The FTIR-ATR Spectroscopy as a Biosensing Strategy for Thermal Effects in Permissibility Verification of Lard-Adulterated Palm Oil

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Abstract

Ensuring authenticity of edible oils is vital for consumer trust, regulatory compliance and permissibility assurance, particularly for Muslim consumers. This study introduces a spectral biosensing strategy using Fourier transform infrared spectroscopy coupled with attenuated total reflectance (FTIR-ATR) and chemometric modelling to detect lard adulteration in palm oil (PO) under thermal stress. PO samples spiked with 1%–50% v/v lard were heated from 25°C to 200°C for 30 min, simulating industrial and culinary conditions. FTIR-ATR spectra showed distinct shifts in carbonyl and fingerprint regions due to lard incorporation and heat-induced lipid degradation. Discriminant analysis (DA) achieved 100% classification accuracy across the full spectrum (4000–650 cm^{-1}), demonstrating strong discriminatory power. Partial least squares–discriminant analysis (PLS-

DA) identified the fingerprint region (1000–650 cm^{-1}) as most diagnostic, yielding robust performance with R^2Y = 0.895, R^2X = 1.000, Q^2 = 0.893 and 100% correct classification in both training and validation datasets. Principal component analysis (PCA) revealed clear clustering of pure and adulterated samples, even under severe thermal conditions. Moreover, using the optimised FTIR-ATR/PLS model, the lard adulteration in thermally treated PO could be reliably detected at levels as low as 1% v/v with LOD and LOQ ranges of 0.01%–1.14% and 0.02%–3.34% v/v, respectively. These findings position FTIR-ATR with multivariate chemometrics as a rapid, nondestructive and thermally resilient platform for lard detection in PO. The approach extends to broader food quality and safety monitoring in real-world processing scenarios. © 2026 John Wiley & Sons Ltd.

Author keywords

chemometric analysis; FTIR-ATR spectroscopy; lard adulteration; permissibility authentication; spectral biosensing

Indexed keywords

Engineering controlled terms

Discriminant analysis; Food safety; Least squares approximations; Nondestructive examination; Palmprint recognition; Principal component analysis; Regulatory compliance; Spectrum analysis; Supersaturation; Thermal processing (foods)

Engineering uncontrolled terms

Attenuated total reflectance; Attenuated total reflectance spectroscopy; Biosensing; Chemometric analysis; Fourier transform infrared; Fourier transform infrared spectroscopy coupled with attenuated total reflectance spectroscopy; Lard adulteration; Permissibility authentication; Spectral biosensing; Transform infrared spectroscopy

Engineering main heading

Fourier transform infrared spectroscopy; Palm oil

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