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

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AIM

To evaluate the effectiveness of Fourier Transform Infrared (FTIR) Spectroscopy technology in bulk milk samples to discriminate the dairy herds of Parmigiano Reggiano Consortium.

INTRODUCTION

Parmigiano-Reggiano (PR) cheese, known for its unique flavor and traditional production practices, is a globally renowned Italian cheese. The FTIR tool is normally used for milk quality assessment [1]. 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 [2-3].

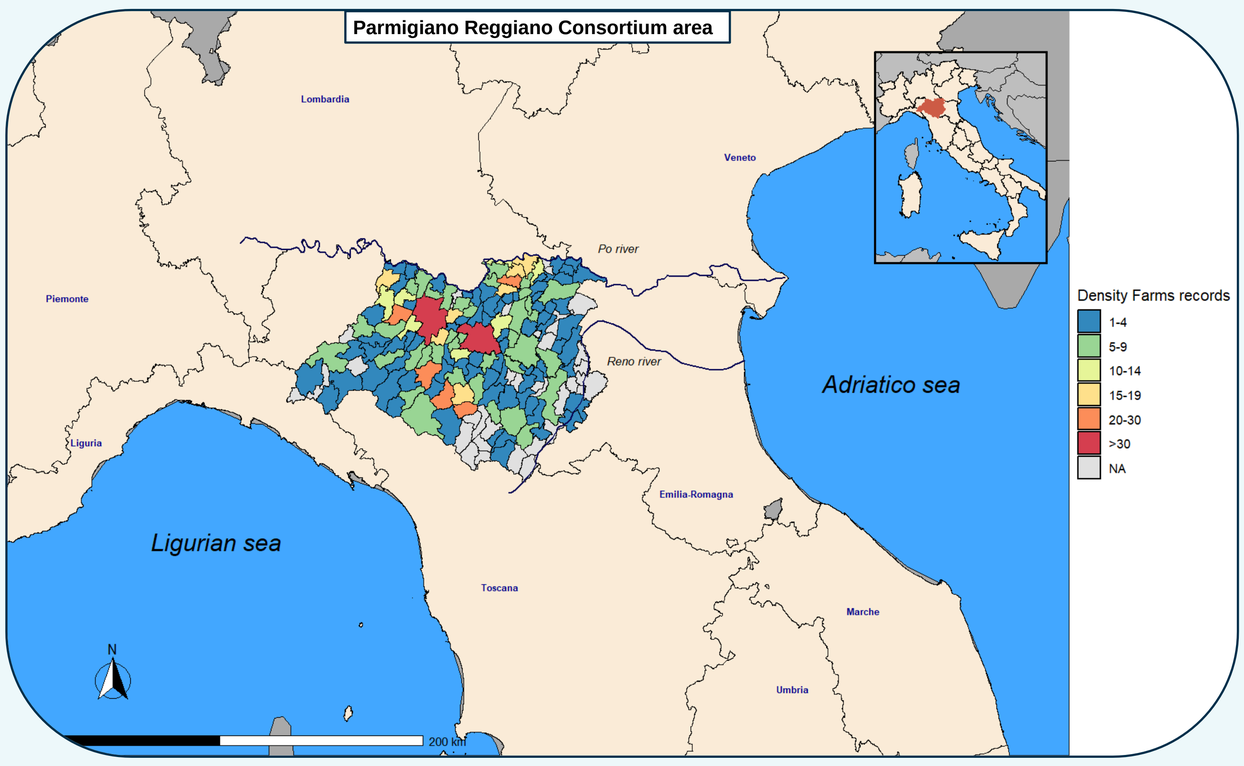
FIELD DATA

- Farm parameters:

- Altitude zone (AZ: mountain, hill, plain)
- Housing system (HS: free or fixed)
- Breed (BR: specialized or non-specialized for dairy)
- Usage of total mixed rations (TMR: Yes or No)
- Proportion of concentrate (CONC: high or low)
- Season (SE: winter, spring, and summer)
- Animal welfare-related features (A - management, B - structure equipment, C - animal measures) evaluated using a CReNBA scoring scale (0-100) categorized as high, medium, or low.

- FTIR Spectral Data:

The FTIR spectral data was obtained from the official laboratory of Emilia Romagna Region (ARAER, Reggio Emilia, Italy) between January and August 2022. The dataset comprised 936 farms, and on average, each farm had 4.9 (±1.1) sample spectra available.



STATISTICAL ANALYSIS

To handle the large number of variables (spectra wavelengths), Linear Discriminant Analysis (LDA) was employed in this study. LDA aims to find a linear combination of variables that optimally separates classes and is less affected by class imbalance than other procedures [4]. The dataset was divided into calibration (60%) and validation (40%) sets to ensure independence. LDA was trained using 10-fold cross-validation, with the farm parameter as the dependent variable and the spectral wavelengths as the independent variables. The model's performance was evaluated using the Area Under the Curve (AUC) metric and the Correct Classification (%).

RESULTS

The results revealed strong discriminant power for the BR, SE, HS, and TMR parameters, with high ROC-AUC values of 0.99, 0.98, 0.90, and 0.87, respectively. The CONC parameter demonstrated moderate performance (0.73), while the remaining parameters (Class A, B, C, and AZ) had poorer performance (Table 1).

Farms that adopt TMR exhibit characteristics such as specialized dairy breeds, a free housing system, and higher usage of feed concentrates. In contrast, non-specialized breeds are commonly associated with a fixed housing system, the absence of TMR, and lower amounts of feed concentrates. These findings highlight the importance of considering the combined impact of multiple parameters.

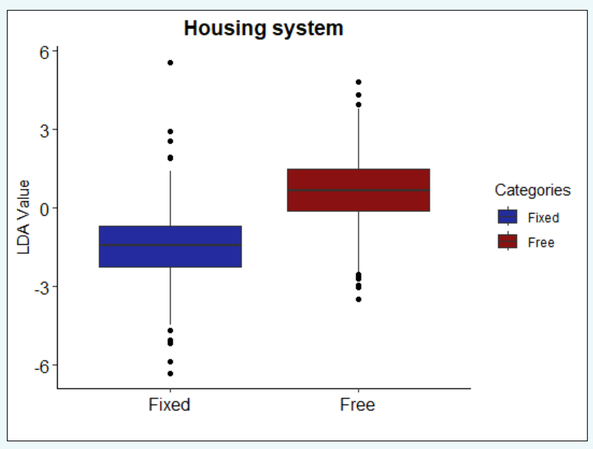
CONCLUSION

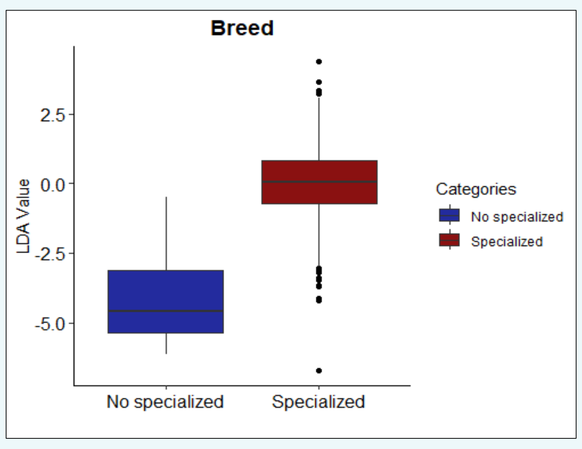
The analysis of bulk milk using FTIR technology provides valuable information for differentiating farm characteristics, such as the breed reared, housing practices, season of milk sampling, and the use of TMR. This technology serves as a valuable tool to support informed decision-making and promote sustainable and efficient dairy farming practices. Moreover, the utilization of infrared technology and chemical composition analysis enables the identification and authentication of farm practices, ensuring the integrity and authenticity of agricultural processes.

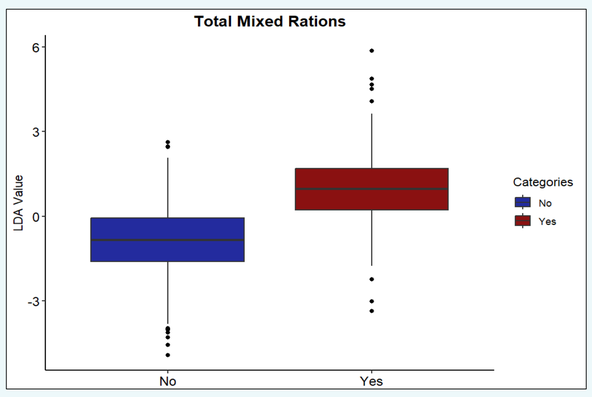
Table 1. Performance results of the LDA classification model

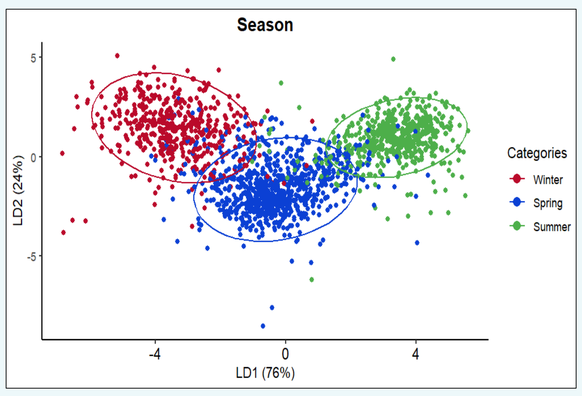
		Test				Train		
Parameter	Categories	CC (%)	IC 95% CC	ROC-AUC		CC (%)	IC 95% CC	ROC-AUC
HS	Free	88.60	87-90	0.90		92.84	92-94	0.96
	Fixed	73.62	70-77			82.64	80-85	
SE	Winter	91.81	89-94	0.98		95.66	94-97	0.99
	Spring	89.47	87-92			93.60	92-95	
	Summer	93.84	92-96			98.42	98-99	
Classe A	High	47.12	43-51	0.55		64.92	62-68	0.76
	Medium	31.48	28-35			54.41	51-58	
	Low	37.41	33-42			53.89	51-57	
Classe B	High	7.37	4 - 11	0.53		23.28	18-28	0.78
	Medium	25.33	22-29			46.45	43-50	
	Low	71.52	69-74			84.00	82-86	
Classe C	High	33.20	30-37	0.54		51.30	48-54	0.79
	Medium	61.35	58-65			79.62	78-82	
	Low	10.00	6-14			37.35	32-42	
AZ	Coline	6.56	3-10	0.59		28.15	23-33	0.82
	Mountain	37.66	33-42			49.86	46-53	
	Plain	73.29	71-76			88.79	87-90	
TMR	No	84.25	82-87	0.87		86.23	84-88	0.93
	Yes	74.88	72-78			85.59	83-88	
BR	No specialized	70.21	57-84	0.99		97.33	94-100	1.00
	Specialized	99.45	99-100			99.85	100-100	
CONC	High	87.68	86-90	0.73		91.07	90-92	0.83
	Low	40.67	37-44			50.82	47-54	

LDA RESULTS VALUES:









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