Food Fraud Unmasked

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Content

Oral Presentations

Sowing an integrity-centric digital ecosystem in the Dutch broiler supply chain: defining credibility of quality & traceability systems and identifying the drivers and barriers of blockchain technology implementation

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Abstract

The global food supply chain landscape has grown increasingly complex, posing challenges to preserve the integrity of food information as it moves along the chain. Given context is fuelled by fragmented collaboration and poor information exchange among actors, coupled with the absence of cohesive traceability and quality systems. In recent years, Blockchain Technology (BCT) has emerged as a promising solution to creating more unified chains, by offering an immutable digital record of history without intermediaries. Strictly exploring the case of the Dutch Broiler Chain, this study focused on defining credibility of quality and traceability market devices, while also identifying the drivers and barriers associated with BCT implementation. An industry overview was extracted from executing a literature review, followed by a thematic content analysis performed on interviews (n=11) with Broiler Chain shareholders. Interviewees emphasized factors such as *accuracy*, *transparency*, *fairness*, and *unambiguity of information* fundamental in attributing credibility to market devices. Company size and network dynamics within the supply chain, emerged as crucial aspects influencing BCT implementation. Vertically Integrated (VI) chains mentioned few barriers, and often explain there are already simil-BCT systems implemented in the organization. Isolated companies indicate greater challenges, including *supply chain readiness to open up and collaborate*, *lack of knowledge* about the system and a great *privacy concern*. Despite differences, both groups acknowledge drivers such as *increased transparency* and *trust in product integrity maintenance* with BCT implementation. This study has shed light on the divided dynamic of the Dutch Broiler Chain and going forward, such issue may be addressed by educating shareholders about the potential applications of BCT, particularly highlighting what are the privacy boundaries of the system and gradually fostering a more open and collaborative industry dynamic.

Combining volatilomics with chemometrics to discriminate ginger powder with particle size variations

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Abstract

Particle size is an important morphological feature of spice powder that can cause variations in the physicochemical properties. This study aimed to evaluate the organic volatile compounds variation in ginger powder with different particle sizes and also explored other underlying factors that could influence the composition of ginger powder. Volatolomics analysis on ginger powder was conducted using headspace solid-phase microextraction coupled with gas chromatography-mass spectrometry (HS-SPME-GC-MS) along with chemometrics. The results showed that particle size has no/limited influence on volatolomics profiles of ginger powder. The volatolomics variations of ginger powder were caused by other factors during production including geographical origin, production practice and processing procedure. In addition, the volatolomics profiles of ginger are more easily affected by sample handling. Ultimately, this study is a step further in paving the way for understanding the sources of variation and their effects on the volatolomics and metabolomics analysis in food quality and/or authentication analysis.

Scientific approaches to soy sauce authenticity: Past efforts and future prospects

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Abstract

Background: Soy sauce, originating from China, has a long history in Asian countries. Recently, global production has markedly increased, and the consumer base is growing. The complex production process, involving various raw materials and multiple steps, poses multiple risks of fraud, some of which are related to food safety. Hence, soy sauce authentication is crucial.

Scope and approach: This review starts by investigating recent global production and trade volumes of soy sauce in major producing countries. It then outlines production standards and additive usage criteria in key countries. Building on this, it analyzes fraudulent activities observed in soy sauce over the past two decades. Finally, the review introduces principles, equipment, and data processing methods applied in analytical chemistry approaches for studying soy sauce authentication, considering both principles and applications.

Key findings and conclusions: In soy sauce production, soybean protein hydrolysis relies mainly on microbial fermentation, with an optional use of acid hydrolysis. The latter raises safety concerns, making fraudulent events in soy sauce production through these methods a significant concern. In recent years, soy sauce bottles have displayed various high-quality attribute labels, such as GM-free, organic, addictive-free, and handmade, etc. However, discerning the quality attributes in soy sauce through clear indicators is often very challenging. For the above issues, scientists have established a series of targeted and non-targeted analytical methods based on spectroscopy, mass spectrometry, and molecular biology techniques to verify the authenticity of soy sauce, In the future, it is essential to increase soy sauce numbers and related metadata. Building upon this foundation, establishing diverse spectroscopic and mass spectrometry profiles, along with developing portable spectroscopy-based devices, will further ensure the authenticity of soy sauce sold in many markets across the world.

Keywords**:** Soy sauce; Standard; Authenticity analysis; Fraud; Analytical techniques

Regulatory regime and food fraud vulnerability: Impact of Brexit

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Abstract

On the 24th June 2016, the majority of the UK voted to leave the European Union. After completing a transitional period, the UK formally departed the EU on 31st December 2020 (Springford, 2021). With this departure, the UK began diverging from EU law. One of the most important and recent divergences is the Border Target Operating Model introduced by the UK (Reland, 2023). Despite the UK's departure from the EU, the UK landbridge can be still utilized to transport goods between Ireland, the UK, and the EU as a whole, albeit with increased requirements and documentary checks. This has the potential to lead to higher costs and possible delays for agri-food goods, as well as the complication that goods using the landbridge ultimately exit and re-enter the EU through a third country. The resulting increased administrative costs, paperwork, and efforts can potentially act as motivators for fraudulent activities. The objective of this study is to assess the effects of Brexit on the Irish food and drink industry, particularly focusing on regulatory divergence and food fraud vulnerability. A qualitative study involving 12 Irish food and drink industry specialists was undertaken via a series of semi-structured interviews, to understand their perspectives and behaviors concerning post-Brexit inconsistencies. The resulting transcripts are thematically analyzed using the NVivo software. According to the preliminary results, Brexit has created changes in general organizational procedures, food import-export procedures, increased cost, time, and resource consumption in the food supply chain, changes in factories and warehouses located in the UK, and a reduction in using the UK landbridge. Additionally, the research involved the collection of the latest data from the EU's RASFF and the Decernis international database to map the movement of vulnerable foods, post-Brexit. This data will identify vulnerable food categories on the market and their sources, and a process flow map from 3rd country origins to the Republic of Ireland and Northern Ireland will be generated. Despite existing challenges, the UK remained Ireland's primary agri-food export destination, with a value of €6.7 billion (Department of Agriculture, Food and the Marine, 2023). The Irish food industry, with government backing, should proactively prepare for regulatory changes by providing comprehensive training for stakeholders to foster the development of a sustainable industry.

Keywords**:** Brexit; Regulatory divergence; Food Fraud; Irish food and drink industry

Drivers and barriers to QR code implementation in the olive oil supply chain

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Abstract

Olive oil is one of the most frequently reported fraudulent food products due to its nutritional characteristics and increasing prices. The identification devices, such as QR codes, can contribute to traceability to improve the transparency of the olive oil supply chain. Although this viewpoint has gained widespread consensus, the identification devices have not been fully popularized, and there is a lack of insight into the drivers and barriers to the identification device implementation from the perspective of olive oil supply chain actors. In this study, the drivers and barriers to QR code implementation in the olive oil supply chains were originally extracted through a literature review, and experts were interviewed to verify these proposed drivers and barriers during the empirical study. The result shows that six drivers were validated by all experts, including easy access to information, mature and proven technology, increase in sales and profit, possibility for precision management, cheaper technology, and high willingness to pay. Just one barrier ‘cannot be updated’ was recognized by most experts while the other five barriers were dismissed. A practical understanding of olive oil supply chain actors' decisions concerning the QR code implementation is provided, which can promote the wide usage of QR codes in olive oil.

The classification, detection and control of the nine sins of tea fraud

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Abstract

Tea, one of the most consumed beverages worldwide, is vital to daily life and health due to its numerous health benefits. In the meantime, as a major commodity traded across continents, tea is vulnerable to fraud because of complex global trading networks, untransparent supply chains, and global disruptions such as climate change, pandemics, the Red Sea crisis, and trade wars. Analyzing common tea fraud types is beneficial for the mitigation and prevention of tea fraud, with measures tailored to address the unique challenges associated with tea products. As a results, a total of nine different forms of tea fraud have been identified. The adulteration and substitution of high value varieties and chain of custody abuse were the top three tea fraud issues found. A range of analytical techniques including chromatography, mass spectrometry, elemental and stable isotype-based analysis, vibrational spectroscopic techniques, nuclear magnetic resonance spectroscopy, and electronic sensors employed in tea fraud detection were summarized. As with all forms of food and beverage authenticity testing these methodologies have their own strength and limitations. At present, there is no single analytical tool capable of providing comprehensive decision-making regarding authenticity issues. Therefore, it is necessary to use several approaches, combining targeted determination and non-targeted fingerprinting analysis, augmented with artificial intelligence to detect tea fraud.

Food fraud in the food supply chain in Nigeria

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Abstract

Food fraud is a crucial global issue that poses a public health threat to consumers, the food supply chain, and the economy of a country. Based on recent local media reports and National Agency for Food and Drug Administration and Control (NAFDAC), there has been a surge in reports of food fraud in Nigeria. Findings from publicised reports on food fraud acts in Nigeria clearly indicate that food fraud is real in Nigeria. This study aims to determine the patterns, challenges, and possible solutions to food fraud in the food supply chain in Nigeria. A nationwide survey was conducted, and data were analysed applying descriptive and chi-square ($\chi 2$) analysis using Statistical Package for Social Science (SPSS) software Version 28.0. The findings show that most participants were educated consumers who tend to purchase food products 1 – 2 times a week, prepare food on a daily basis and almost 50% of the participants were aware of the term food fraud. Participants identified financial benefits and the ease to commit food fraud as the possible reasons for food fraud in Nigeria. Adulteration was indicated as the major type of food fraud act, food manufacturing as the most vulnerable link in the food supply chain while food products like fats, oils, herbs, and spices were indicated as the most vulnerable food products. Hypotheses 1 (There is a significant relationship between demographic characteristics and 'Food fraud awareness') and 3 (There is a significant relationship between demographic characteristics and 'Is food fraud a threat in Nigeria'), were accepted with significant association between education $X2(8)=51.81$ ($p<0.001$), employment $X2(6)=13.492$ ($p=0.036$), and 'Food fraud awareness'(with 50% unaware consumers), and significant association between gender $X2\ (6)=27.976$ ($p<0.001$) age $X2(12)=21.356$ ($p=0.045$), and 'Is food fraud a threat in Nigeria?' The survey also revealed that not all consumers were aware of food fraud and its' threats in Nigeria. This shows the need to create awareness of food fraud, types of food fraud, effects on public health and the economy, ways of identifying fraudulent foods, and necessary ways to encourage consumers to whistle blow as about 50% of the participants are unaware of food fraud activities. Regulatory bodies, medical personnel, enforcement bodies, the government, and consumers who are aware of food fraud should enlighten other consumers of its impact. Further studies which is the Ph.D. phase includes a semi-structured interviews with food producers, health workers, and regulatory agencies will be carried out.

An investigation into the impact of Brexit on consumer perception of trust in the food industry

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Abstract

This ongoing project investigates the impact of Brexit on consumer perceptions of trust in the food industry. Brexit has significantly impacted the food industry, triggering a paradigm shift in the movement of food/agricultural produce, regulations, and cross-border collaborations between Great Britain, Northern Ireland, and the Republic of Ireland. In a world where the dynamics have shifted, because of regulatory changes that impact trade, and free movement of foods and agricultural produce between these three countries, monitoring and controlling every stage of the food supply chain have become challenging, increasing the potential for food fraud and food safety incidents. As consumers play a pivotal role in shaping the market, understanding any shifts in trust, post-Brexit, enables them to navigate the market with confidence and awareness.

This study aims to explore the complexities of consumer perceptions, focusing on trust as a cornerstone of consumer confidence in the post-Brexit food landscape. The objectives include comparing trust in official controls pre- and post-Brexit, determining consumer awareness of food fraud, and devising recommendations that reflect the evidence from this primary research regarding consumer trust in food authenticity post-Brexit.

The research design follows an exploratory sequential mixed methods approach, incorporating qualitative methods such as focus groups and structured interviews, along with quantitative research through a large-scale survey. Participants from UCD and Ulster University campuses, comprising academic and non-academic staff, students, and researchers, will provide insights into the impact of Brexit on consumer trust.

Preliminary findings from focus groups and interviews highlight changes in labelling, reduced quantity, and quality of foods in both Northern Ireland and the Republic of Ireland, fewer food choices, and increased food prices since Brexit. Also, the trust in official control has reduced because of Brexit with the majority of the consumers expressing their concern for food safety post Brexit.

The study aims to further investigate and quantify these impacts through a comprehensive large-scale survey involving participants from Northern Ireland and the Republic of Ireland. The results will inform official controls and consumer-facing messaging contributing valuable insights to navigate the evolving post-Brexit food landscape.

Keywords: Brexit; Consumer trust; Food fraud; Food industry

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Seafood Mislabelling: histology and infrared spectroscopy as effective and reliable inspection tools

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Abstract

Food fraud prevention and detection still is a challenging problem, and it concerns economic-related and health-related issues. According to the last ACN (Alert and Cooperation Network) Annual Report, in 2022 the food category *Fish & products thereof* represented the third category most reported, and it was notified primarily due to cases of faulty labelling or claims for non-compliant indications of the weight, water ice glaze, or storage conditions. In particular, notifications on fish and fish products mainly concerned cases of adulteration, such as substitution of fish with lower value species or processed products.

When specifically considering seafood frauds, selling frozen-thawed fish, labelled as fresh, is revealed to be one of the most common fraudulent practices. This food fraud, besides causing economic damages to consumers, can be associated with serious risks to human health and safety. That is why it is necessary to develop reliable analytical techniques which can allow to detect the fraudulent substitution of a fresh product with a thawed one. However, it is not easy to make a clear distinction between these products, as the sensory properties of frozen-thawed fishes are very similar to those of the fresh ones.

When it comes to considering valid techniques to disclaim this type of fraud, histology and near-infrared spectroscopy have emerged as consistent inspection tools. Histological analysis examines microscopic differences in muscle fibres, particularly for freezing-related lesions. Near-infrared spectroscopy, on the other hand, can differentiate between spectra obtained from fresh and frozen-thawed fish or fish products. The reliability of histology in detecting fraudulent practices has led to its recognition as a reference method for defining fish product preservation conditions in Italy. Standardizing techniques based on infrared spectroscopy may be complex due to their reliance on untargeted approaches. However, the promising outcomes and ease of use associated with this method suggest its potential significance in fighting seafood mislabelling in the future.

The presentation will illustrate the process which led to the validation of the abovementioned histological method. The focus will also be on examples of both histological analysis on fish products and activities carried out to determine the feasibility of the use of near-infrared spectroscopy in differentiating fresh and frozen-thawed fish.

Authentication of the dietary background and geographical origin of Irish grass-fed beef using fatty acids profiling approach

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Abstract

Pastoral-based beef production systems have been regarded as more environmentally and animal welfare-friendly compared to other mainstream feedlot systems. That led to an increased focus on beef origin, particularly grass-fed beef, highlighting the need for reliable and robust methods to verify the provenance of beef and ensure product label claims are genuine. In this study, we investigated the potential of fatty acids analysis of intramuscular fat for authentication of beef provenance. Irish commercial beef samples (n = 400) from grass-fed and other three concentrate-based production systems (100 samples per treatment), where diets were self-declared by farmers, were compared using a one-way ANOVA followed by a Tukey's multiple comparison test. Additional international beef samples (n = 86) from grass-fed and other diverse production systems and geographical origins have also been tested for their provenance. Irish grass-fed beef is characterized by significantly increased levels of total conjugated linoleic and linolenic acids, trans fatty acids, and medium- and long-chain n-3 polyunsaturated fatty acids, as well as a lower n-6:n-3 ratio compared to concentrate-fed and other international beef (all $P < 0.001$), providing an evidence of their provenance. Overall, the results suggest that the lipid profile of beef can be used to distinguish the dietary background and geographical orientation of commercial Irish grass-fed beef.

Keywords: Grass-fed beef; Geographical origin; Fatty acid profile

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Maple syrup adulteration: Utilizing fluorescence fingerprints and machine learning for enhanced detection

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Abstract

Introduction: Maple syrup is often tampered with by dilution or substitution with other syrups due to its high demand and price. Extensive processing required to transform sap into syrup degrades the genetic material, lowering the efficacy of traditional approaches, such as DNA fingerprinting, in detecting possible adulteration. In contrast, fluorescence fingerprints (i.e., excitation-emission matrices or EEMs) rely on the presence of fluorophores in the samples and have the potential to provide valuable information to detect adulteration.

Aim: This study evaluates the capabilities and limitations of EEMs to discriminate between pure and adulterated maple syrup samples as well as the requirements to process these dense datasets.

Methods: EEMs of pure amber and dark maple syrups and admixtures with common adulterants (beet, corn, and rice syrups at 1-50%) were obtained using a Fluoromax-4 spectrophotometer (λ_{ex}=250-500 nm, and λ_{em}=270-700 nm, slits=3 nm). The major components of the EEMs were identified using PARAFAC, and confirmed by LC-MS/MS. Three approaches were taken to garner information from EEMs, to detect adulteration. Firstly, the ratio of intensities of the two most prevalent EEM features (I_{425}/I_{350} at λ_{ex}= 290) was calculated. Secondly, the emission spectra collected at $\lambda_{ex}/\lambda_{em}$ = 290/310-550nm and λ_{ex} /λ_{em} = 350/ 370-550nm were identified as potentially discriminatory based on the results of the EEMs. Hence, these data sets were analyzed using deep learning techniques. A feed-forward artificial neural network (ANN) built on Tensorflow & Keras was developed based on the emission at the two selected excitation wavelengths to discriminate presence, level and type of adulteration. Thirdly, EEMs were analyzed in their totality as images using a convolutional neural network (CNN) approach.

Results: EEMs allowed for the identification of valuable discriminatory information. The ratio of the emission intensities at (I_{425}/I_{350}) at λ_{ex}= 290 nm provided easy discrimination of adulterated samples (70-86% correct identifications depending on the adulterant). This ratio was particularly effective for beet syrup adulteration, detecting it at concentrations as low as 1%. The application of computational algorithms improved detection for all types of adulterants. ANN, using the emission spectra at λ_{ex} = 290 nm and 350 nm, correctly identified adulteration type and level (>82 % for all samples and >90% when only C3 plants were examined). The CNN approach, utilizing the full EEMs image, accurately classified 80-100% of adulterated dark syrups but required additional computational power and denser data sets.

Conclusion: This study aids in providing a non-invasive, efficient, and quick monitoring tool for maple syrup adulteration based on its chemical composition, without the need to transform or derivatize the samples. Therefore, it has potential in its applicability in the supply chain, as part of the Quality Assurance/Quality Control (QA/QC) process to detect potential adulteration.

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A comparative analysis of phenotype and DNA-based approaches for olive variety identification

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Abstract

Olive oil, esteemed for its health benefits and unique qualities, faces a significant risk of adulteration due to high demand and economic value. Identification of the olive variety used is crucial, given the vast array of over 2,000 varieties worldwide and how it affects the olive oil production. Reliable authenticity and traceability methods are essential to protect consumers and support producers.

Our research aims the development of a DNA-based method for identifying distinct olive oil varieties. The ultimate goal is to adapt this method to micro Total Analysis System (μTAS) solutions, paving the way for on-the-spot detection capabilities.

Eight olive and leaf samples from Cyprus and Turkey were used. Traits related to the olives' endocarp were assessed to determine the varietal identity and authenticity. DNA was extracted with DNeasy Plant Pro kit (Qiagen, Germany), and certain regions from the Cycloatenol synthase and Luperol synthase genes were amplified by end-point PCR. Gel electrophoresis was used to visualize the amplicon bands. Subsequently, these amplicons were subjected to Sanger Sequencing by Macrogen (Seoul, South Korea). The obtained sequences were analyzed with Geneious Prime® software (version 2023.1.2).

Firstly, samples were identified and authenticated morphologically. Results obtained showed that samples analyzed belonged to varieties ‘Ladoelia’ (two samples), ‘Kato Drys‘(one sample) from Cyprus, ‘Kalamata’ (one sample) and ‘Koroneiki’ (three samples) from Greece and ‘Kilis Yaglik (one sample) from Turkey. Upon morphological analysis, it was discovered that two of the initially identified varieties were misclassified. Once correctly identified, the DNA sequences were analyzed to find specific markers to enable cultivar identification in processed and/or complex matrixes.

Our work highlights that the combination of morphological and molecular data, alongside authenticated reference collections, is crucial to validate the identity and authencity varietal in olive.

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Verifying pine nuts authenticity through sesquiterpene fingerprints

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Abstract

Pine nuts are one of the most valuable nuts in the market, with a supply value accounting for 1.34 billion dollars[1], and the main producers are China, Russia, and North Korea, for the Asia's pine nut; and Turkey, Spain and Portugal for the Mediterranean. Mediterranean pine nuts, particularly those from Spain, are highly valued, exhibiting retail prices exceeding 100 €/kg[2], while Chinese and Russian pine nuts present much lower prices[3]. Consequently, pine nuts are highly susceptible to fraudulent practices involving the counterfeiting of the declared geographical origin. Given the current situation, further aggravated by the lack of effective control methods, there is a pressing need to develop reliable pine nut authentication methods to protect consumers interests.

This study presents a novel and fast methodology based on the analysis of the sesquiterpene hydrocarbon fingerprint of pine nuts to authenticate their origin beyond agronomical and processing conditions. It is worth to noting that the geographical origin is typically associated to a specific pine nut species: *Pinus pinea* L. grows predominantly in the Mediterranean region, while *Pinus koraiensis*, and *Pinus sibirica* are primarily sourced from China and Russia. The proposed method was tested on a set of 253 pine nut samples from four countries (China, Russia, Spain, and Turkey) and different harvest years. Partial lest squares discriminant analysis (PLS-DA) was applied to discriminate among Iberian and non-Iberian pine nuts. Within Iberian samples, all belonging to the *Pinus pinea* species, another PLS-DA model was built, aimed to distinguish between two production regions: Catalonia and Castile and León. Both models were externally validated, and their performance was assessed through percentage of correct classification, sensitivity, and specificity.

The external validation results showed percentages of correct classification higher than 98% for all models and classes, achieving high values of sensitivity and specificity closer or equal to 1. These findings prove the suitability of the sesquiterpene fingerprint as a pine nut authentication method that could be used as a screening tool to support official controls.

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Food fraud vulnerability assessment of the honey supply chain

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Abstract

Food fraud and food integrity issues have attracted a growing research interest in the scientific community over the last few decades. Although many laboratory-based analytical methods have been used to detect food fraud, food fraud cases continue to increase. To better understand the root drivers of food fraud and identify the most vulnerable nodes in a food supply chain, a food fraud vulnerability assessment was conducted. As a valuable commodity in the market, honey is highly susceptible to fraudulent activities. To assess the fraud vulnerability of the honey supply chain and understand the similarities or differences among tier groups across the supply chain, the SSAFE food fraud vulnerability assessment tool was used. The fraud vulnerability in the honey supply chain was examined through data collected from 20 participants, including 8 honey producers, 3 manufacturers, 2 retailers, and 7 certification agencies. For data exploration, frequency analysis was performed. Also, the vulnerability assessment of the honey supply chain and its tier groups (producers, retailers) was conducted according to three factors: opportunities, motivations, and control measures. From this study, it appears that the overall honey supply chain is highly vulnerable to fraud. Moreover, retailers perceive higher vulnerability than honey producers. The main reasons for these results are the high fraud opportunities, increased economic motivations, and lack of adequate control measures. This vulnerability assessment will contribute to developing comprehensive guidelines to overcome systemic enablers and barriers to implementing innovative solutions. These valuable insights will support the development of a traceability framework through the application of emerging digital technologies across the honey supply chain.

The sound of coffee

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Abstract

Whether one consumes a quick instant coffee on the go, or coffee that has seen a species' intestine before reaching the coffee machine, various coffee drinks have been internationally recognized as an important part of numerous cultures and traditions. The popular drink has been described as liquid gold, recognizing the wide trading market and its value. However, this makes the product prone to adulteration and corruption. Hence, there is a need for the identification and verification of high- and low-quality coffee products. This research investigated the possibility of distinguishing instant coffee products containing Arabica coffee grounds (4.61 USD/kg1) and Robusta coffee grounds (3.38 USD/kg1), using their acoustic profile. For the assessment, Broadband Acoustics Resonance Dissolution Spectroscopy (BARDS) was used. This novel technique measures the change in frequency (Hz) upon dissolution of the sample by tapping the glass container over time. Due to the introduction of gases, previously present between the sample particles or formed upon chemical reactions occurring between sample and solvent, the compressibility of the solvent changes. This leads to a change in observed frequency. The acoustic responses, as well as the total volume of gas released upon the addition of the sample to the solvent, were assessed for both instant coffee types with various grain sizes (<1.00 mm; >1.00 and <2.00 mm; >2.00 mm). From the results could be concluded that the acoustic profile differs between both coffee types. Arabica instant coffee has a steeper increase, while Robusta instant coffee describes a ridged s-curve. Moreover, Arabica reaches the stable state, leading to flattening of the curve, more quickly (275 seconds compared to 550 seconds for Robusta). This corresponds to quicker deaeration of the solution. In addition, the acoustic profile of Robusta corresponds to a larger total gas volume being released. Furthermore, a significant difference in minimal frequency could be observed for both instant coffee types (2.30 KHz and 1.52 KHz for Arabica and Robusta, respectively).

An increase in grain sizes led to a decrease in minimal frequency for both instant coffee types and differed significantly between both types for each fraction. Moreover, larger grains of Arabica lead to a steeper increase in frequency, corresponding to faster deaeration of the solution. However, no change in total released gas volume was observed. For larger grains of Robusta, an increased gas release at the start (t=0 till t=40 seconds) could be observed, leading to a larger total gas release. However, a large variation between samples of all fractions could be observed for Robusta. Lastly, different ratio combinations (100/0, 75/25, 50/50, 25/75, 0/100) of both types were reviewed. These were further analyzed using PCA to obtain a calibration curve of their acoustic responses. Ensuing, two mystery samples were measured, and their theoretical ratio of Arabica and Robusta instant coffee were determined. The calculated values varied on average 7% from the initial ratio.

These results show that Arabica and Robusta instant coffee, as well as mixtures, can be distinguished based on their acoustic profiles. However, the preparation and storage of (instant) coffee influence the food product's properties as well as its powder properties. Subsequently, the deaeration is affected and thus their acoustic profile. Therefore, investigating these influences would provide a greater understanding of the observed differences and potential future applications.

[1] Values based on coffee bean market price in 2024 by YCharts.

Intelligent food assurance systems: Rapid responses to food inauthenticity

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Abstract

An Intelligent Food Assurance System (IFAS) represents a potential next generation "smart" system, set to be integrated with state-of-the-art sensor and digital technologies, following an Internet of Food approach. The design of IFAS aims to extract valuable insights from the vast amount of data within the supply chain by employing various numerical models. This study constructs a food assurance model based on the food risk matrix, incorporating elements such as food quality, safety, authenticity, and defence. The design concept of an IFAS is elaborated by first outlining the fundamental concepts and definitions of food systems, and then providing a comprehensive review of recent advancements in technology and intelligent systems. Through the literature review, it was identified that although numerous studies have applied digital technology to food assurance, there exists a gap in the utilisation of data at different locations of the supply chain, particularly in providing a rapid response to food inauthenticity. The IFAS design will focus on bridging information gaps between different segments of the supply chain by employing a unified system to enable stakeholders to collaboratively identify and address risks. Overall, the potential impact of IFAS in enhancing transparency and authenticity in the food chain, reducing cost and waste for sustainable development, and boosting consumer confidence is emphasized.

Poster Presentations

How to mitigate food fraud on economic and health issues in food processing

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Abstract

Introduction: Food processing is a widely practiced and ancient technology to ensures not only increased shelf life but also may make some foods more digestible. Consuming susceptible organic substrates as part of their metabolic processes. Such interactions are fundamental to the decomposition of natural materials, and to the ultimate return of chemical elements to the soil and air without which life could not be sustained.

Aims: This review will cover contemporary trends and issues of AI and blockchain technology to combat food fraud on economic and health issues of microorganisms in food processing industries, particularly to meet consumer demand safely.

New findings: From an international anti-fraud body, using data analysis technology (machine learning) holds promise and it can unearth hidden patterns in vast datasets, leading to better detection and prevention of crimes for easy identification of suspicious activity in the context of food crime. Also, researchers found out that blockchain technology empowers consumers to make better decisions when they buy food, this technology offers the possibility of giving everyone from supermarket chains to individual consumers the ability to trace their food's journey back to its origin, with ease and confidence.

Conclusion: While new technology offers promise in fighting food crime, there is the need to implement blockchain across the global food supply chain, also making technology less expensive for small food producers and bringing law enforcement, industry professionals, organizations, and academics, proper ethical oversight from their institutions.

Keywords: Food fraud; Mitigate; Blockchain; AI; Technology; Metabolic processes

Using PTR-ToF-MS to identify volatile features that could substantiate the identity of infant formula

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Abstract

Food counterfeiting, a form of food fraud, poses not only economic risks but also health hazards, particularly for vulnerable populations such as infants. The aim of this study was to explore if volatile compositions could be used to authenticate geographically diverse stage one infant formula products in the fight against food counterfeiting. Sixty samples from six countries (ten different brands per country) were collected from Australia, Brazil, China, the Netherlands, South Africa and United States of America, and the volatile organic compounds (VOCs) determined using Proton Transfer Reaction Time-of-Flight Mass Spectrometry (PTR-ToF-MS. Based on the PTR-ToF-MS results, Principal Component Analysis-Agglomerative Hierarchical Clustering (PCA-AHC) was conducted to cluster the samples, and MANOVA was used to explore the statistical significance among different groups. Partial least squares-discriminant analysis (PLS-DA) was then utilized to discriminate between the PCA-AHC groups, illustrating that alkyl fragments, 2-propenal, 2-propanone, hexanol, acetic acid, dimethyl sulphone or dimethyl disulphide and p-cymene, which are generated from the fats and proteins, play important roles in clustering the groups based on PCA-ACH. Overall, the results show that the ingredient source is reflected in the VOC compositions of stage one infant formula, which sheds light on the influence of ingredients. However, infant formula is a complex, composite product that is influenced by various factors that should be further investigated to develop robust methods for the detection of counterfeits.

Portable NIR spectrometer coupled chemometrics to detect nutshells in cinnamon powder

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Abstract

Cinnamon (*Cinnamomum* sp.) powder, a highly valuable spice widely utilized in food and pharmaceutical products, is particularly vulnerable to adulteration due to its powdered form. Among the potential adulterants, nutshells pose a significant threat owing to their similar physical characteristics. This study aimed to develop a novel analytical approach leveraging a portable NIR spectrometer and chemometric techniques to identify nutshell adulteration (peanut shell, pecan shell, and walnut shell) in cinnamon powder. Principal Component Analysis (PCA) was employed to effectively capture the spectral variance within the dataset, facilitating the clustering of samples into distinct groups based on their purity or adulteration status. Furthermore, Partial Least Square Discriminant Analysis (PLS-DA) was utilized to discriminate between pure cinnamon and adulterated samples, achieving sensitivity levels exceeding 70% and accuracy rates surpassing 80%. In summary, the integration of portable NIR spectrometry with chemometric methodologies presents a promising screening tool for the detection of nutshell adulterants in cinnamon powder. This innovative approach holds significant potential for ensuring the integrity and quality of cinnamon products in the food and pharmaceutical industries.

Detection of sugar syrup adulteration in honey using novel DNA markers

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Abstract

Honey is a valuable natural food product, meaning it could be susceptible to fraudulent practices such as dilution with cheaper sugar syrups, for economic gain. Current methods for honey authentication have limitations and are faced with challenges due to the large variations in natural honey composition, or the incapability to detect certain types of plant syrups/confirm species origin. Molecular methods such as DNA barcoding have shown great promise in identifying plant DNA sources in honey and could be applied to detect plant-based sugars. We aim to investigate the suitability of using DNA markers for sugar adulterant detection in honey, with the goal of developing novel methodology for honey authentication.

DNA markers were designed for common sugar syrups (corn, rice and sugar beet) and tested for specificity using plant controls. DNA was extracted from sugar syrups (n=18) and tested with qPCR to assess the presence of plant DNA. Pure honeys (n=17) were spiked with syrup at different levels of adulteration (1, 5, 10 and 30%) to evaluate the suitability of the method and determine limit of detection. The level of marker amplification in the different pure honeys was evaluated and thresholds were set to prevent false positive results.

Plant DNA was detected in all the sugar syrups tested using commercial DNA extraction kits and the markers for corn and rice were successfully amplified in syrup extracts. The rice and corn markers were respectfully detected at 1% adulteration level, showing that the method is highly sensitive. Furthermore, the amplification of the 1% spiked honey samples were clearly distinguished from the background amplification in natural honey, with a false positive rate of 0%.

We demonstrate that DNA barcoding can be used as a robust method to detect rice and corn syrup adulteration in honey, with a detection limit of 1%. This could be applied to confirm the species origin of the sugar alongside current screening methods, to improve existing honey authentication tests and contribute to the weight of evidence approach.

A critical review on biological and chemical approaches for traceability of adulteration and contamination in dairy alternatives

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Abstract

In recent years, there has been a notable shift in consumer behavior and attitudes towards food, marked by a growing demand for foods that prioritize safety, nutrition, and sustainability. Today, consumers are increasingly making choices driven by health considerations, environmental consciousness, and ethical or religious beliefs. The implementation of robust authentication and traceability systems throughout the supply chain is crucial for enhancing food safety and preventing instances of food fraud. The objective of this study is to assess the potential of both biological and chemical approaches in revealing the composition of food products, as well as detecting instances of food adulteration and cross-contamination during processing. Biological techniques such as conventional PCR, qRT-PCR, ddPCR, DNA barcoding, high-resolution melting, and chemical methods such as HPLC, QuEChERS, LC-MS/MS, and GC-MS/MS can be employed to achieve this objective. It can be inferred that DNA-based methods are predominantly utilized for identifying adulterants in food products, whereas analytical methods are primarily employed for detecting contaminations such as mycotoxins, pesticides, and chemical elements.

Advances in the analysis of pesticide and polychlorinated biphenyls (PCBs) using Orbital ion Trap High-Resolution Mass Spectrometry

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Abstract

As regulatory demands evolve, reflecting lower maximum residue limits and broader analytical scopes mandated by the European Union, our team has developed and validated comprehensive analytical methods using Gas Chromatography High-Resolution Accurate Mass Spectrometry (GC-HRMS) and Liquid Chromatography High-Resolution Mass Spectrometry (LC-HRMS). This method addresses the need for detecting pesticide across diverse food matrices to ensure consumer safety and regulatory compliance.

Our approach combines GC-HRMS and LC-HRMS technologies to concurrently quantify over 470 pesticides, including polychlorinated biphenyls (PCBs). The validation of these methods shows superior performance characteristics — enhanced linearity, precision, recovery rates within 85-115%, and reproducibility — essential for adhering to EU Regulations 396/2005 on pesticide residues.

The poster will delve into the challenges and solutions in analysing complex matrices such as fruits, vegetables. It will also explore the practical implications of these methods for regulatory bodies, the adaptability to high-throughput environments, and the technical hurdles of implementing advanced analytical technologies in routine testing. A comparison of High-Resolution Accurate Mass (HRAM) Orbitrap systems to QQQ systems will be made regarding the advantages and limitations of both techniques and their use for non-targeted analysis.

This presentation aims to share actionable insights and robust methodologies that enhance food safety standards and fraudulent activity across the EU and beyond.

Keywords: Pesticide Analysis; HRAM Mass Spectrometry; LC-HRMS; Food Safety; Method Development; Regulatory Compliance; EU Regulations

Enhanced oxidase-like activity and surface enhanced Raman spectroscopy (SERS) performance of γ-cyclodextrin-capped nanoparticles for bimodal detection of chlorpyrifos with dual sensitivity modes

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Abstract

Despite the prohibition of synthetic pesticides in organic production, their traces are frequently detected in organic foods, highlighting the pressing challenges of food fraud and environmental contamination. There is a pressing need for the development of a robust and efficient pesticide detection platform. In this study, a Surface-Enhanced Raman Spectroscopy (SERS)-colorimetric bimodal biosensor based on γ-cyclodextrin (γ-CD) capped silver and gold nanoparticles has been functionalized for high-efficiency quantification of pesticide, chlorpyrifos (CPF). The γ-CD capped nanoparticles exhibit remarkable oxidase-like characteristics and SERS enhancement of catalyzing the colorless 3,3′,5,5′-tetramethylbenzidine (TMB) oxidation to its blue oxide (oxTMB) and simultaneously enhance the SERS signal of oxTMB. Furthermore, the nanoparticles synthesized by γ-CD, known for their unique host-guest structure, capture CPF molecules, thereby enhancing the interaction of CPF with nanoparticles. As a result, the introduction of CPF inhibits the oxidation of TMB, leading to color fading and a diminishment of the SERS signal. Consequently, the absorbance peak of oxTMB at 370 nm and the Raman peak at 1190 cm^{-1} exhibit an inverse linear relationship with increasing CPF concentrations. This positions the bimodal sensing platform thereby emerges as a potent tool for the SERS-colorimetric detection of CPF, offering a straightforward, rapid, cost-effective, and highly sensitive method for CPF detection, thereby contributing significantly to efforts to combat food fraud.

Emerging fraud challenges against alternatives proteins

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Abstract

Emerging alternative sources of proteins from plants, insects, algae, microbe fermentation, and cell-culturing techniques have exhibited different degrees of potential as complementary and/or substitutes for animal-based proteins. Within the context of food security and nutrition, protein is a vital macronutrient that provides a variety of amino acids essential for human development and growth. Therefore, one of the top priorities is to find sustainable and efficient ways to increase food production, especially in relation to protein sources in agreement with reducing carbon dioxide emissions from animal-based proteins. Health risks associated with the consumption of alternative proteins have not been well-studied and denote a concern for both the food industry and regulatory authorities. One cause of these risks occurring in alternative sources of proteins could be fraud, exemplified by notable protein fraud scandals in the world such as melamine added in infant formula and the horsemeat scandal in the UK. Based on past food fraud incidents, the probability of an alternative protein scandal is high. This study aims to exploit cutting-edge analytical technology to develop rapid, efficient, and portable on-site analytical methods to determine food authenticity and understand possible fraud risks in the global alternative protein food supply chains. The methodology development to authenticate sources of plant and insect-based proteins will consist of three targets: a) detection of DNA (b) nitrogen-rich chemicals adulterant detection (c) identification of adulterant proteins. Consequently, machine learning algorithms will be chosen and utilised during the data processing to improve the method's performance.

Metabolic fingerprinting for verifying authenticity in raw and toasted PDO hazelnuts

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Abstract

The dependence of hazelnut market prices on cultivar and origin makes them potentially vulnerable to fraud. Due to hazelnuts' extensive utilization in both raw and semi-processed forms across various industries, fraudulent practices represent a concern within the industrial sector. This is especially true for products recognized under EU designations like Protected Designation of Origin (PDO) and Protected Geographical Indication (PGI). Therefore, reliable verification tools are essential to ensure authenticity and protect consumers.

The unsaponifiable lipid fraction, containing stable metabolites influenced by genetics and environment, emerged as a promising method for authenticating raw hazelnut cultivars and origins[1]. Moreover, untargeted methods, especially fingerprinting methods, surpass traditional approaches by incorporating comprehensive analytical data, thus significantly enhancing authentication efficiency.

This prospective study aimed to evaluate the unsaponifiable fraction fingerprint, obtained through gas chromatography-mass spectrometry and pattern recognition analysis, for authenticating "*Avellana de Reus*" (Spain) PDO hazelnuts from commercial Turkish hazelnuts, both in their raw and roasted forms. Chromatographic fingerprints from traceable hazelnuts were used to develop three partial least square-discriminant analysis (PLS-DA) models to classify: (i) PDO vs. Turkish raw hazelnuts (n=60); (ii) PDO vs. Turkish roasted hazelnuts (n=60); (iii) PDO vs. Turkish hazelnuts regardless of their processing, within a comprehensive model incorporating both raw and roasted samples (n=120).

For each model (raw, n=60; roasted, n=60, raw +roasted, n=120) the sample set was randomly divided into training (80%) and validation (20%) sets. This random splitting was run 3 times, obtaining three different training and test sets for each model. The external validation of the three models yielded a 100% correct classification, suggesting a high potential of unsaponifiable fraction fingerprinting for hazelnut geographical authentication even after a thermal processing. Further testing on a larger sample set will refine and strengthen classification models. This research represents a significant step towards establishing robust tools to safeguard the integrity of the hazelnut market and consumer trust.

[1] Torres-Cobos, B., Quintanilla-Casas, B., Rovira, M., Romero, A., Guardiola, F., Vichi, S., & Tres, A. (2024). Prospective exploration of hazelnut's unsaponifiable fraction for geographical and varietal authentication: A comparative study of advanced fingerprinting and untargeted profiling techniques. Food Chemistry, 441, 138294.

A two-tier approach for the detection of contaminants and adulterants in sunflower oil to protect consumer safety

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Abstract

The global vegetable oil market is valued at US$105.6 billion, with sunflower seed oil ranking fourth in consumption. However, recent events like the COVID-19 pandemic and the Ukraine war have disrupted production and supply chains, leaving it vulnerable to fraudulent practices such as adulteration with cheaper oils and mineral oils. This poster analyses the underlying causes and consequences of adulteration in the sunflower oil industry, as well as the analytical techniques utilized for its identification and mitigation. Consuming low-quality imported food due to economically motivated adulteration can have adverse effects on the economy and consumer health. For instance, the food poisoning epidemic caused by Spain's fake olive oil scandal severely jeopardized the consumer health of the country. Thus, considering these factors a two-tier approach is required to identify and mitigate the occurrence of fraud and any contaminants. The tier 1 rapid screening tool is a Raman spectroscopic technique coupled with chemometrics for the on-package in situ inspection, and the tier 2 confirmation tool is a chromatographic technique augmented with Mass spectrometry to authenticate suspected samples identified in tier 1 screening. Incorporating Artificial Intelligence and the Internet of Things (IoT) in a two-tier approach can efficiently ensure food safety in the global supply chains.

Watson: To improve the food authenticity and traceability of EU food supply chains by the digital technology-based framework

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Abstract

Recently, food fraud has become a major issue that poses risks to the food safety and integrity of the food supply chains. Due to the rising global population and the increased demand for safe and healthy food, a digital transition from traditional chemical testing to a smart monitoring system is necessary to implement mitigation strategies for food fraud. Therefore, this study aims to strengthen food authenticity and traceability driven by digital techniques to combat food fraud by investigating the emerging trends of digital technologies in the food supply chain. The ongoing study framework is part of an EU project, Watson, which aims to improve the food authenticity and traceability of EU food supply chains by the application of different digital technologies.

According to its design of Watson, this digital framework involves the use of various digital technologies and platforms, such as portable DNA-based devices, multi-sensor scanning devices, the IoT platform, the blockchain platform, mobile Apps, and the digital passport, at different supply chain stages to prevent food fraud. Additionally, an early warning system based on robust and explainable artificial intelligence (AI) will also be established in this food fraud prevention framework.

The research in Watson framework also contributes to raising consumer awareness regarding food safety and value, ultimately leading to adopting healthier lifestyles and developing sustainable food ecosystems. By addressing the current condition in the food supply chain and continuously improving the presented framework, the integrity, authenticity, and traceability of the EU food supply chain can be collectively enhanced, ultimately protecting consumers and fostering trust in the food industry.

Food authenticity analysis: current state of the art in analytical biosensor methods

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Abstract

Food authenticity is a major concern in the food industry, causing ethical and moral concerns, economical impacts and posing health and safety problems. Following scandals of meat adulteration, there has been a call for reliable testing of products and tighter labelling legislations. The current approaches to food authentication revolve heavily around laboratory-based techniques as the gold standard for detecting food contaminants, particularly in relation to meat authentication. Methods available include PCR, ELISA and mass spectrometry however there is a lack of a commercially available meat speciation tool that tests simultaneously for the species adulteration of animal and vegetarian, vegan and halal products.

The development of biosensors in this area offers a faster, multiplex approach that can be used by a wider community of individuals and business that need reliable results in a small timeframe. Antibodies have been used in ELISAs to generate species-specific tests, and PCR kits are available to test for species-specific DNA in raw food products. An evaluation of the current analytical and biosensor methods of analysis has been completed with the aim to develop a state-of-the-art biosensor tool for speciation detection.

The effects of formulation, boiling process and their interaction on the stable hydrogen isotopic ratios in noodles

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Abstract

Stable isotopes are commonly utilized for the geographical origin verification of foods including wheat. However, assessing processed products poses a greater challenge due to the alterations that take place during processing and which have not been fully elucidated yet. In the current study, the effects of formulation (the mass ratios of gluten to starch), boiling process and their interaction on the stable hydrogen (δ^2H) isotopic ratios of wheat noodles were evaluated. The δ^2H of the noodles with different formulations (the mass ratios of gluten to starch) as raw materials, in the uncooked and cooked (boiled in water) noodles were examined. Results indicated that the δ^2H of boiled noodles ranged from -80.1‰ to -46.8‰ were significantly lower than those of the raw materials ranged from -73.0‰ to -39.2‰ and uncooked noodles ranged from -73.3‰ to -39.6‰. In addition, Formulation is the main factor which influenced δ2H followed by the Boiling process and Formulation × Boiling Process. This study also shows that the hydrogen stable isotopic compositions of noodles were significantly changed during boiling process and the isotopic fractionation varies with the different formulations. The current will provide a theoretical basis and data reference for applying valid analytical methods for the traceability and authentication of processed wheat products in future study.

Authenticating Tibetan pork based on species and geographical features by using stable isotope and multi-elements analysis

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Abstract

Multi-elements (11 trace elements and 6 minor elements) and isotopes analysis ($\delta^{13}C$ and $\delta^{2}H$) was used to examine the authenticity of Tibetan pork based on species and geographical origins. Meat samples from two muscle types (*Longissimus thoracis* muscle and *Semitendinosus* muscle) were sourced from 93 pigs, which included Tibetan pigs from two regions (Tibet and Sichuan) and two lowland pig types (Jilin and Duroc×Landrace×Yorkshire from Liaoning). The $\delta^{13}C$ and $\delta^{2}H$ were determined using an isotope-ratio mass spectrometer, while the concentrations of minor and trace elements were measured using inductively coupled plasma mass spectrometry (ICP-MS). The data were subjected to multivariate analysis, including linear discriminant analysis (LDA), clustering analysis, and correlation analysis, which revealed significant discrimination effects for authenticating Tibetan pork. Cross-validation of LDA models displayed high accuracies for discriminating species and regions (95.7% and 97.8%), respectively. The elements Fe, Cu, Cs, Rb, and Mo were found to be important markers for authenticating Tibetan pork and were positively linked with pig breeds living in high-altitude and low-precipitation regions, whereas $\delta^{13}C$ and $\delta^{2}H$ had negative relationships with altitude. Multi-elements combined with isotope analysis could be utilized to develop a reliable technique for characterizing Chinese high-altitude pig breeds and preventing pork fraud.