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Identifying the Fraud and Authenticity of Meat Products by Infrared Spectroscopy: A Systematic Review

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ABSTRACT

Meat and meat products are very valuable and widely consumed, therefore, it is necessary to detect fraud in these products. The purpose of this review is to introduce and debate on quick and easy diagnostic methods for the identity of meat and meat products. For carrying out this review, scientific databases and search engines for finding the articles were “Google Scholar”, “SID”, “Scopus”, “PubMed”, “Science Direct”, and “ISI”. The search was done for articles published that included the search term containing, authentication, meat products, health, and risk assessment in their title. This study focused on published articles from 2016 to 2022. The studies indicated that classical analytical methods have replaced fast, simple and non-invasive methods to increase productivity and profitability in the meat supply chain. Fourier transform infrared (FTIR) spectroscopy, near infrared (NIR) spectroscopy have become valuable analytical methods for structural or functional studies related to foods as a fast, non-destructive, cost-effective, and sensitive physicochemical fingerprinting method. The studies indicate that ATR-FTIR spectroscopy had better results statistically and functionally.

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Intordution

Despite the increase in the variety of foods consumed and the diversity of nutritional culture, meat as a common food and the main source of protein has maintained its main place in the diet of families, so it is necessary to pay attention to the health of meat and its products (Sarab, 2020; Shahhosseini et al., 2017; Mohamed Elshater et al., 2022; Harsij et al. 2020; Mohamed Elshater et al. 2022; Wibisono et al. 2023).
Meat and meat products are the main suppliers of protein to the body, which indicates the importance of their consumption in human nutrition (Alikord et al., 2017; Ahmadi et al. 2021). Today, and especially in urban communities, meat products such as sausages have a special place in the diet of people around the world, so that Germany, as the largest producer of meat products, has a per capita consumption of more than 40 kg per year and per capita consumption in Iran more than 5kg (Naseri-Razlighi et al. 2005; Rokni, 2006). Meat products are products that contain at least half of them meat. Most meat products prepared in our country are hot sausages (Sadeghpour. et al. 2020). It is one of the most important food safety topics (Deniz, et al.

2018). Food fraud poses a threat to public health and has become a major challenge for industry and government due to its opportunistic nature (López-Maestresalas et al., 2019). Many consumers today have immediate concerns about the meat they consume, and accurate labeling is an important step in making an informed consumer choice. Covering counterfeit meat products is an important process for a number of reasons, mostly related to health concerns (Alikord. et al., 2018). The abuse of some food producers has led to more attention being paid to the ingredients of meat products. Therefore, the correct labeling of products, especially in processed products, where the ability to distinguish one component from other components is difficult, is of particular importance (Alikord et al., 2017). Given the relatively high cost of raw meat, the possibility of fraud and the replacement of illegal animal tissues with red meat in these food products is not out of the question (Naseri-Razlighi et al. 2005). Consumers are concerned about various issues such as food authenticity and fraud (Mandli et al., 2018). Fraud in processed meat products is very severe, due to the composition of minced meat, which can be easily replaced with unlabeled meat species (Zhang et al., 2022).

In the discussion of fraud, meat has been used in meat products in a mixed and minced form and inseparably with the naked eye (López-Maestresalas et al., 2019). Deliberate cheating of meat is the replacement of valuable species with cheaper species or fresh meat with frozen meat, Food choices often reflect aspects of lifestyle, culture, religion, diet, and health concerns (Cavin et al. 2016). The consequences of intentional meat fraud can endanger people's health, such as infectious diseases, metabolic disorders or allergies, and the transmission of many common diseases between animals and humans (Cavin et al. 2016). It raises economic and lifestyle concerns (e.g., vegetarianism or organic foods, among others) and religious concerns (e.g., lack of pork in halal products or beef in Hindu diets) (Woolfe. et al., 2013). Unauthorized tissues as defined by the Institute of Standards and Industrial Research of Iran, including viscera, breast, liver, lung, spleen, bladder, spinal cord, as well as glandular and cartilaginous tissues (vessels, pi), peritoneal fats, and meat (meat) and their use is prohibited. The use of chicken meat and textures such as chicken gizzards and stratifies in red meat products is also prohibited. These tissues are much cheaper than meat, which leads profiteers to cheat (Sadeghpour et al. 2020). A research on thousand types of meat products has shown that nearly 20% of products are not of reliable quality because they are labeled (Li et al. 2019). Another study found that 25.6% (64 samples) of sausages containing chicken, pork, beef and duck purchased from local markets in Sichuan, China, were potentially counterfeit. The most common false label was adding undeclared ducks to products with chicken and pork labels. In addition, it showed that 57% of packaged meat products, including sausages from Italian markets, contain unlabeled ingredients of pork, beef and chicken (Zhang et al., 2022). Deliberate cheating of meat is the replacement of valuable species with cheaper species or fresh meat with frozen meat (Alamprese et al., 2016). Meat adulteration is a broad topic, and meat products are often among the main categories of food products that are susceptible to adulteration. Studies show that, in terms of authenticity, meat products are the most studied foods of animal origin (Figure 1). To solve the problems related to meat adulteration, many techniques based on protein and DNA, chromatography, elemental profiling and isotopic analysis have been used (Creydt et al., 2020; Hassoun et al., 2020). Although, most of the above methods have disadvantages such as being time-consuming and costly and their destructive nature. There is a desire to develop non-destructive, fast, accurate, strong and powerful analytical methods (Hassoun et al. 2020); Therefore, fast, sensitive and reliable analytical methods are needed to recognize multiple meat types in meat products. In this review paper, we have tried to introduce and debate on quick and easy diagnostic methods for the identity of meat and meat products.

Methods

Search strategy

The databases and search engines including “Google Scholar”, “SID”, “Scopus”, “PubMed”, “Science Direct”, and “ISI” were search. The search was done for articles published that included the search term containing, authentication, meat products, health, and Risk assessment in their title. This study focused on published articles from 2016 to 2022.

Study assortment

The flowchart of the study desingn has been indicated in figure 1. 870 records identified through database searching by a combination of keywords.

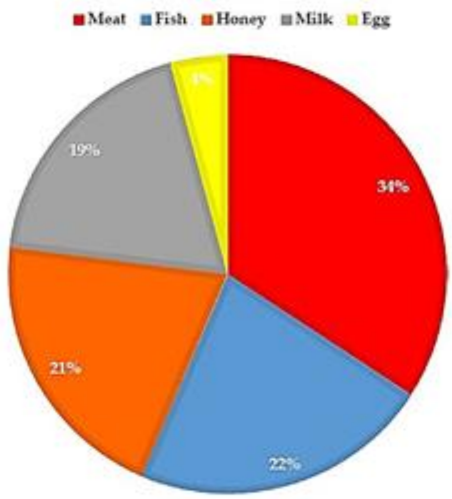

Figure 1. Publications distributed between the different foods categories

Table 1. Summary of references applying infrared spectroscopy to meat products adulteration detection.

Meat and Meat Products	Matrix/adulterant/ sample type	Detect technique	Spectral range/Feature	Data processing	Refference
Beef	Identification of non-meat component	FT-IR	4000–525 cm-1	PLS-DA	(Nunes et al. 2016)
Mutton, beef, pork	Identification of the type of species	FT-IR	4000–450 cm-1	PLS-DA	(Yang et al. 2018)
Poultry	Identification of the type of species	FT-IR	4000–550 cm-1	PCA, PLS-DA	(Gao et al. 2017)
Pig	Identification of feeding regime	NIR	900–1700 nm	LDA, QDA	(Piotrowski et al., 2019)
Beef, lamb, pork	Identification of the type of species	FT-NIR	1100–1938 nm	SIMCA	(Pieszczek et al., 2018)
Pork	Identification of the type of species	FT-NIR	750–2500 nm	PLS-DA	(Chiesa et al., 2016)
Lamb, beef, pork	Identification of the type of species	HSI VIS-NIR	548–1701 nm	CNN	(Al-Sarayreh et al., 2018)
Rat	Identification of the type of species	FT-IR	4000–400 cm-1	PCA, PLSR	(Rahmania et al., 205)
Pork	Identification of the type of species	FT-NIR	-	PCA, SVM	(Schmutzler et al., 2015)
Beef	Meat detection	VIS-NIR HIS	496–1000 nm	SVM, LS-SVM, PLSR	(Zhao et al., 2019)
Turkey cuts, processed products	Meat detection	VIS-NIR	400–2500 nm	PCA, LDA	(Barbin et al. 2020)
Lamb, beef	Identification of the type of species	NIR	1100–2300 nm	PCA, PLS-DA	(López-Maestresalas et al., 2019)
Duck, beef, pork	Identification of the type of species	NIR	12500–5400 cm-1	DA, PLSR	(Leng et al., 2020)
Beef	Identification of the type of species	NIR	350–2500 nm	SVM, RF, PLSR,	(Weng et al., 2020)
Tan mutton	Meat detection	NIR HSI	900–1700 nm	PLS-DA	(Li et al., 2019)
Chicken	meat/frozen-thawed chicken meat	FT-IR	4000–500 cm-1	HCA, ANN	(Grunert et al., 2016)
Beef	Beef meatballs/dog meat/extracted fat	FT-IR	ATR/4000–650 cm-1	PLS-R, PCA	(Candoğan et al., 2021)
Beef	Beef/textured soy protein/dried samples	FT-IR	ATR/4000–400 cm-1	PCA, PLS-R, ANN	(Keshavarzi et al., 2019)
Beef	Beef/chicken meat/dried Samples	FT-IR	ATR and transmittance/4000–400 cm-1	PCA, PLS-R, ANN	(Keshavarzi et al., 2020)
Beef	Beef mixtures/pork, horse, and donkey meats	FT-IR	ATR/4000–850 cm-1	PCA, HCA	(Candogan et al., 2020)

Results and Discussion

Fraud and authenticity of meat product

The Food Manufacturers Association estimates that global food adulteration costs between 10$ and 15$ billion per year, affecting approximately 10% of all commercially sold food products (Manning et al., 2014). Although adulteration was common in the past, nowadays issues of food authenticity are more important (Manning et al., 2016). Leng et al., showed the counterfeiting of duck, cow and pig meat was revealed by NIR (Leng et al., 2020) and Candoğan et al., showed the counterfeiting of beef meat was revealed by FT-IR (Candoğan et al., 2021). However, studies show that food fraud continues to occur, especially in meat products (Robson et al., 2016). The globalization of the market and the increase in international trade, the great variety of these products, as well as the more complex forms of fraud are the reasons (Fiorino et al., 2018; Ghidini et al., 2019). Adulteration of products of animal origin can occur in many ways, such as incorrect labeling of origin, differences in processing methods, field methods, and undeclared ingredients (Figure 2) (Hassoun et al., 2020).

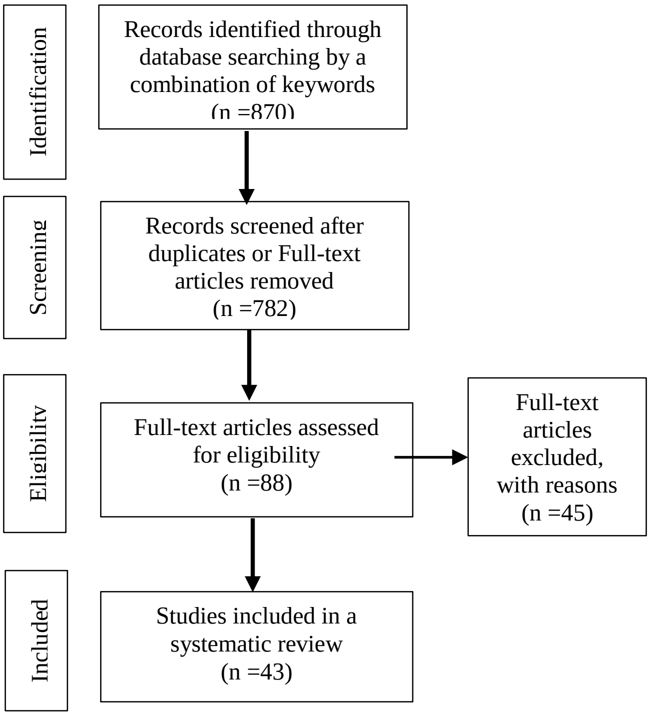

Figure 2. A flowchart of study

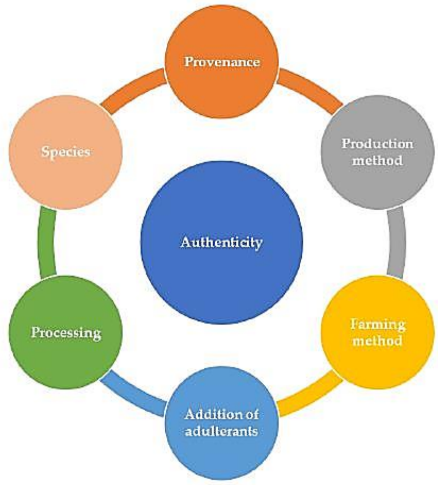

Figure 3. The most frauds that have occurred in meat products

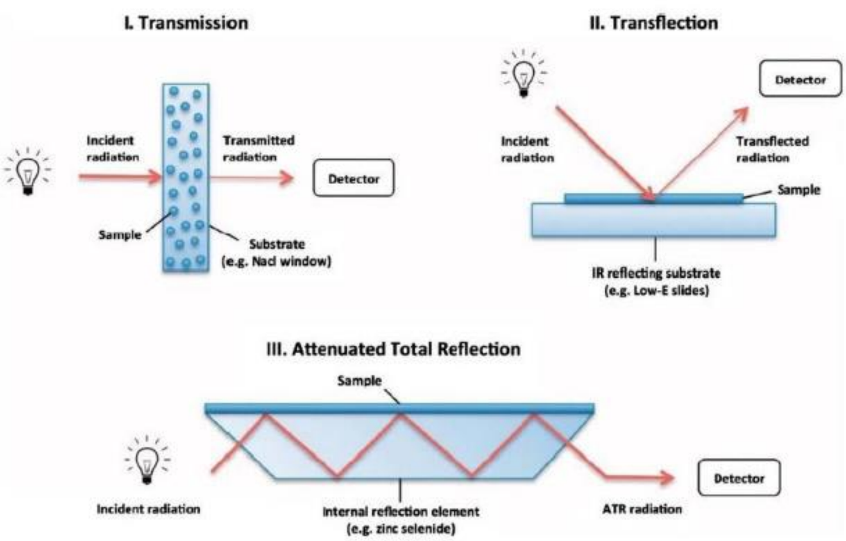

Figure 4. Different types of sample presentation in FTIR methods

Infrared vibrational spectroscopy

Infrared spectroscopy is a vibrational spectroscopy technique based on the relationship between the interactions of infrared (IR) radiation with matter (Candoğan et al., 2021). Mid-infrared spectroscopy is a part of the vibrational spectroscopy method in which mid-infrared radiation is used. When a substance is affected by infrared radiation, the absorbed spectrum leads to the excitation of molecules and the creation of a vibrational transition state. The absorbed wavelength is a function of the energy difference between the two vibrational levels; therefore, according to the absorbed wavelengths, the vibrational levels and molecular structure of the substance can be understood. For this purpose, first the background spectrum of the infrared source is recorded, then the output spectrum is recorded with the presence of the sample. The ratio of the sample spectrum to the background spectrum has a direct relationship with the absorption spectrum; because any wavelength that is present in the background output spectrum, but not in the sample spectrum, has been absorbed by the sample (Su wt al., 2019; Sun et al., 2009). Waveforms are actually the sum of simple sinusoidal functions with different frequencies. Fourier transform can decompose the waveform which is a function of time into its constituent frequencies. In fact, the Fourier transform can be applied to waveforms that are a function of time, space, or any other variable, and in this way, the corresponding wave can be decomposed into its component sinusoidal functions. Infrared Fourier transform spectroscopy can be used in various sciences and industries by providing advantages such as low cost and high speed (Su wt al., 2019; Sun et al., 2009). The three methods used to examine and present the sample in the FTIR method are schematically stated (Figure 3) (Su wt al., 2019; Sun et al., 2009).

Conclusions

Food adulteration is a widespread concern for all food consumers. Food fraud detection strategies are being developed. In the past decades, infrared spectroscopy has been used as a powerful tool to detect food fraud. These techniques demonstrate the ability to detect food adulteration without destroying the integrity of samples. It was found that infrared spectroscopy has a high potential in the use of other non-destructive analysis techniques in the field of food adulteration and is also a fast, easy and generally cost-effective way to detect food adulteration. Spectrophotometric data integration is a promising tool, especially in food analysis, where the complexity of the matrix can sometimes be investigated with only two or more techniques.

Declarations

Conflict of interest

The authors declare that they have no conflict of interest.

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Consent for publications

The authors approved the manuscript for publication.

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None.

Authors' contributions

MP and NS had contribute in writing, editing and approving the manuscript.

Ethical considerations

Ethical issues (including plagiarism, misconduct, data fabrication, falsification, double publication or submission, redundancy) have been completely observed by the author.

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