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Quantitative and Qualitative Halal Authentication Analysis of Malaysian Animal-Based Fermented Food Products Using HPLC-DAD, FTIR-ATR Spectroscopy and Chemometric Approaches

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Abstract	Halal status verification of animal-based fermented food products is critical for protecting consumer health and ensuring regulatory compliance in Muslim-majority markets. This study presents a comprehensive evaluation of qualitative and quantitative aspects of Malaysian fermented food products using integrated chemical, spectroscopic, microbiological, and chemometric approaches. Histamine quantification by HPLC-DAD revealed concentrations ranging from 44.2-570.3 mg/kg, with 47% of samples exceeding the Codex Alimentarius limit of 100 mg/kg, indicating potential chemical safety concerns. FTIR-ATR spectral profiling distinguished fermentation-induced lipid modifications and differentiated halal products from non-halal reference lard samples, revealing distinct molecular fingerprints across animal, plant, and fermented food matrices. Chemometric analysis using principal component analysis (PCA) and orthogonal partial least squaresdiscriminant analysis (OPLS-DA) in the wavenumber fingerprint region (1500-650 cm-1) achieved clear sample discrimination and confirmed the absence of non-halal lipid adulteration. Microbiological assessments revealed total plate counts within acceptable regulatory limits, no detection of Escherichia coli, and controlled levels of Staphylococcus aureus, indicating satisfactory hygienic quality. These amalgamated findings establish a robust, multi-modal framework for halal authentication and quality control of fermented food products with direct implications for strengthening regulatory oversight, preventing food adulteration, and ensuring consumer protection in halal-certified food systems.	
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