA system); range: 0 (worst) – 100 (best). 3 classes, lower (<70), intermediate (71-80), higher (>80)

  A: management

  B: structure and equipment

  C: animal-based measures

Bulk milk, from January to October 2022:

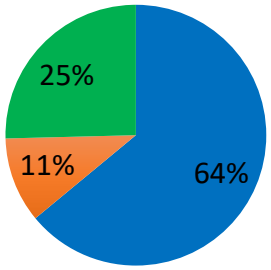
Season: 3 classes (Winter: January-February-March; Spring: April-May-June; Summer: July-August)

Merge

Materials and methods

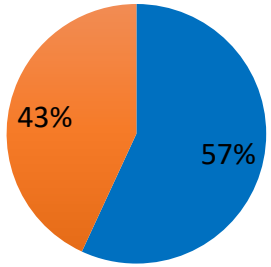
Altitude

Plain Hill Mountain



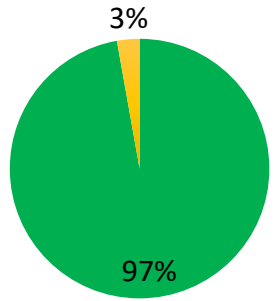
Feeding system

Traditional TMR



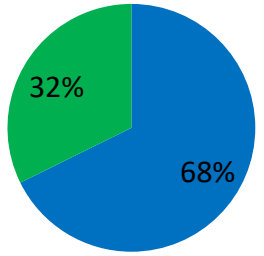
Genetic group

Specialized Non specialized



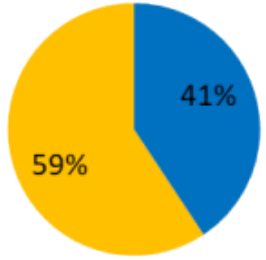
Housing system

Free stall Tie stall



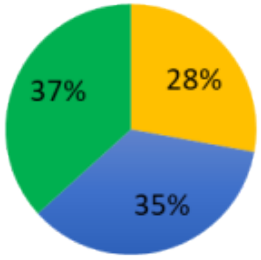
Concentrate

Lower Higher



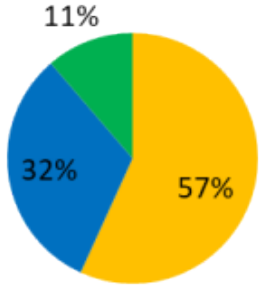
Area A: management

Lower Intermediate Higher



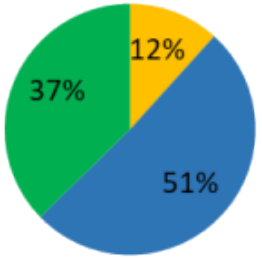
Area B: structure and equipment

Lower Intermediate Higher



Area C: animal-based measures

Lower Intermediate Higher



Materials and methods

Statistical analysis:

Linear Discriminant Analysis (LDA):

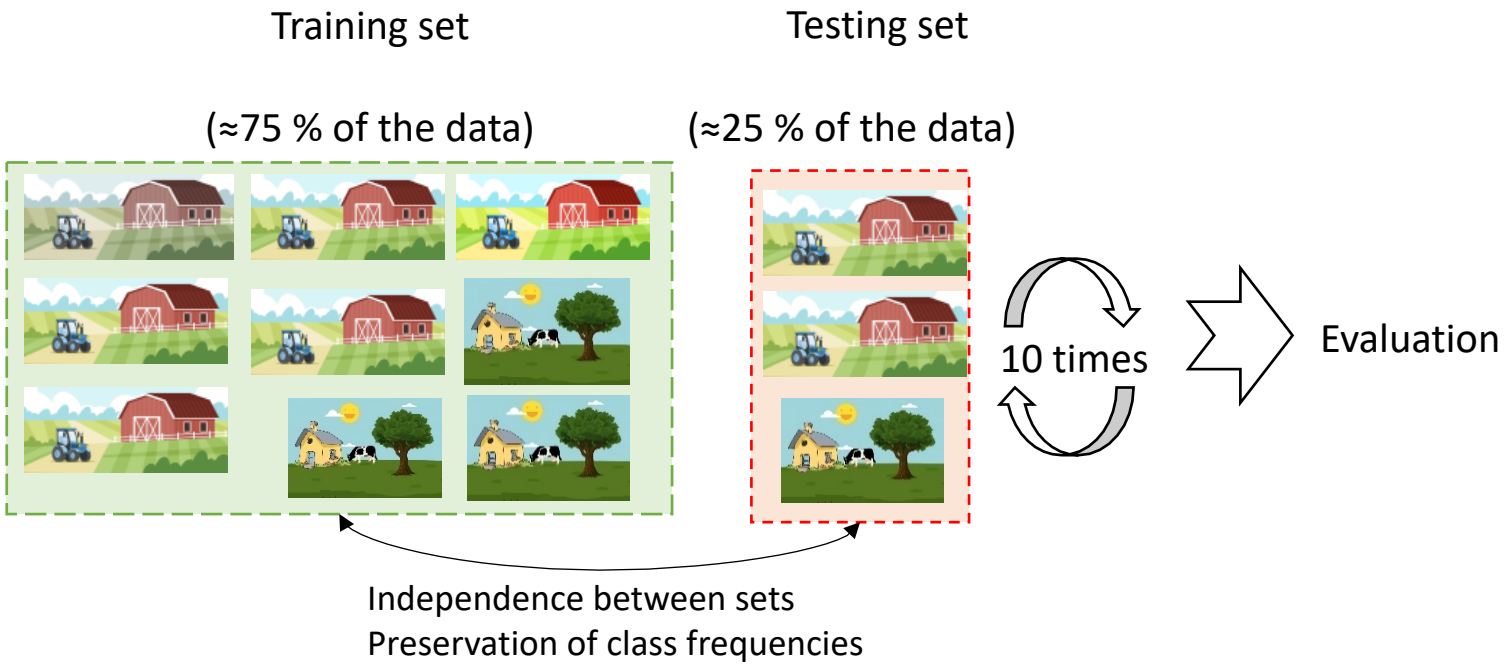
- Dependent variable: The farm characteristics
- Independent variables: The spectral wavelengths

*Caret (*Kuhn, 2016) and *Mass* R (Ripley, 2022) packages

Model performance evaluation:

Average and range (maximum and minimum) for:

- Percentage of correctly classified (**CC%**) observations for each class
- Receiver operating characteristic curve (**ROC-AUC**). Calculated using one-vs-rest approach



Results

Item[1]	Categories	Train		Test	
		CC (%)[2]	ROC-AUC	CC (%)	ROC-AUC
Environment					
Season	Winter	95 (95 – 96)	0.99 (0.99 - 0.99)	93 (90 – 95)	0.98 (0.98 – 0.99)
	Spring	94 (93 – 94)		90 (88 – 92)	
	Summer	97 (97 – 98)		95 (93 – 98)	
Altitude	Plain	90 (89 – 91)	0.79 (0.78 - 0.80)	83 (81 – 86)	0.60 (0.58 - 0.62)
	Hill	16 (14 – 19)		4 (2 – 5)	
	Mountain	44 (40 – 48)		30 (27 – 32)	
Structure					
Housing System	Free stall	93 (93 -94)	0.95 (0.95 - 0.96)	89 (85 – 92)	0.91 (0.88 - 0.93)
	Tie stall	82 (80 -84)		77 (69 – 84)	
Genetic group	Non specialized	96 (94 – 98)	1 (1 – 1)	82 (73 – 96)	0.98 (0.96 - 0.99)
	Specialized	100 (100 –100)		99 (99 – 100)	
Feeding practices					
Feeding System	Traditional	88 (88 – 89)	0.93 (0.93 - 0.94)	81 (79 – 82)	0.86 (0.84 - 0.88)
	TMR	84 (82 – 85)		76 (73 – 80)	
Concentrates, % as fed	Higher	90 (89 – 91)	0.84 (0.83 - 0.85)	84 (81 -87)	0.72 (0.67 - 0.75)
	Lower	56 (54- 58)		44 (34 – 50)	
Animal welfare Scores[3]					
Area A	Higher	64 (62 – 66)	0.73 (0.72 - 0.74)	48 (41 – 53)	0.55 (0.53 – 0.57)
	Intermediate	50 (47 – 54)		34 (31 – 37)	
	Lower	47 (45 – 50)		31 (28 – 34)	
Area B	Higher	18 (14 – 20)	0.75 (0.74 - 0.76)	6 (3 – 10)	0.55 (0.54 – 0.56)
	Intermediate	41 (36 – 48)		27 (22 – 31)	
	Lower	85 (83 – 86)		75 (71 – 82)	
Area C	Higher	50 (45 – 55)	0.75 (0.74 - 0.76)	36 (30 – 42)	0.56 (0.54 - 0.59)
	Intermediate	76 (73 – 79)		64 (59 – 71)	
	Lower	29 (25 – 31)		10 (8 – 14)	

Model performance:

Significant:

- ✓ High ROC-AUC
- ✓ Good levels of CC% in all the different classes

Intermediate:

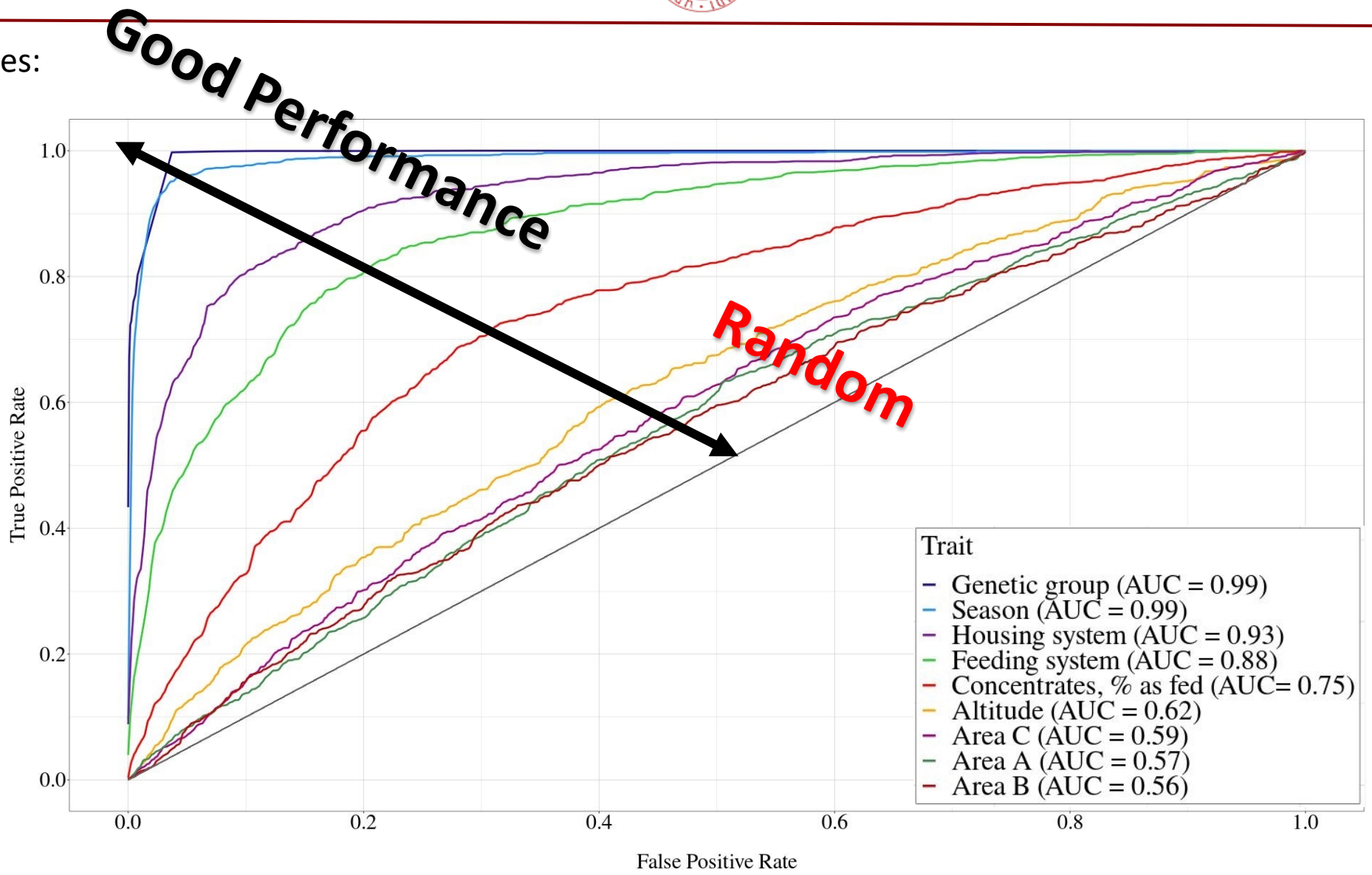
- ✓ Moderate ROC-AUC
- **X** Good classification for only one class

Low:

- **X** Small ROC-AUC
- **X** Poor classification for more than one class

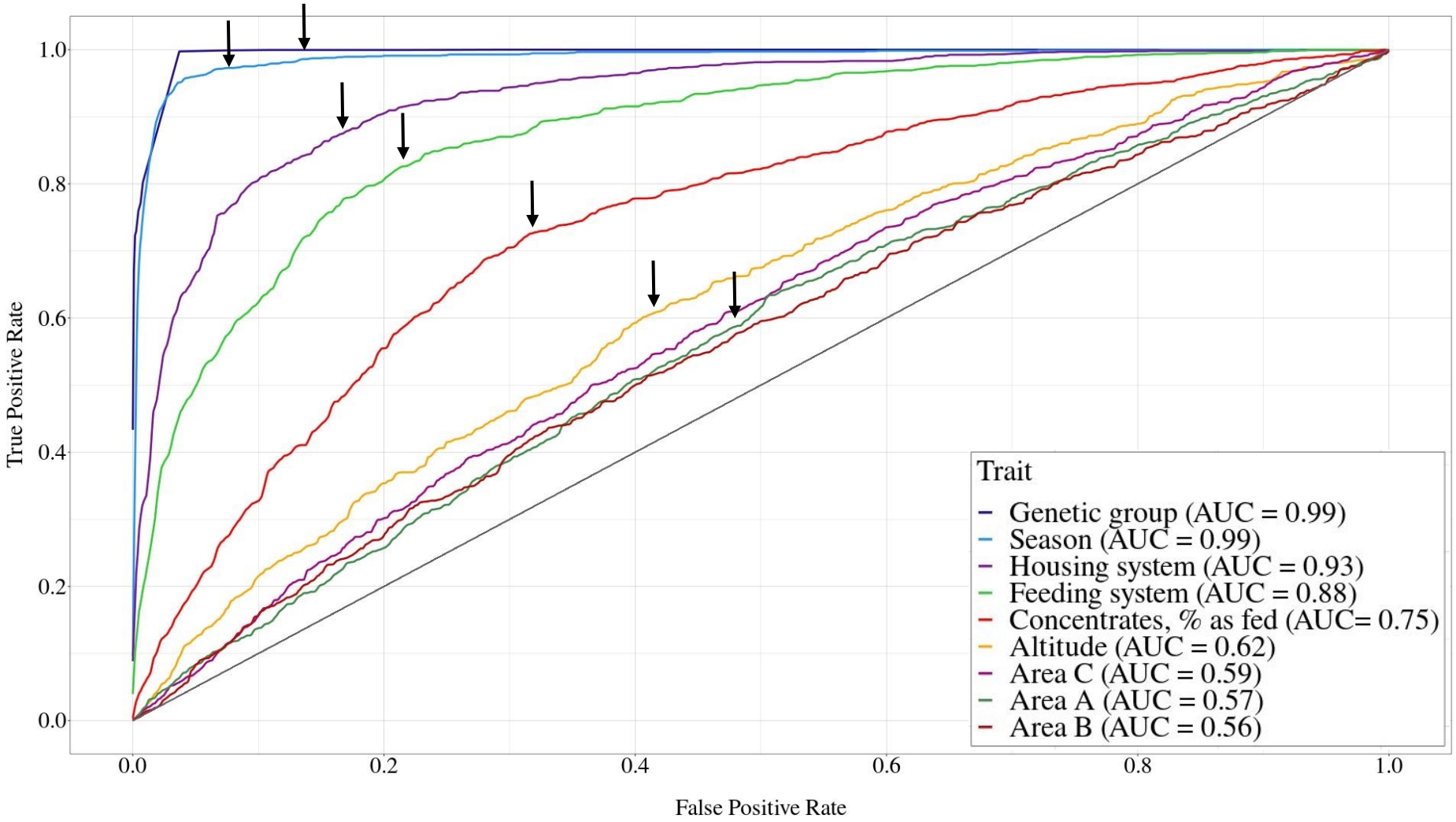
Results

ROC curves:



Results

ROC curves (best LDA cycle results):



Conclusion

1. The analysis of bulk milk using FTIR technology provides valuable information that could potentially be useful for distinguishing farm characteristics

2. This technology could function as a important tool to support informed decision-making and promote sustainable and efficient dairy farming practices

3. The use of infrared technology, together with the analysis of the chemical composition of milk, has the potential for the identification and authentication of agricultural practices.

Thank you!

dairyomics_unipd

dairyomics.com

Viale dell'Università
16, 35020, Legnaro
(PD), Italy

mvz.ramirezmauricio@gmail.com

HR EXCELLENCE IN RESEARCH

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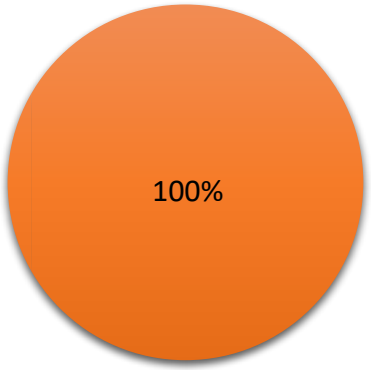
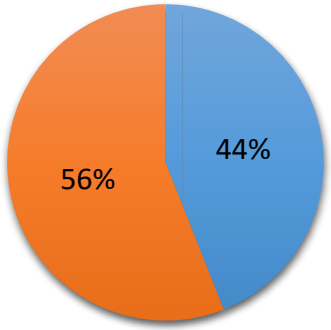
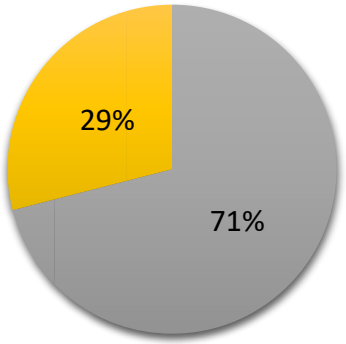
Genetic group *Feeding system* *Housing system* Concentrates, % as fed

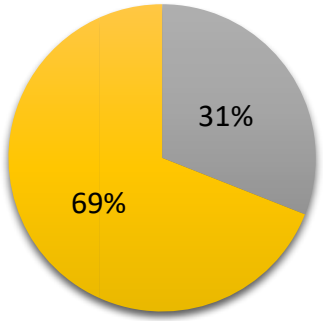
2.8% Non specialized

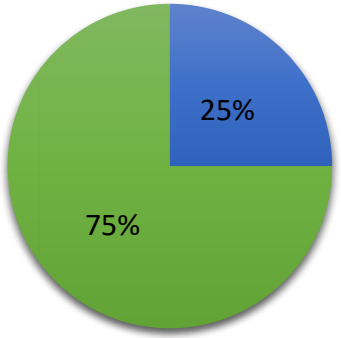
97.2% Specialized

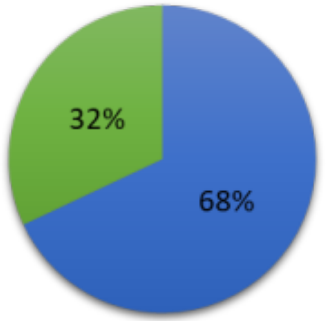












TMR Traditional Tie stall Free stall Higher Lower

Feeding system

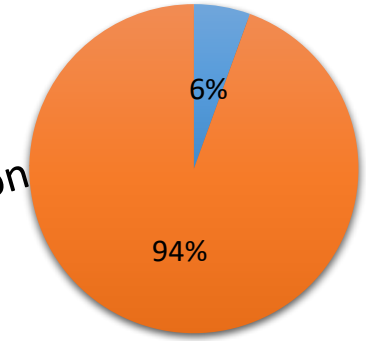
Genetic type

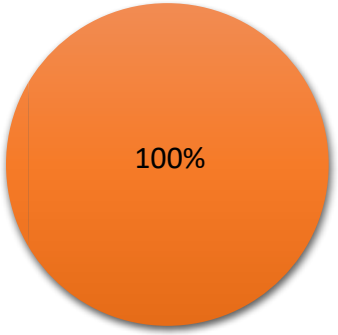
Housing system

Concentrates, % as fed

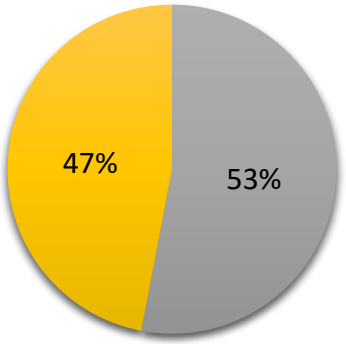
56.9 % Tradition

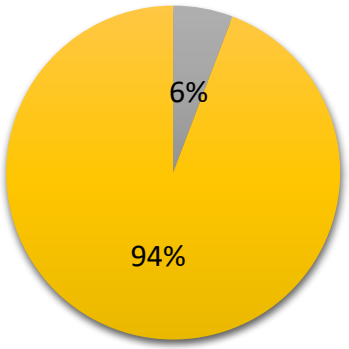
43.1% TMR



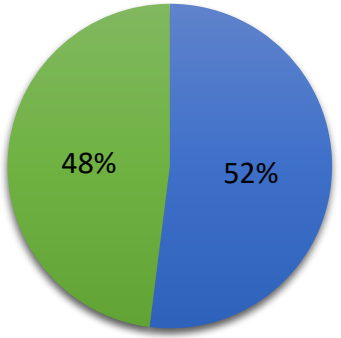


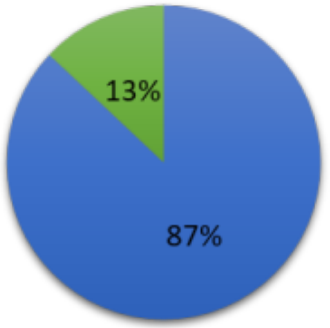
Non specialized Specialized



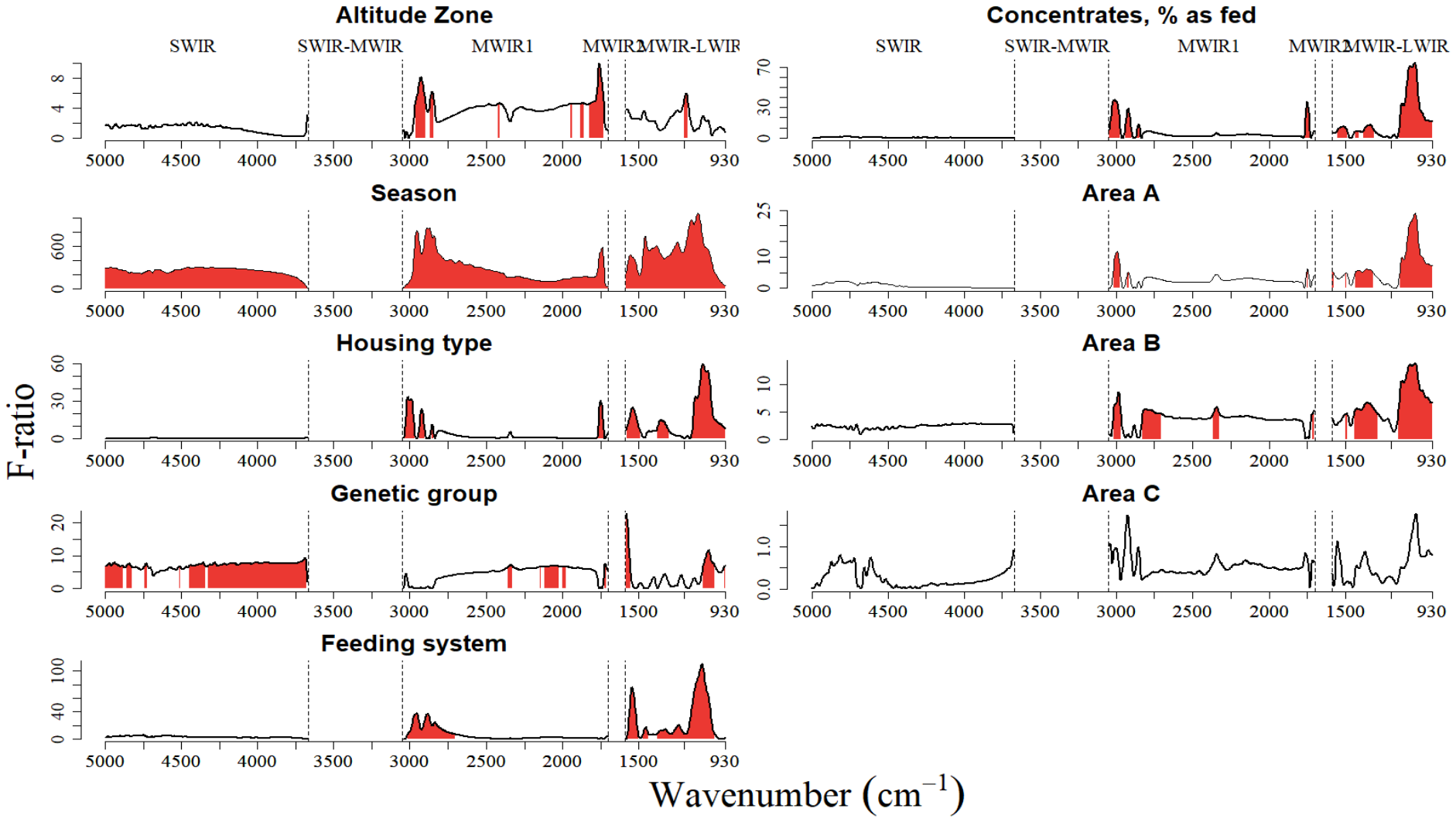


Tie stall Free stall





Higher Lower


Altitude Zone
Concentrates, % as fed
Season
Area A
Housing type
Area B
Genetic group
Area C
Feeding system
SWIR
SWIR-MWIR
MWIR1
MWIR2
MWIR-LWIR
F-ratio
Wavenumber (cm⁻¹)