

## Documents

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**Halal detection technologies: analytical method approaches, validation and verification, and multivariate data analysis for halal authentication**

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**Abstract**

Halal detection technologies (HDTs) involve the latest tools to investigate products' halal status, including food, cosmetics, and pharmaceuticals. The application of HDTs is acknowledged by the halal certification body worldwide since they have become a confirmatory mechanism as part and parcel of the halal assurance system. However, analysts in halal-testing laboratories find difficulties on (1) sample handling and choosing the suitable HDTs, (2) the requirements to establish validated and verified analytical method, (3) the requirements to utilize multivariate data analysis, and (4) challenges against the HDTs. Hence, this chapter reviews these issues and recommends that analysts employ suitable HDTs in halal-testing laboratories. © 2023 Elsevier Inc. All rights reserved.

**Author Keywords**

analytical method; halal authentication; halal certification; Halal detection technologies; halal-testing laboratories; multivariate data analysis

**References**

- Abbas, O., Zadavec, M., Baeten, V., Mikuš, T., Lešić, T., Vulić, A., Pleadin, J.  
**Analytical methods used for the authentication of food of animal origin**  
(2018) *Food Chemistry*, 246, pp. 6-17.
- Abdullah Amqizal, H.I., Al-Kahtani, H.A., Ismail, E.A., Hayat, K., Jaswir, I.  
**Identification and verification of porcine DNA in commercial gelatin and gelatin containing processed foods**  
(2017) *Food Control*, 78, pp. 297-303.
- Abdullah Sani, M.S., Ismail, A.M., Azid, A., Samsudin, M.S.  
**Establishing forensic food models for authentication and quantification of porcine adulterant in gelatine and marshmallow**  
(2021) *Food Control*, 130 (June), p. 108350.
- Ahmad, A.N., Yang, T.A., Hani, N.M.  
**Alcohol in food: Current fatwa in contemporary rulings Southeast Asian Countries**  
(2014) *Ulūm Islāmiyyah Journal*, 14 (January), pp. 1-18.
- Ahn, S.J., Costa, J., Emanuel, J.R.  
**PicoGreen quantitation of DNA: Effective evaluation of samples pre- or post-PCR**  
(1996) *Nucleic Acids Research*, 24 (13), pp. 2623-2625.
- Alexandre, T.L., Goraieb, K., Bueno, M.I.M.S., Wiley, J.  
**Quality control of beverages using XRS allied to chemometrics: Determination of fixed acidity, alcohol and sucrose contents in Brazilian cachaca and cashew juice**  
(2010) *X-Ray Spectrometry*, pp. 285-290.
- Ali, M.E., Kashif, M., Uddin, K., Hashim, U., Mustafa, S., Che Man, Y.B.  
**Species authentication methods in foods and feeds: The present, past, and future of**

**halal forensics**

(2012) *Food Analytical Methods*, 5 (5), pp. 935-955.

- Alikord, M., Momtaz, H., keramat, J., Kadivar, M., Rad, A.H.  
**Species identification and animal authentication in meat products: A review**  
(2018) *Journal of Food Measurement and Characterization*, 12 (1), pp. 145-155.
- Alzeer, J., Abou Hadeed, K.  
**Ethanol and its halal status in food industries**  
(2016) *Trends in Food Science and Technology*, 58, pp. 14-20.
- Amaral, J.S., Santos, G., Oliveira, M.B.P.P., Mafra, I.  
**Quantitative detection of pork meat by EvaGreen real-time PCR to assess the authenticity of processed meat products**  
(2017) *Food Control*, 72, pp. 53-61.
- Amid, A.  
(2021) *Multifaceted protocols in biotechnology, volume 2*, 2.  
A. Amid (Ed.), Springer Nature Switzerland
- Armbrecht, M., Gloe, J., Goemann, W.  
**Determination of nucleic acid concentrations using fluorescent dyes in the Eppendorf BioSpectrometer® fluorescence**  
(2013) *Eppendof*, (issue 271).
- Azilawati, M.I., Hashim, D.M., Jamilah, B., Amin, I.  
**Validation of a reverse-phase high-performance liquid chromatography method for the determination of amino acids in gelatins by application of 6-aminoquinolyl-N-hydroxysuccinimidyl carbamate reagent**  
(2014) *Journal of Chromatography. A*, 1353, pp. 49-56.
- Azilawati, M.I., Hashim, D.M., Jamilah, B., Amin, I.  
**RP-HPLC method using 6-aminoquinolyl-N-hydroxysuccinimidyl carbamate incorporated with normalization technique in principal component analysis to differentiate the bovine, porcine and fish gelatins**  
(2015) *Food Chemistry*, 172, pp. 368-376.
- Azir, M., Abbasiliasi, S., Azmi, T., Ibrahim, T., Noorzianna, Y., Manaf, A., Mustafa, S.  
**Detection of lard in cocoa butter—Its fatty acid thermal characteristics**  
(2017) *Foods*, 6 (98), pp. 1-12.
- Chin, S.T., Che Man, Y.B., Tan, C.P., Hashim, D.M.  
**Rapid profiling of animal-derived fatty acids using fast GC x GC coupled to time-of-flight mass spectrometry**  
(2009) *JAOCS, Journal of the American Oil Chemists' Society*, 86 (10), pp. 949-958.
- Costa, J., Mafra, I., Oliveira, M.B.P.P.  
**Advances in vegetable oil authentication by DNA-based markers**  
(2012) *Trends in Food Science and Technology*, 26 (1), pp. 43-55.
- Dalsecco, L.S., Palhares, R.M., Oliveira, P.C., Teixeira, L.V., Drummond, M.G., de Oliveira, D.A.A.  
**A fast and reliable real-time PCR method for detection of ten animal species in meat products**  
(2018) *Journal of Food Science*, 83 (2), pp. 258-265.
- (2017) *Malaysian Standard MS 2627: 2017 detection of porcine DNA – Test method – Food and food products.*,  
Ministry of International Trade and Industry for Malaysia

- (2018) *MS ISO/IEC 17025:2017 Malaysian Standard - General requirements for the competence of testing and calibration laboratories.*, Ministry of International Trade and Industry for Malaysia
- (2019) *Malaysian Standard MS 1500: 2019 Halal food – General requirements (third revision).*, Ministry of International Trade and Industry for Malaysia
- (2019) *Malaysian Standard MS 2400-1: 2019 Halal supply chain management system – Part 1: Transportation – General requirements (first revision).*, Ministry of International Trade and Industry for Malaysia
- (2019) *Malaysian Standard MS 2400-2: 2019 Halal supply chain management system – Part 2: Warehousing – General requirements (first revision).*, Ministry of International Trade and Industry for Malaysia
- (2019) *Malaysian Standard MS 2400-3: 2019 Halal supply chain management system – Part 3: Retailing – General requirements (first revision).*, Ministry of International Trade and Industry for Malaysia
- (2019) *Malaysian Standard MS 2424:2019 Halal pharmaceuticals – General requirements (first revision).*, Ministry of International Trade and Industry for Malaysia
- (2019) *Malaysian Standard MS 2634: 2019 Halal cosmetics – General requirements.*, Ministry of International Trade and Industry for Malaysia
- Department of Islamic Development, M.  
(2020) *Malaysian halal management system 2020*, Prime Minister Department of Malaysia
- Esteki, M., Shamsavari, Z.  
**Use of spectroscopic methods in combination with linear discriminant analysis for authentication of food products**  
(2018) *Food Control*, 91, pp. 100-112.
- Ferraro, V., Gaillard-Martinie, B., Sayd, T., Chambon, C., Anton, M., Santé-Lhoutellier, V.  
**Collagen type I from bovine bone. Effect of animal age, bone anatomy and drying methodology on extraction yield, self-assembly, thermal behaviour and electrokinetic potential**  
(2017) *International Journal of Biological Macromolecules*, 97, pp. 55-66.
- Galal-Khallaf, A.  
**Multiplex PCR and 12S rRNA gene sequencing for detection of meat adulteration: A case study in the Egyptian markets**  
(2021) *Gene*, 764 (July 2020), p. 145062.
- (2021) *Basic local alignment search tool*, National Center for Biotechnology Information, U.S. National Library of Medicine
- Ha, J., Kim, S., Lee, J., Lee, S., Lee, H., Choi, Y., Yoon, Y.  
**Identification of pork adulteration in processed meat products using the developed mitochondrial DNA-based primers**  
(2017) *Korean Journal for Food Science of Animal Resources*, 37 (3), pp. 464-468.
- Hair, J.F., Black, W.C., Babin, B.J., Anderson, R.E.  
**Multivariate data analysis**  
(2014) *Pearson education limited.*, Available from
- Hashim, D.M., Man, Y.B.C., Norakasha, R., Shuhaimi, M., Salmah, Y., Syahariza, Z.A.  
**Potential use of Fourier transform infrared spectroscopy for differentiation of**

- bovine and porcine gelatins**  
(2010) *Food Chemistry*, 118 (3), pp. 856-860.
- Henderson, J.W., Brooks, A.  
(2010) *Improved amino acid methods using Agilent ZORBAX Eclipse Plus C18 Columns for a Variety of Agilent LC Instrumentation and Separation Goals.*, Agilent Technologies
  - Idris, M.H.H., Manaf, Y.N., Desa, M.N.M., Hashim, A.M., Sani, M.S.A., Zaki, N.N.M., Mustafa, S.  
**A conjunction of sn-2 fatty acids and overall fatty acid composition combined with chemometric techniques increase the effectiveness of lard detection in fish feed**  
(2021) *Chemometrics and Intelligent Laboratory Systems*, 213 (March), p. 104308.
  - Ismail, A.M., Sani, M.S.A., Azid, A., Zaki, N.N.M., Arshad, S., Tukiran, N.A., Ismail, A.  
**Food forensics on gelatine source via ultra-high-performance liquid chromatography diode-array detector and principal component analysis**  
(2021) *SN Applied Sciences*, 3 (79), pp. 1-19.
  - Izadpanah, M., Mohebbali, N., Elyasi gorji, Z., Farzaneh, P., Vakhshiteh, F., Shahzadeh Fazeli, S.A.  
**Simple and fast multiplex PCR method for detection of species origin in meat products**  
(2018) *Journal of Food Science and Technology*, 55 (2), pp. 698-703.
  - Jamaludin, M.A., Amin, A., Fadzillillah, N.A., Kartika, B., Othman, R., Sani, S., Ramli, A.  
**Study on physiochemical properties and the halalness of commercially marketed vinegar in Malaysia**  
(2017) *International Food Research Journal*, 24 (December), pp. 428-435.
  - Jamaludin, M.A., Hashim, D.M., Rahman, R.A., Ramli, M.A., Majid, M.Z.A., Othman, R., Amin, A.  
**Determination of permissible alcohol and vinegar in Shariah and scientific perspectives**  
(2016) *International Food Research Journal*, 23 (6), pp. 2737-2743.
  - Jančić-Stojanović, B., Rakić, T.  
**Chemometrics in data analysis and liquid chromatographic method development**  
(2015) *Analytical Separation Science*, pp. 279-298.  
Wiley-VCH Verlag GmbH & Co. KGaA
  - Jannat, B., Ghorbani, K., Shafieyan, H., Kouchaki, S., Behfar, A., Sadeghi, N., Sadeghi, M.  
**Gelatin speciation using real-time PCR and analysis of mass spectrometry-based proteomics datasets**  
(2018) *Food Control*, 87, pp. 79-87.
  - Kang, S.S.N., Lee, H.G., Kim, H.  
**Development and comparison of a porcine gelatin detection system targeting mitochondrial markers for Halal authentication**  
(2018) *LWT—Food Science and Technology*, 97, pp. 697-702.
  - Kang, T.S., Tanaka, T.  
**Comparison of quantitative methods based on SYBR Green real-time qPCR to estimate pork meat adulteration in processed beef products**  
(2018) *Food Chemistry*, 269, pp. 549-558.
  - Khatun, M.A., Hossain, A., Hossain, M.S., Munshi, M.K., Huque, R.  
**Detection of species adulteration in meat products and Mozzarella-type cheeses using duplex PCR of mitochondrial cyt b gene: A food safety concern in Bangladesh**  
(2021) *Food Chemistry: Molecular Sciences*, 2 (March), p. 100017.

- Kim, Y.S., Yu, H.K., Lee, B.Z., Hong, K.W.  
**Effect of DNA extraction methods on the detection of porcine ingredients in halal cosmetics using real-time PCR**  
(2018) *Applied Biological Chemistry*, 61 (5), pp. 549-555.
- Komsta, L., Vander, Y., Sherma, J.  
(2018) *Chemometrics in chromatography.*,  
Taylor & Francis Group, LLC
- Lauwaars, M.  
**Methods validation: AOAC's three validation systems**  
(1998) *Accreditation and Quality Assurance*, 3, pp. 32-35.
- Lubis, H., Salihah, N.T., Hossain, M.M., Ahmed, M.U.  
**Development of fast and sensitive real-time qPCR assay based on a novel probe for detection of porcine DNA in food sample**  
(2017) *LWT - Food Science and Technology*, 84, pp. 686-692.
- Martín, I., García, T., Fajardo, V., Rojas, M., Pegels, N., Hernández, P.E., Martín, R.  
**SYBR-Green real-time PCR approach for the detection and quantification of pig DNA in feedstuffs**  
(2009) *Meat Science*, 82, pp. 252-259.
- Martín-Fernández, J.A., Barceló-Vidal, C., Pawlowsky-Glahn, V.  
**Dealing with Zeros and Missing Values in Compositional Data Sets Using Nonparametric Imputation**  
(2003) *Mathematical Geology*, 35 (3), pp. 253-278.
- McKiernan, H.E., Danielson, P.B.  
**Molecular diagnostic applications in forensic science**  
(2017) *Molecular diagnostics*,  
Third Edition, Elsevier Ltd
- Messmore, J.M., Fuchs, D.N., Raines, R.T.  
**Ribonuclease A: Revealing structure – Function relationships with semisynthesis**  
(1995) *Journal of the American Chemical Society*, 117 (31), pp. 1-10.
- Mohamad, N.A., Mustafa, S., Khairil Mokhtar, N.F., El Sheikha, A.F.  
**Molecular beacon-based real-time PCR method for detection of porcine DNA in gelatin and gelatin capsules**  
(2018) *Journal of the Science of Food and Agriculture*, 98 (12), pp. 4570-4577.
- Mohamadi, M., Afzali, D., Esmaeili-Mahani, S., Mostafavi, A., Torkzadeh-Mahani, M.  
**Spectroscopic and electrochemical studies of the interaction between oleuropein, the major bio-phenol in olives, and salmon sperm DNA**  
(2015) *Spectrochimica Acta – Part A: Molecular and Biomolecular Spectroscopy*, 148, pp. 260-265.
- Mohanty, B., Mahanty, A., Ganguly, S., Sankar, T.V., Chakraborty, K., Rangasamy, A., Sharma, A.P.  
**Amino acid compositions of 27 food fishes and their importance in clinical nutrition**  
(2014) *Journal Amino Acids*, 2014, pp. 1-7.
- Mualim, M.S., Tukiran, N.A., Sani, M.S.A., Fadzillillah, N.A.  
**Identification of non-halal recycled cooking oils using differential scanning calorimetry (DSC) combined with principal component analysis (PCA)**  
(2018) *National Research and Innovation Seminar*, pp. 6-12.
- Naquiah, A.N.N., Marikkar, J.M., Mirghani, M.E., Nurrulhidayah, A.F., Yanty, N.A.M.  
**Differentiation of fractionated components of lard from other animal fats using**

- different analytical techniques**  
(2017) *Sains Malaysiana*, 46 (2), pp. 209-216.
- Nawawi, M.S.A.M., Radzi, C.W.J.W.M., Mamat, M.Z., Hasbullah, M., Mokhtar, M.I., Jenatabadi, H.S., ... Pauzi, N.  
**Halal food industry in Thailand: History, prospects and challenges**  
(2017) *International halal management conference, August*, p. 302–307.
  - Novák, P., Havlíček, V.  
**Protein extraction and precipitation**  
(2016) *Proteomic profiling and analytical chemistry*, p. 52–62.  
Available from
  - Nur Azira, T., Che Man, Y.B., Raja Mohd Hafidz, R.N., Aina, M.A., Amin, I.  
**Use of principal component analysis for differentiation of gelatine sources based on polypeptide molecular weights**  
(2014) *Food Chemistry*, 151, pp. 286-292.
  - Nurdeng, D.  
**Lawful and unlawful foods in Islamic law focus on Islamic medical and ethical aspects**  
(2009) *International Food Research Journal*, 16 (4), pp. 469-478.
  - Nurrulhidayah, A.F., Che Man, Y.B., Rohman, A., Amin, I., Shuhaimi, M., Khatib, A.  
**Authentication analysis of butter from beef fat using Fourier Transform Infrared (FTIR) spectroscopy coupled with chemometrics**  
(2013) *International Food Research Journal*, 20 (3), pp. 1383-1388.
  - Palarea-Albaladejo, J., Martín-Fernández, J.A.  
**Values below detection limit in compositional chemical data**  
(2013) *Analytica Chimica Acta*, 764, pp. 32-43.
  - Park, S., Kim, J.C., Lee, H.S., Jeong, S.W., Shim, Y.S.  
**Determination of five alcohol compounds in fermented Korean foods via simple liquid extraction with dimethyl-sulfoxide followed by gas chromatography-mass spectrometry for Halal food certification**  
(2016) *LWT – Food Science and Technology*, 74, pp. 563-570.
  - Pollet, T.V., Meij, L.V.D.  
**To Remove or not to remove: The impact of outlier handling on significance testing in testosterone data**  
(2017) *Adaptive Human Behavior and Physiology*, 3, pp. 43-60.
  - Raharjo, T.J., Chudori, Y.N.C., Agustina, F.W.  
**TaqMan probe real-time polymerase chain reaction targeting the ATPase 6 gene for the detection of pork adulteration in meat and meatballs**  
(2019) *Journal of Food Safety*, 39 (6), pp. 1-6.
  - Rambla-Alegre, M., Esteve-Romero, J., Carda-Broch, S.  
**Is it really necessary to validate an analytical method or not? That is the question**  
(2012) *Journal of Chromatography A*, 1232, pp. 101-109.
  - Rani, N.L.A., Azid, A., Sani, M.S.A., Samsudin, M.S., Yusof, K.M.K.K., Amin, S.N.S.M., Khalit, S.I.  
**Development of missing data prediction model for carbon monoxide**  
(2019) *Malaysian Journal of Fundamental and Applied Sciences*, 15 (1), pp. 13-17.
  - Rohman, A., Che Man, Y.B., Hashim, P., Ismail, A.  
**FTIR spectroscopy combined with chemometrics for analysis of lard adulteration in some vegetable oils Espectroscopia FTIR combinada con quimiometría para el**

- análisis de adulteración con grasa de cerdo de aceites vegetales**  
(2011) *CyTA – Journal of Food*, 9 (2), pp. 96-101.
- Rohman, A., Gupitasari, I., Purwanto, P., Triyana, K., Rosman, A.S., Shuhel Ahmad, S.A., Mohd Yusof, F.  
**Quantification of Lard in the mixture with olive oil in cream cosmetics based on FTIR spectra and chemometrics for halal authentication**  
(2014) *Jurnal Teknologi*, 69 (1).
  - Rohman, A., Windarsih, A., Erwanto, Y., Zakaria, Z.  
**Review on analytical methods for analysis of porcine gelatine in food and pharmaceutical products for halal authentication**  
(2020) *Trends in Food Science and Technology*, 101, pp. 122-132.
  - Saiful, M., Azid, A., Iskandar, S., Shirwan, M., Sani, A., Lananan, F.  
**Comparison of prediction model using spatial discriminant analysis for marine water quality index in mangrove estuarine zones**  
(2019) *Marine Pollution Bulletin*, 141 (February 2018), pp. 472-481.
  - Sani, M.S.A., Jamaludin, M.A., Al-Saari, N., Azid, A., Azri, N.S.N.  
**Halal antimicrobials in food: A review on prospects and challenges of antimicrobials from animal sources**  
(2020) *Journal of Halal Industry and Services*, 3 (1), pp. 1-14.
  - Sani, M.S.A., Jamaludin, M.A., Sowhini, N.S.H.A., Asri, N.A.A.M.  
**Food antimicrobials: Addressing potential sources, challenges and testing as halal food preservatives**  
(2020) *In: Scientific conference WHS 2020*, p. 269–272.
  - Sani, M.S.A., Yuswan, M.H., Desa, M.N.M., Azid, A.  
**Procedure of method validation and verification, and multivariate data analysis of chemical measurement for halal-testing laboratories**  
(2020) *In: Scientific conference world halal summit 2019*, (vol. 1, p. 1–13.
  - Sarah, S.A., Faradalila, W.N., Salwani, M.S., Amin, I., Karsani, S.A., Sazili, A.Q.  
**LC-QTOF-MS identification of porcine-specific peptide in heat treated pork identifies candidate markers for meat species determination**  
(2016) *Food Chemistry*, 199, pp. 157-164.
  - (2021) *Standards catalogue. The Standards and Metrology Institute for Islamic Countries.*, Available from
  - Sultana, S., Hossain, M.A.M., Zaidul, I.S.M., Ali, M.E.  
**Multiplex PCR to discriminate bovine, porcine, and fish DNA in gelatin and confectionery products**  
(2018) *LWT – Food Science and Technology*, 92, pp. 169-176.  
Academic Press
  - Thompson, M., Ellison, S.L.R., Wood, R.  
**Harmonized guidelines for single-laboratory validation of methods of analysis (IUPAC Technical Report)**  
(2002) *Pure and Applied Chemistry*, 74 (5), pp. 835-855.
  - Tiscione, N.B., Alford, I., Yeatman, D.T., Shan, X.  
**Ethanol analysis by headspace gas chromatography with simultaneous flame-ionization and mass spectrometry detection**  
(2011) *Journal of Analytical Toxicology*, 35 (7), pp. 501-511.
  - (2020) *Guidelines for the validation of analytical methods for nucleic acid sequence-based analysis of food, feed, cosmetics and veterinary products*,  
FDA Foods Program Regulatory Science Steering Committee (RSSC)

- van der Spiegel, M., van der Fels-Klerx, H.J., Sterrenburg, P., van Ruth, S.M., Scholtens-Toma, I.M.J., Kok, E.J.  
**Halal assurance in food supply chains: Verification of halal certificates using audits and laboratory analysis**  
(2012) *Trends in Food Science and Technology*, 27 (2), pp. 109-119.
- Williams, B., Brown, T.  
**Exploratory factor analysis : A five-step guide for novices**  
(2012) *Journal of Emergency Primary Health Care*, 8 (3).
- Wolf, C., Lüthy, J.  
**Quantitative competitive (QC) PCR for quantification of porcine DNA**  
(2001) *Meat Science*, 57 (2), pp. 161-168.
- Woodward, C., Henderson Jr, J.W.  
(2007),  
High-speed amino acid analysis (AAA) on 1.8 µm reversed-phase (RP) columns. Agilent Technologies
- Wu, H., Qian, C., Wang, R., Wu, C., Wang, Z., Wang, L., Wu, J.  
**Identification of pork in raw meat or cooked meatballs within 20 min using rapid PCR coupled with visual detection**  
(2020) *Food Control*, 109 (April 2019), p. 106905.
- Xing, R.R., Wang, N., Hu, R.R., Zhang, J.K., Han, J.X., Chen, Y.  
**Application of next generation sequencing for species identification in meat and poultry products: A DNA metabarcoding approach**  
(2019) *Food Control*, 101 (November 2018), pp. 173-179.
- Yang, H., Irudayaraj, J.  
**Comparison of near-infrared, Fourier transform-infrared, and Fourier transform-Raman methods for determining olive pomace oil adulteration in extra virgin olive oil**  
(2001) *Journal of the American Oil Chemists' Society*, 78 (9), pp. 889-895.
- Yuswan, M.H., Sani, M.S.A., Manaf, Y.N.A., Desa, M.N.M.  
**Basic requirements of laboratory operation for halal analysis**  
(2020) *In: International conference on Islam, economy, and halal industry*, p. 55–65.  
Available from
- Zdeňková, K., Akhatova, D., Fialová, E., Krupa, O., Kubica, L., Lencová, S., Demnerová, K.  
**Detection of meat adulteration: Use of efficient and routine-suited multiplex polymerase chain reaction-based methods for species authentication and quantification in meat products**  
(2018) *Journal of Food and Nutrition Research*, 57 (4), pp. 351-362.
- Zhang, D., Hu, P., Liu, T., Wang, J., Jiang, S., Xu, Q., Chen, L.  
(2018) *GC bias lead to increased small amino acids and random coils of proteins in cold-water fishes*, pp. 1-10.  
Springer Nature 2023 BioMed Central Ltd
- Zhao, N., Wang, X., Pan, H., Hu, Y., Ding, L.  
**Spectroscopic studies on the interaction between tryptophan-erbium(III) complex and herring sperm DNA**  
(2010) *Spectrochimica Acta - Part A: Molecular and Biomolecular Spectroscopy*, 75 (5), pp. 1435-1442.
- Zia, Q., Alawami, M., Mokhtar, N.F.K., Nhari, R.M.H.R., Hanish, I.  
**Current analytical methods for porcine identification in meat and meat products**



(2020) *Food Chemistry*, 324 (April 2019), p. 126664.

- Zulkarnail, M.Z., Tukiran, N.A., Sani, M.S.A.  
**Characterization of L-cysteine sources using ATR-FTIR and Raman spectroscopy**  
(2021) *Halalsphere*, 1 (1), pp. 83-95.
- Zulkarnail, M.Z., Tukiran, N.A., Sani, M.S.A., Ismail, A.M.  
**Recent advanced techniques in cysteine determination: A review**  
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