

# HALALSPHERE

International Islamic University Malaysia - INHART



## Challenges Faced by *Halal* Meat Industry: A Review

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### Abstract

The demand trend for *Halal* meat and meat-based products among *Muslims* worldwide has increased in recent years. Meanwhile, the awareness among non-*Muslims* of *Halal* meat and meat products is due to their high quality and safety, thus resulting in more access to *Halal* meat and meat-based products for them. Due to the technological advancements in the meat processing sector, adulteration and fraud have grown more widespread due to the financial gain that can be realized. The issues associated with *Halal* meat have created an opportunity for researchers, scientists, consumers, manufacturers, and regulators to work together to determine whether meats produced in the industry are *Halal*, safe to be consumed and free from food-borne pathogens. *Halal* authentication technology can assist in addressing this issue, whilst as a result, can assist juries in assessing the status of the products with a high degree of precision. The objectives of this review paper are to discuss and review the challenges of the *Halal* meat industry, including the analytical procedures used to ensure that *Halal* meat products have long-term viability in Malaysia. The methods used to review the selected topics are searching the extant literature available in the online and offline sources, screening for topic inclusion, assessing, extracting and discussing the available data obtained in the updated journals. In conclusion, numerous challenges are faced by the *Halal* meat industry, and they should be addressed by focusing on realistic prospects to enhance the production of local meat, which is critical in guaranteeing the supply of *Halalan Toyyiban* meat is bounteous and secured.

## 1. Introduction

*Halal* is a root word derived from the Arabic language that means 'permissible' or 'lawful'. *Halal* can also be defined as something permitted by *Islamic* law without punishment being put on the perpetrator. It is banned and unlawful to do something *Halal*, which is *Haram*. Meanwhile, *Toyyib* is a root word derived from the term *Toyyib*, which means 'good'. As a result, *Halalan Toyyiban* refers to a product that is 'permissible to consume or use and must be good and useful to the user'. *Halal* and *Toyyib* lifestyle is a way of life where only the best allowed and wholesome choices are applied or practised to ensure the safety and well-being of humankind (For this write up, the terms *Halal* and *Toyyib* are written in print). Such a lifestyle is practised throughout the world and not only in countries with a *Muslim* majority but also in *Muslim* minority populations (Hidayat & Siradj, 2015).

Customers are entitled to acquire the wholesomeness and the best food product that does not contain illegal elements harmful to health. Besides, for *Muslims*, consuming *Halal* food is an obligation. Raw materials that contain animal meat slaughtered according to *Shari'ah* guidelines will be safe to

eat because their hygiene and safety are guaranteed. Thus, it is the right of *Muslim* consumers worldwide to confirm that the meat products are not contaminated with the presence of pork or pork derivatives as well as there is no adulteration with the *Halal* logo endorsed by each community (Erwanto *et al.*, 2018).

Food authenticity is the completeness of significant components and is not messed up with the complete or partial replacement of food ingredients with non-proclaimed alternative ingredients (typically cheaper), cover-up food damage or the use of cheap foodstuffs and the addition of an unannounced substance to increase the mass of the production to improve the taste of a product (Luxminarayan *et al.*, 2017) as well as the application of pork by-product. Pork by-products used in meat processing comprise lard extracted from adipose tissue, Mechanically Recovered Meats (MRM), pork gelatine and pork blood plasma. In *Islamic* legislation, consuming pork derivatives have been banned, as addressed clearly in the *Qur'an* and consuming pork and its derivatives are forbidden for *Muslims* (*Qur'an* 5:3). Scientifically, pigs are hosts to several parasites that can endanger human health. Thus, the scientific findings enlighten the forbiddance

of consuming pigs and their derivatives in *Islamic* law. From this matter, it is necessary to develop and test a standardization of analytical methods to identify pig derivatives in food products (Mursyidi, 2013).

The analytical techniques for contaminating pig's derivatives and other prohibited elements are Fourier Transform Infrared (FTIR) Spectroscopy, Electronic Nose, Chromatography Method and Polymerase Chain Reaction (PCR). These authentication techniques can assist in addressing adulteration issues in meat. Therefore, this review paper aims to review and discuss the current state of the challenges and issues of adulterating meat and several techniques used to identify prohibited elements such as pork in food products to create an understanding among readers regarding the challenges faced by the *Halal* meat industry including the technical method to validate the *Halal* status of the meat products by reviewing the selected topics are through the searching of the extant literature available in the online and offline sources, screening for topic inclusion, assessing, extracting and discussing the available data obtained in the updated journals.

## 2. Basic concepts of *Halal* meat

The basic concept of *Halal* food is clearly explained in the *Qur'an* and *Hadith*. *Muslims* are required to consume the meat of an animal upon which Allah's name has been called, according to the *Qur'an* (invocation during the slaughtering of the animal) as stated in the *Qur'an* in *Surah Al-An'am* Verse 118:

*"Therefore, eat of that upon which Allah's name has been mentioned if you are believers in His communications," (Qur'an 6:118)*

*Halal* meat must not be derived from any of the forbidden meats listed in the *Qur'an*, as stated in *Surah Al-Maidah* Verse 3:

*"Forbidden to you is that which dies of itself, blood, and flesh of swine, and that on which any other name than that of Allah has been involved, and the strangled (animals) and beaten to death, and that killed by a fall and that killed by being smitten with the horn, and that which wild beasts have eaten, except what you slaughter before, and what is sacrificed on stones set up (for idols); and that you divide by the arrows, that is transgression. This day, those who disbelieved have despaired of your religion, so fear them not, and fear Me. This day, I have perfected your religion for you and completed My favour on you and chosen Islam as the religion for you, but whoever is compelled by hunger, not inclining willfully to sin, surely Allah is Forgiving, Merciful" (Qur'an 5:3)*

All animals that are slaughtered accordingly to *Islamic* practices are *Halal* except for *Haram* animals which were mentioned in the holy *Qur'an*, such as pigs, dogs, and predatory animals that are slashed and killed, such as lions, tigers, cats, bears, and similar animals; animals with tusks such as elephants; animals that are permissible to be exterminated in *Islam* such as centipedes, scorpions, rats, and other similar animals; while land animals are *Halal*. Similarly, all birds are *Halal* except for birds of prey and

scavengers, defined as those with claws that feed by snatching and tearing, such as eagles, and birds that are prohibited from being killed in *Islam*, such as woodpeckers (Anonymous, 2021).

From the verses of the *Qur'an* mentioned above, the specifications of *Halal* meats are clearly explained. Technically, in the food industry, raw materials for food production should be obtained from *Halal* sources coming from *Halal* certified suppliers. *Halal* sources of food are not only *Halal* as described by the Holy *Qur'an*. However, they must also be certified by an authorized organization such as the Department of *Islamic* Development Malaysia (JAKIM), the agency responsible for *Islamic* affairs, including *Halal* certification in Malaysia.

## 3. Prohibition of pork and its by-product

*Muslims* are not allowed to eat pork and its derivatives; consuming it is sinful (*Haram*). Scientifically, many studies have proven that consuming pork and its derivatives will lead to adverse effects on human health. According to Musdja (2018), pigs have several negative characteristics, such as being the most voracious animal, filthy and raunchiest in their class, and gluttonous pigs that go above and beyond the gluttony of other animals. Pigs also enjoy eating carrion and the faeces of other animals they come into contact with. Because of the greedy nature of pigs, if there is nothing else for them to eat, they will consume the vomit from their stomachs.

Furthermore, pigs are notorious for urinating on their food, and they will eat food contaminated with other pigs. Besides their negative characteristics, they are a variety of harmful bacteria and viruses found in pigs that can be transmitted to humans. Hence, their meat is more difficult for the human body to digest as it is almost identical to human genetics out of all species studied (Murdja, 2018).

According to Denner (2014), the retrovirus virus found in the pig is harmful, and this virus is responsible for developing cancer disorders. Besides retrovirus, the virus H3N2 (Hong Kong flu) is a pig-borne virus that has caused sickness. Hong Kong's influenza epidemic in 1968 triggered the pandemic, resulting in over 34,000 deaths in the United States (Kulkarni, 2019). On the other hand, the pig breeder is always looking for ways to gain an economic advantage. As a result, pig breeders will only breed pigs with a genetic predisposition to obesity. In this instance, the pigs' enzyme and obesity gene may drive the consumer to become obese. According to a medical study, obesity is a significant risk factor for cardiovascular disease owing to the high cholesterol and fat content of pork, both of which are difficult for the human body to metabolize (Anand *et al.*, 2015). Foods cause various disorders with high cholesterol and fats. These include, among other things, arterial hardening, increased blood pressure, gripping chest discomfort (angina pectoris) and inflammation (pain) of the joints of the body (Denner, 2014).

## 4. *Halal* meat adulteration issues

Adding undisclosed chemicals or materials to a product to increase the bulk or weight is considered adulteration. This practice makes the product appear more valuable than it is (Roberts & Turk, 2017). In the case of meat and meat

products, adulteration relates not only to the substitution of ingredients but also to the provision of incorrect information regarding the provenance of raw materials (Johnson, 2014). Literature research has revealed various difficulties associated with confirming food product adulteration. Some of the issues are as follows:

#### 4.1 Carcasses

The term 'carcass' is employed when it comes to animals that have died, whether from an accident or disease. The death of an animal without slaughter is usually caused by one of two factors: first, the animal dies on its own without the intervention of people, such as sickness; and second, the animal dies because humans do not comply with Shariah's standards for slaughter. Due to the non-halal status of the dead carcass or animal, before it is slaughtered, it is not permissible to consume it (Fatmawati, 2020). In parts of Malaysia, chickens are likely to drown due to discharge into the water. Besides, there have also been cases of chickens being slaughtered twice after the first slaughter was imperfect. Hence, it is already dead before it is slaughtered.

#### 4.2 Formalin meat

Formalin is a type of chemical that has been used to preserve meat. Formaldehyde solution in water or also known as formalin typically used to cure carcasses or dead bodies. It contains 30% - 40% formaldehyde. The use of formalin in foodstuffs, on the other hand, has the potential to be detrimental due to the presence of carcinogenic chemicals that can result in cancer. Additionally, eating meat that includes formalin might lead to the consumer's development of asthma and skin disorders. Besides, formalin is also used to preserve the chicken from decomposition at room temperature for two days and keep flies away from the meat (Ricke *et al.*, 2019).

#### 4.3 Mixing meat

Meat that has been mixed typically combines two sorts of animals, with expensive and *Halal* meat combined with expensive and *Haram* meat. For example, butchers frequently combine beef and pork meats to generate additional profits because swine is cheaper than beef in most cases. On the other hand, a visual inspection will be more challenging to distinguish between formalin beef and pig. Muflih *et al.* (2017) published an article about tilapia fed pig faeces. The report was compiled and published based on activities conducted by the Perak *Islamic* Department at the fish farms in Tronoh, Papan and Batu Gajah. Farmers claim that feeding their fish with pig faeces has accelerated the growth of the fish, allowing them to be marketed in three months instead of a year if they were not provided such a diet. Another example is the Chinese Ministry of Public Safety seizing rat meat sold as goat meat in Shanghai in 2013 and foxes and rats meats sold as goat meat in some places (Buckley, 2013).

#### 4.4 Fake meat

Substituting textures, natural characteristics, and relish of meat as a new physical texture and taste of other meat is considered fake meat. According to Ali *et al.* (2015), in China, there are many ways to produce fake meat, especially counterfeit pork, into beef by chemically using cow

flavouring. However, long term effects from this chemical will have adverse effects on human health, such as intoxication, and chronic diseases such as cancer. Besides that, other fake meat issues reported involving butchers who sell fake beef and mutton obtained from repulsive animals such as foxes and rats. Meanwhile, other worse issues related to fake meat created from recycled human waste were reported by a team of researchers in Japan waste (Salahudin *et al.*, 2018).

### 5. Challenges in the *Halal* meat industry

There have been challenges associated with the *Halal* meat industry. Among others are issues related to authority, awareness, cost, supply chain management and adulteration that are discussed in the sub-topic below:

#### 5.1 Authority

The most pressing issue today is *Halal* food legislation, which is under the jurisdiction of several government agencies, each of which has its own set of *Halal*-related rules. In addition to the Trade Descriptions Act (TDA) of 1972 and the Food Act of 1983, the Consumer Protection Act of 1999 and the Animal Rules of 1962 (Ahmad *et al.*, 2018) are connected to *Halal*. Besides, as the extent of *Halal* jurisdiction is broad (Soraji *et al.*, 2017), this impacts the implementation of *Halal* laws in Malaysia, allowing for overlapping enforcement efforts. There are also other government organizations tasked to deal with *Halal* issues, *Halal* meat and meat-based products that cannot be dealt with promptly as it necessitates thorough investigation to determine the core cause of the issue. Only meat and animal-based products that comply with the criteria of the Malaysian government can be made available in this country. The requirements consist of abattoirs and processing plants that are recognized by the Department of Veterinary Services (DVS) and JAKIM; meat and meat-based products that have been *Halal* certified by the approved foreign *Halal* certification body of the respective country which JAKIM recognizes; health certificate from the authorized veterinary agency from the respective exporting countries is provided and the imported meat approval is obtained from the Department of Malaysian Quarantine and Inspection Services (MAQIS), before permitting meat and meat-based products enter the Malaysian market (Jusoh, 2020).

With the recent *Halal* meat scandal and fraud involving the cartels of *Halal* meat importers, it is impossible to resolve this issue quickly and efficiently. Indeed, this meat scam has stoked the flames of discontent among the *Muslim* majority and, as a result, has compromised the Malaysian *Halal* system (Whitehead, 2021). Consequently, this incident has spurred the need for the Malaysia *Halal* Council (MHC) to be reactivated as soon as possible, with the Malaysian Prime Minister serving as the council's temporary chairman to address the meat cartel controversy. A significant effort is being made to develop separate *Halal* regulations in each country, but this goal has yet to be achieved (Palanisamy, 2021). No official *Halal* laws deal with *Halal* difficulties, such as *Halal* meat issues, making the situation uncontrollable.

#### 5.2 Smuggling

Another issue, the lack of severe monitoring at the entry point into Malaysia, has triggered another challenge, particularly at the land border crossing between Malaysia and Thailand.

Several problems have been reported in the media, including the seizure of frozen chicken worth RM500,000 at the Bukit Kayu Hitam entry point (Bernama, 2021); the widespread smuggling of frozen chicken and meat along the border of Kelantan and Narathiwat (Abdullah, 2020) and numerous other cases involving smuggling activities at the border have also been reported.

### 5.3 Cost

Another obstacle that meat industry operators must overcome is the rising cost of keeping animals (Webmaster, 2017). The meat sector continuously faces the ebbs and flows of demand and supply. Due to it being challenging to foresee market volatility, pricing will fluctuate as a result, although, on the whole, it is increasing. According to a recent Technavio report (Linker, 2020), the global meat processing equipment market will grow at a compound annual growth rate (CAGR) of more than 6% over the next four years, owing to an increase in demand for pork in China, a greater emphasis on processed meat products, and an increase in consumer preference for protein-rich foods. Processors must find a means to deal with rising expenses on a short or potentially long-term basis to enhance production to overcome this issue. To get an answer, it is necessary to examine the cost of the protein in raw material and compare it to the cost of the protein in the finished product. Understanding this may assist processors in lowering costs while still maintaining quality (Webmaster, 2017).

The meat industry's reliance on imported feedstuffs such as maize, vegetables and animal proteins for ingredients in feed rations is also a significant concern, given the industry's high dependency on imported feedstuffs. The cost of imported feed ingredients is subject to fluctuations in foreign exchange markets. As a result of the currency crisis, it is costly to sustain present levels of feedstuff importation, which leads to an increase in feed prices (Mohamad Hifzan Rosali, 2015).

### 5.4 Supply chain

Managing *Halal* goods from different suppliers to different levels of purchasers or customers is all about supply chain management (SCM) in the *Halal* food sector (Shah *et al.*, 2016). According to Whitehead (2021), the *Halal* meat industry must deal with the risk of cross-contamination or violation of any Shariah principles because of the lengthy and complex *Halal* meat supply chain that must be followed before reaching Malaysia. This problem occasionally occurs due to the differences in regulatory standards between the exporting countries and Malaysian regulations. In logistics, issues arise in transportation, warehousing, and storing goods (possibilities of hybrid storage and cross-contamination). The ability to provide logistic service management capabilities is critical in maintaining the integrity of *Halal* products (Karia, 2019).

### 5.5 Adulteration

There is insufficient information and technology available to detect counterfeit and contaminated items. Regarding physical site inspection, only a tiny percentage of the facilities can be covered. It is difficult to determine the actual number of foreign sources of the products being used (Choudhary *et al.*, 2020).

According to the Food and Drug Administration, the most significant obstacle to food adulteration is a lack of acceptance in the market due to a suspicion of its originality (Ayza & Yilma, 2014).

A finding involving the adulteration of *Halal* food violated the Food Act 1983 and its rules. In 2017, the Malaysian Quarantine and Inspection Services (MAQIS) seized four containers suspected of containing a mixture of pork and mutton products. This scenario was meant to never occur in Malaysia because the incidence violated the Food Regulation 1985, specifically Clause 11 (c), which dealt with labelling. It was essential to state on the label whether the item contained beef, pork, or derivatives of these meats and fats. This standard is sufficient to regulate the adulteration of *Halal* food in Malaysian markets (Ruzulan *et al.*, 2021).

Furthermore, under Clauses 36 (2) and (3) of the Food Hygiene Regulation 2009, food handlers are required to separate food processing from swine-origin (*sus suscrofa*) and the appliances (Ruzulan *et al.*, 2021). Similarly, MS1500:2019 specifies that it is not permissible to transport *Halal* meat in the same vehicle as non-*Halal* meat. As a result, it will cause widespread consternation among *Muslims*, who will be concerned about the possibility that *Halal* meat and its products have been contaminated with non-*Halal* chemicals, leading to widespread panic.

## 6. Authentication method for *Halal* meat

### 6.1 DNA-based method

Due to advancements in gene technology, detection methods based on genetic differences for *Halal* authenticity have been developed quickly. For example, DNA is more stable at high temperatures than proteins, can be found in all tissue types, and exhibits more significant variation with genetic code. DNA is a relatively stable molecule that can provide universal and identical information from all tissues of an organism and can withstand the pressure, chemical stresses and extensive heat of food processing. In meat speciation, DNA-based techniques have the advantage of being more accurate and reproducible. Uncompromising conditions such as natural decomposition or deteriorated specimens where protein-based markers have been denatured or degraded; this method is equally stable in uncompromised situations. Therefore, the DNA-based technique is more robust than the protein-based technique (El Sheikha *et al.*, 2017).

### 6.2 Polymerase chain reaction (PCR) technique

A polymerase chain reaction (PCR) is a chain activity involving polymerase DNA enzymes that, in principle, results in DNA fragmentation when particular primers are utilized. The polymerase chain reaction (PCR) is considered one of the most sensitive procedures for determining the identity of a chemical. A significant advantage of this technology is that it is susceptible and can detect unlawful chemicals in a short period, even in tiny quantities of DNA. Target ranges are applied to DNA moulding, and the result is that DNA can be detected even in small amounts (Mustafa, 2017). PCR is also known as a chain action involving DNA polymerase enzymes. It is used to distinguish the animal species in the laboratory, hence can be classified into two categories:

Conventional PCR is straightforward and valuable, but it depends on end-point analysis. However, it cannot provide quantitative information on the targets initially present in the sample under consideration. Traditional PCR methods consist of three main steps: extraction of DNA from the sample to be studied and preparation of PCR reactions, which can be divided into three main processes: denaturation, annealing and extension. The last step is the detection of reaction results using agarose gel electrophoresis. Through using a fluorescently tagged signalling probe, real-time PCR has successfully circumvented this constraint by allowing for direct and independent monitoring of cycle-to-cycle amplification. The intensity of the fluorescent signal is directly proportional to the number of PCR products that have accumulated in each cycle, allowing for detection in real-time at an early point in the process. The rt-PCR method has several advantages, the most important of which are quicker analysis times, more sensitive results, and the absence of dangerous substances. As it is self-automated, it is intrinsically more accurate and promising than conventional PCR, and it does not require the time-consuming agarose gel or polyacrylamide electrophoresis (Mustafa, 2017). The rt-PCR method has several advantages and the most important of which are quicker analysis times, more sensitive results, and the absence of dangerous substances (Salahudin *et al.*, 2018).

In a study by Qin *et al.* (2019), they developed a detection method using a multiplex PCR system to simultaneously identify adulterated ingredients of chicken, duck and pork in beef with a limit detection of 0.05% for each species. Primer pairs were designed and tested for the mitochondrial genes Cyt b, CO III, ATPase subunit 8/6, and Cyt b in chicken, duck, pork and beef. The multiplex PCR method identified five beef samples adulterated with pork and one beef sample adulterated with chicken among the 35 commercial samples examined, demonstrating the feasibility of this method for identifying adulterated chicken, duck and pork ingredients in commercial beef products.

The advantages of multiplex PCR include the fact that it is highly repeatable. It saves time and money because it allows for the simultaneous identification of different species using a single PCR experiment and is more economical when compared to other methods. It can simultaneously amplify primer mixes in a one-step PCR reaction, overcoming the limitation of single PCR detection, which only amplifies a pair of primers in a single reaction. Besides, multiplex PCR has several drawbacks, namely low amplification efficiency, variable efficiency across different templates and poor universality. All these points to the necessity for a more sophisticated multiplexing strategy to be developed. Furthermore, a DNA template that is both substantially longer and length-variable for diverse species is required (Mustafa, 2017).

### 6.3 Fourier-transform infrared (FTIR) spectroscopy

Fourier transformed infrared (FTIR) spectroscopy is considered a green analytical method because it requires only a tiny amount of chemical reagents and solvents. Besides, it is fast, non-destructive, and in some cases, does not require any sample preparation. As a result, FTIR spectroscopy can be considered a green analytical technique. FTIR spectroscopy and multivariate calibration have been used in *Halal* authentication analysis to analyze lard mixed with other

animal fats such as beef, chicken and lamb. It has also been used for the quantitative analysis of lard present in chocolate products and cake formulation, as well as the quantitative analysis of lard extracted from pork in beef meatball products and meatball broth (Rahayu *et al.*, 2018).

Based on one study by Guntarti *et al.* (2018), they developed a detection method using Fourier Transformed Infrared (FTIR) spectroscopy combined with chemometrics to analyze the pork content in beef meatballs. The identification of pork in meatballs using FTIR yielded a determination coefficient of 0.9984 and a relative mass standard error of 1.09%. It is proven that the chemometrics method can be used to discriminate between pork meatballs and beef meatballs. Moreover, Rahayu *et al.* (2018) assessed the suitability of FTIR spectroscopy coupled with multivariate analysis of partial least square regression (PLSR) along with pattern recognition technique of principal component analysis (PCA) for rapid quantitative and qualitative (identification) analysis of dog meat in beef meatball formulation. The results of FTIR spectroscopy combined with multivariate analyses of PLSR and PCA proved to be a valuable method for screening dog meat in meatball products in a short amount of time.

The effectiveness of FTIR is a non-destructive technique, and it has high precision. Besides, it requires no external calibration, is fast and time-saving, mechanically simple, sensitive to changes in molecular structure, and can detect functional group ranges. The absence of a signal is a conclusive indication that the functional group is absent, and the identification of a compound is confirmed by comparing its spectrum to that of a known sample. The limitation is that the structure cannot be determined only by infrared imaging; hence some signals may be confusing (Rahayu *et al.*, 2018).

### 6.4 The electronic nose

The electronic nose (E-nose) is a low-cost analytical technique for food authenticity that is quick, simple and easy to use. This non-destructive analytical method has a wide range of applications, including quality control, the differentiation between real and fraudulent food and the determination of the provenance of food. In its most basic form, the E-nose is benchtop portable equipment meant to duplicate the critical functions of the human nose in terms of recording, detection, memory search and identification to profile an odour (Yakubu *et al.*, 2021). Although the uses of E-nose in the food sector are widely recognised, including monitoring processes, authenticity, shelf-life, freshness, and other quality controls, the capability of E-nose in validating *Halal* status is relatively new and has only a limited number of applications.

Sarno *et al.*, (2020) successfully analyzed seven meat classes, comprising seven different mixtures of beef and pork, using an Optimized Electronic Nose System (OENS). OENS has advantages such as proper noise filtering, an optimized sensor array and optimized support vector machine (SVM) parameters. Noise filtering is accomplished using cross-validation with various mother wavelets, including the Haar, Dmey, Coiflet, Symlet, and Daubechies wavelet families. Principal component analysis optimized the sensor array by reducing the number of dimensions (PCA). The optimization of the SVM parameters is accomplished through the proposed method (Sarno *et al.*, 2020). The first and seventh classes contained 100 per cent beef and 100 per cent pork, respectively.

In contrast, the second, third, fourth, fifth, and sixth classes held 10%, 25%, 50%, 75%, and 90% of beef in a sample of 100 grams, and the eighth class contained 10%, 25%, 50%, 75%, and 90% of beef in a sample of 100 grams, respectively. Tests on the samples were carried out for 15 minutes per sample. The classification test results to distinguish between beef and pork were accurate to 98.10% when the support vector machine (SVM) was optimised. As a result, OENS has a favourable performance in detecting pork adulteration in beef for *Halal* authenticity.

### 6.5 Differential scanning calorimetry (DSC)

A type of thermos analytical technique, Differential Scanning Calorimetry (DSC), or calorimetry method, is used to detect changes in the physical and chemical properties by detecting changes in its thermal conductivity. As the most versatile technique, differential scanning calorimetry (DSC) has a wide range of applications based on the premise of heat differences in a sample caused by thermo-physical transitions (exothermic and endothermic changes) (Sudhakar *et al.*, 2021). The DSC offers information on the melting and crystallization processes of oils, which are directly impacted by their physicochemical features, such as the composition of fatty acids and triglycerides (TAG) and their structural and chemical qualities (Sudhakar *et al.*, 2021). The DSC method is based on maintaining the same temperature for both the sample and the reference in separate micro-ovens. The amount of electrical power required for the adjustment is equal to the calorimetric effect that exists. Thermal analysis by DSC is a direct approach to evaluating the thermal properties of a variety of materials. It can potentially be used as a quality control procedure for food adulteration in the future (Sudhakar *et al.*, 2021).

For *Halal* authentication, a study by Any Guntarti *et al.* (2017) has proven to be successful in detecting wild boar meat in meatball formulation using differential scanning calorimetry (DSC) combined with multivariate calibration. DSC thermal profiles of oil derived from wild boar meat show substantial differences in cooling and heating compared to other oils. A study has also been conducted to determine how oil's specific exothermic and endothermic events alter as crystallization and melting enthalpy increase and how these processes develop across a tighter temperature range. Wild boar meat in beef meatballs was the subject of this study, in which the created DSC and multivariate calibration of Partial Least Square (PLS) calibration examined the wild boar meat. The chemometrics of Principle Component Analysis (PCA) is utilized to differentiate between wild boar meat and beef in the meatball.

Meanwhile, for the correlation between actual wild boar meat (x-axis) and DSC predicted value (y-axis), the validation model using crystallization profiles yielded a coefficient of determination ( $R^2$ ) of 0.999 with an equation of  $y = 0.9999x + 0.0027$ , as well as a root mean square error of cross-validation (RMSECV) of 0.380 per cent and a root mean square error of prediction (RMSEP) of 0.203%. PCA is effective for classifying wild boar meat in beef meatballs. Wild boar meat in meatballs can be analyzed using DSC in conjunction with PLS and PCA, a more cost-effective alternative to traditional methods.

## 7. Conclusion

*Islam* highly emphasises the importance of food consumption among its adherents. If a *Muslim* consumes meat, it has to be from *Halal* animals that have been slaughtered following *Islamic* practice. The meat must also not be harmful to humans and be essentially free of impurities. Accordingly, to address the issues that are currently facing the *Halal* meat industry, authority, public perception of the industry's importance or awareness, cost, supply chain management, and adulteration, scientifically based analytical methods are urgently required to detect elements that are prohibited by *Islam*, mainly pork or any other aspects that are considered harmful to humans. For the most part, this study aids in supplying extra knowledge to *Muslim* scholars, allowing them to provide a specific *Islamic* judgement on a topic of great importance. Besides that, Malaysia urgently needs proper and systematic *Halal* meat management to ensure enough *Halal* meat is available to meet the growing demand of the *Muslim* community. The use of local meat rather than imported meat is desirable to maintain a higher level of integrity. Furthermore, it can shorten the *Halal* meat supply chain, as *Halal* meat adulteration has been found to occur often in imported meat and meat-based products.

According to reports, the fact that numerous government entities are involved with *Halal* topics raises the possibility that they may be ineffective in dealing with *Halal* triggering issues. Based on current circumstances, establishing stand-alone *Halal* legislation under the jurisdiction of JAKIM alone may be necessary to improve the *Halal* assurance system in Malaysia. Furthermore, the participation of young entrepreneurs in government-sponsored programmes is critical because many opportunities exist to expand the amount of meat produced in the region. For future research, it is crucial to investigate the agricultural tourism product derived from the *Halal* meat industry since this could substantially impact the commercial operations of local entrepreneurs in Malaysia.

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