Laser backscattering as a non-destructive method for monitoring cheese ripening

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Introduction

Cheese ripening is a complex process that affects texture, flavor, and overall quality. Traditional assessment methods are often destructive and time-consuming. This study explores laser backscatter imaging (LBI) as a non-destructive, real-time technique to monitor ripening in Trappist cheese. By analyzing light scattering at multiple wavelengths, we tracked changes in optical properties over time and correlated them with texture profile analysis. Results show LBI's potential as an effective tool for predicting ripeness using multivariate models.

LBI parameters	Wavelength (nm)						
	532	635	650	780	808	850	1064
A2575	***	***	***	***	**	ns	ns
A50	***	***	***	***	ns	ns	*
D25	***	***	***	***	**	ns	ns
D50	***	***	***	***	ns	ns	*
D75	***	**	***	**	ns	ns	ns

*Table 1. ANOVA results for LBI parameters across different ripening stages at 7 wavelengths (ns: not significant; *: $p < 0.05$; **: $p < 0.01$; ***: $p < 0.001$)*

Figure 1. Laser backscattering images and A2575 value of cheese during 6 weeks at 532 nm

Materials and Methods

Sample Preparation:
Trappist cheese (45% fat) was purchased locally in Budapest, Hungary. It was cut into 12 slices (75 × 75 × 15 mm), wrapped in polyethylene, and stored at 7.0 ± 1.0 °C. Measurements were taken weekly over six weeks.

Testing Methods:
Each slice was tested using LBI, texture profile analysis (TPA), and cutting test (CT).

- TPA: Conducted at room temperature using a flat probe with standard two-cycle compression to 5 mm depth.
- CT: Used a 0.3 mm wire cutter to evaluate cutting force and work of penetration.
- Repetitions: LBI (6×), TPA & CT(3× per timepoint).

LBI Setup:
Laser sources (532–1064 nm, 1 mm beam) and a 12-bit camera (0.113 mm/pixel) captured backscattered light. Samples were centrally positioned on a custom holder.

Data Analysis:
Results were processed using R (v4.5.0) and RStudio (2024.12.1) with multivariate analysis to track ripening-related changes.

Results

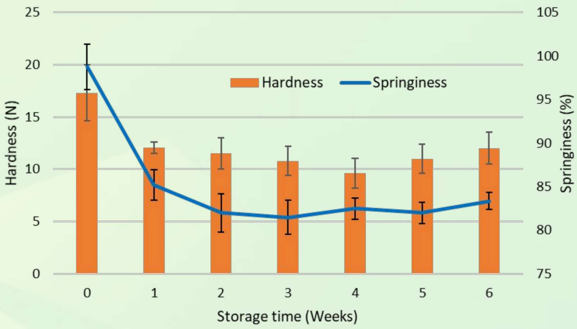

Figure 2. TPA hardness and springiness of cheese during 6 weeks

Hardness and springiness decreased in first 4 weeks, then slightly increased in weeks 5–6, suggesting initial softening followed by structural changes.

Table 2. Classification performance of cheeses at different ripening stages

Classification algorithm	Wavelength (nm)			
	532	635	650	780
Linear Déciminant Analysis (LDA)	59%	17%	30%	26%
k-Nearest Neighbours (kNN)	52%	38%	7%	11%
Support Vector Machine (SVM)	59%	25%	26%	7%
Random Forest (RF)	**78%**	33%	19%	33%

Table 3. Predicted results with different algorithms at different ripening stages (blue: TPA, green: CT)

	RF mtry = 1, ntree = 600		kNN k = 3		SVM sigma = 0.0625, cost = 1	
	R^2	RMSE	R^2	RMSE	R^2	RMSE
Hardness	**0.933**	**0.58**	**0.891**	**0.73**	0.645	1.33
Adhesiveness	0.333	0.07	0.376	0.07	0.119	0.09
Resilience	0.321	1.94	0.231	2.00	0.017	2.43
Cohesion	0.145	0.01	0.109	0.01	0.110	0.01
Springiness	**0.963**	**1.07**	**0.883**	**1.85**	**0.968**	**0.99**
Gumminess	0.796	0.52	0.677	0.73	0.681	0.63
Chewiness	0.384	0.51	0.491	0.76	0.257	0.57
Gradient	0.735	0.01	0.534	0.01	0.672	0.01
Maximum force	0.399	0.34	0.288	0.45	0.349	0.44
Total Work	0.645	11.06	0.663	11.65	0.451	11.31

Conclusion

This study demonstrates the viability of using LBI combined with some models for non-destructive assessment of cheese ripening. The RF model emerged as the most effective among the tested algorithms, achieving notable classification accuracy and reliable prediction of key TPA parameters. These results underscore the potential of LBI, particularly when paired with RF models, as a practical solution for real-time, non-invasive monitoring and quality control in cheese production. The integration of such technologies could enhance process optimization and consistency in cheese texture during ripening.

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