

From Mill to Market: NIRLAB's NIR Technology for Quality Control in Olive Pomace Processing

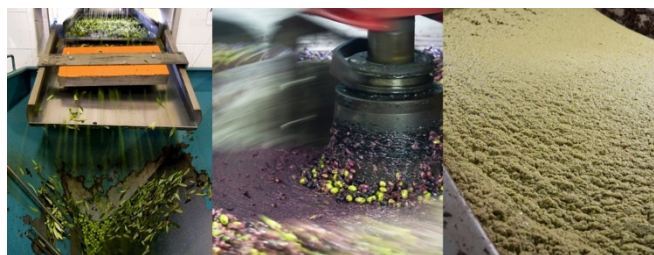
Near Infrared Spectroscopy (NIR) enables the rapid, non-destructive quantification of residual oil and moisture in olive pomace and dried olive pomace - directly at the processing site, in seconds.

Abstract: The olive pomace sector operates at the intersection of process efficiency and commercial accuracy: the residual oil and moisture content of pomace determine purchase prices, drying costs, and extraction yields - yet these critical parameters are still routinely measured by laboratory methods that return results hours or days after the moment of decision. NIRLAB's handheld near-infrared (NIR) solution enables rapid, non-destructive quantification of residual oil content and moisture in both olive pomace and dried olive pomace (olive pit), directly at the processing site. Validated on industrial sample sets of up to 1,084 specimens, NIRLAB's calibration models achieve R^2 values of up to 0.98, empowering olive/pomace mills and olive oil producers to make real-time pricing decisions, optimize process machinery, and monitor drying efficiency with data-driven confidence.

1. Introduction

Olive pomace - the semi-solid paste remaining after the crushing and centrifugation of olives at the olive mill - is one of the most economically significant by-products in olive oil production. While the primary extraction process recovers the majority of the fruit's oil, a meaningful proportion remains trapped in the pomace: typically, between 1.5% and 9% by weight, depending on the efficiency of the milling process, the olive variety, and seasonal conditions.

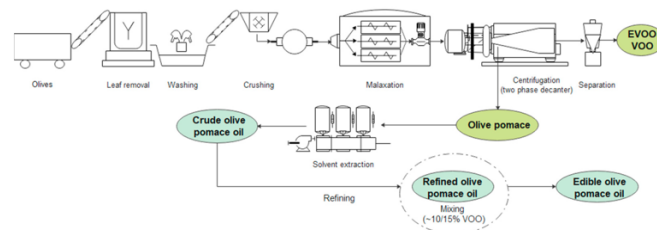
This residual material is sold to specialist olive pomace mills, which process it further — principally through thermal drying followed by solvent extraction — to recover the remaining oil as pomace oil and to produce dried olive pit as a biomass by-product. The economic value of the pomace at every stage of this chain is determined almost entirely by two analytical parameters: residual oil content and moisture.



Despite this, across much of the sector, these measurements are still obtained through laboratory methods that require hours of analysis time, incur per-sample costs, and return results long after the relevant processing or trading decision has been made. The consequence is a sector that routinely prices, buys, and processes material on estimates rather than confirmed data - a structural inefficiency with direct financial implications for every participant in the chain.

2. Challenges with Current Analytical Approaches

Conventional oil determination in olive pomace relies on Soxhlet solvent extraction - a method in which the sample is dried and then subjected to repeated solvent washing cycles over several hours to extract all residual lipids. Moisture is determined gravimetrically by oven drying at controlled temperature. Both methods require laboratory infrastructure, trained personnel, and significant time from sample collection to result - typically four to twenty-four hours under normal operating conditions.



During the milling process. At the olive mill, residual oil in the pomace exiting the decanter is a direct measure of extraction efficiency. Malaxation time and temperature, water addition rates, and centrifugation parameters all influence how much oil is retained in the pomace rather than recovered in the final product. Without real-time feedback on pomace composition, these parameters are tuned by operator experience rather than analytical data, limiting the ability to minimize losses systematically.

At the intake point. When a pomace mill receives deliveries from olive oil producers, the purchase price should reflect the oil and moisture composition of each batch. Without rapid on-site measurement, the price is set either by historical estimate, by intermittent laboratory sampling, or by

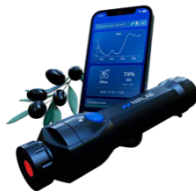
negotiation - all of which introduce systematic inaccuracy. Producers of high-quality, high-oil pomace are systematically undercompensated; buyers accepting low-quality batches at average prices absorb a hidden cost.

At the drying stage. The pomace mill's dryer must reduce moisture from the 44-87% range typical of incoming pomace to a target of approximately 6-10% for effective solvent extraction and optimal calorific value of the dried pit. Over-drying wastes energy; under-drying reduces extraction efficiency. Without frequent moisture measurement at the dryer exit, operators cannot close the control loop around one of the most energy-intensive steps in the process.

For outgoing product certification. The dried olive pomace and olive pit sold downstream must meet moisture and oil specifications. Delayed or infrequent measurement creates compliance uncertainty and limits the documentation available for buyer verification or export certification.

3. NIRLAB's Technological Solution

NIRLAB's solution integrates a compact handheld NIR spectrometer with a mobile application (iOS and Android) and a cloud-connected web portal for analytics and reporting. No sample preparation is required and no specialist training: the operator places the device against the pomace sample, initiates the scan, and receives quantitative results directly on the mobile screen within just 5 seconds.



This handheld solution acquires a near-infrared diffuse reflectance spectrum from the sample surface in the 950–1650 nm wavelength range. Molecular bonds characteristic of oils (C–H stretching) and water (O–H stretching) absorb NIR energy at predictable wavelengths, generating a spectral fingerprint that is wirelessly transmitted to NIRLAB's mobile application and processed against pre-validated machine learning calibration models hosted in NIRLAB's encrypted cloud infrastructure.

The same hardware serves both measurement points in the pomace value chain — olive pomace at the olive mill or pomace mill intake, and dried olive pomace at the dryer exit - with matrix-specific calibration models deployed automatically through the cloud platform. No additional capital investment is required to cover both stages.

4. Calibration Performance and Validation

NIRLAB has developed dedicated calibration models for both olive pomace and dried olive pomace (olive pit), validated on industrial sample sets covering the full practical

operating range of each parameter. The charts below show predicted versus reference values for the two key parameters in incoming olive pomace.

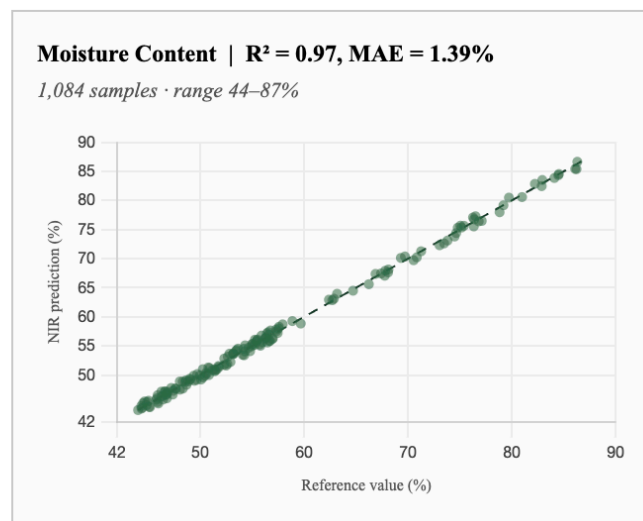
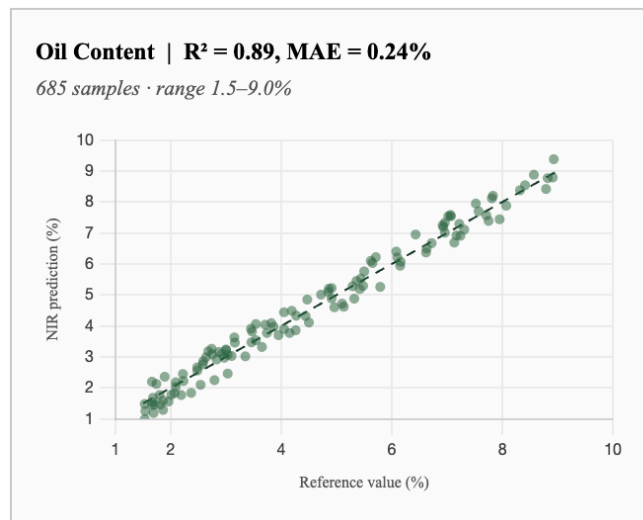


Figure 1. NIR Prediction vs. Reference Value — Incoming Olive Pomace
Dashed line = ideal 1:1 prediction. Shaded band = \pm RMSE. Points represent individual sample predictions against ISO/gravimetric reference values. Both models trained and validated on industrially sourced olive pomace samples.

Parameter	N samples	Range	MAE	RMSE	R ²
Oil	105	0.3-9.2%	0.36%	0.51%	0.98
Moisture	412	4-14.5%	0.30%	0.46%	0.96

Table 1. Calibration Performance Summary-Dried Olive Pomace (Olive Pit)
R² = coefficient of determination (1.00 = perfect prediction). MAE = mean absolute error. RMSE = root mean square error. Dataset expansion is recommended for the oil model (105 samples) to improve coverage of the 1-4% mid-range.

The olive pomace moisture model achieves an R² of 0.97 across a wide operating range of 44-87%, reflecting the

practical variability of pomace at the olive mills on different configurations and seasons. The olive pomace oil model achieves $R^2=0.89$ across 1.5-9.0%, with good linearity across the range - further improvement is expected as the dataset is expanded toward 1,000+ samples. The dried olive pomace models demonstrate excellent performance, particularly for oil content ($R^2=0.98$), enabling reliable monitoring of the solvent extraction process output.

5. Operational Use Cases

Olive mill process optimization. Residual oil in the pomace is the inverse of extraction efficiency. Continuous NIR measurement of pomace exiting the decanter allows mill managers to correlate pomace oil content with decanter speed, malaxation time and temperature, and water addition - and to adjust these parameters in response to actual measured composition rather than historical averages. Even a reduction of 0.5 percentage points in pomace oil content across a season represents a substantial recovery of marketable olive oil output.

Pomace purchase pricing. At the intake of the pomace mill, NIRLAB enables both buyer and seller to confirm the oil and moisture composition of each delivered batch on arrival. Results are displayed on the operator's mobile screen with uncertainty ranges, providing an objective, shared data point for price negotiation. This eliminates the pricing delays and disputes that arise when laboratory confirmation arrives after trucks have already departed and allows high-quality batches to be recognized and compensated accordingly.

Drying process control. At the pomace mill, the drying stage is the most energy-intensive step. Targeting a precise moisture range - typically 6-10% for effective solvent extraction and maximum calorific value of the dried pit - requires accurate, frequent moisture measurement at the dryer exit. NIRLAB converts the dryer from an open-loop operation governed by time and temperature settings into a closed-loop, measurement-driven process, reducing both over-drying losses and quality variability in the output.

Dried olive pomace/Olive pit. Each lot of dried olive pomace or olive pit sold downstream can be scanned and documented at the point of dispatch. NIRLAB's cloud platform stores a complete, timestamped record of every measurement - operator, device, location, raw spectrum, and quantitative result - providing the traceability documentation increasingly required by downstream buyers, particularly in export markets.

6. Quantified Value for Processors

Process yield improvement. For an olive mill processing 200 tones of olives per day at a 10% pomace yield, a one percentage-point reduction in residual pomace oil - achievable through real-time decanter feedback - recovers approximately 200 kg of additional olive oil per day. Across a harvest season of 60-90 operating days, this represents a material improvement in total oil output from the same fruit input.

Laboratory cost reduction. A pomace mill conducting routine oil and moisture analysis on incoming and dried material may send several hundred samples per season for external Soxhlet and gravimetric analysis. NIRLAB's unlimited scan model enables operators to conduct continuous, real-time monitoring at negligible per-scan cost, redirecting laboratory expenditure toward confirmatory analysis of flagged batches rather than routine process monitoring.

Decision speed and throughput. Replacing laboratory turnaround times of 4-24 hours with on-site results in seconds fundamentally changes the operational cadence of pricing and process decisions. Batches that previously required a hold period pending laboratory confirmation can be assessed and routed immediately, improving throughput and reducing working capital tied up in unconfirmed inventory.

7. Conclusion

The olive pomace sector operates on two numbers - oil content and moisture - and yet across much of the industry, these numbers are still obtained too slowly and too infrequently to support the decisions that depend on them. NIRLAB's handheld NIR solution removes this constraint. Validated on large, industrially representative sample sets and designed for deployment by non-specialist operators in active processing environments, NIRLAB brings accurate, real-time measurement to the intake point, the process line, and the dryer exit. With R^2 values of up to 0.98 and mean absolute errors below 0.4% for oil content, the calibration models for olive pomace and dried olive pomace deliver the accuracy required for both commercial transactions and operational process control. For mills and pomace processors operating across a full harvest season, the ability to measure every batch in real time is not a marginal improvement - it is a fundamental change in how the value embedded in olive pomace is identified, captured, and defended.

At NIRLAB, the goal is to make advanced analytical technology practical and accessible - something operators can use every day to make better decisions, run more efficient processes, and ensure that the value in every ton of pomace is fully accounted for. The olive pomace sector deserves tools built for its pace and scale. That is what we deliver.