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Review

Halal authenticity issues in meat and meat products

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ABSTRACT

In the recent years, Muslims have become increasingly concerned about the meat they eat. Proper product description is very crucial for consumers to make informed choices and to ensure fair trade, particularly in the ever growing halal food market. Globally, Muslim consumers are concerned about a number of issues concerning meat and meat products such as pork substitution, undeclared blood plasma, use of prohibited ingredients, pork intestine casings and non-halal methods of slaughter. Analytical techniques which are appropriate and specific have been developed to deal with particular issues. The most suitable technique for any particular sample is often determined by the nature of the sample itself. This paper sets out to identify what makes meat halal, highlight the halal authenticity issues that occur in meat and meat products and provide an overview of the possible analytical methods for halal authentication of meat and meat products.

Contents

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1. Introduction

Food choice normally reflects aspects of lifestyle, culture, religion, diet and health concerns. From the Muslims' point of view, decision to choose one food over the other depends on its halal status. Muslims follow strict dietary laws enshrined in the holy Quran. Historically, meat for Muslim consumption was not widely associated with adulteration and this could be attributed to the fact that it was sold fresh at easily recognisable joints. Today, the food chain has become so long and people's lifestyles have changed greatly. This has resulted in the need to preserve and process meat into various meat products (Vandendriessche, 2008). With technological advances in the meat processing industry, adulteration and fraud have become common due to monetary benefits.

Non-authentic food can be defined as food which is not "of the nature or substance or quality demanded by the consumer. Non-authenticity can take different forms; (1) complete or partial omission or abstraction of valuable constituents. (2) Whole or partial substitution of food components with an undeclared alternative (which is usually cheaper). (3) Concealment of damage or inferior food stuffs. (4) Adulteration (addition of undeclared substances or materials so as to increase product bulk or weight or make the product appear better value than it is) (Hargin, 1996). In most countries, food manufactures choose to use porcine derivatives because they are cheap and readily available (Aida, Che Man, Wong, Raha, & Son, 2005). Porcine derivatives used in the meat processing industry include; pork fat (lard), mechanically recovered meats (MRM), porcine gelatine and porcine blood plasma. Consumption of porcine derivatives is prohibited according to the Islamic law. The identity and authentication of ingredients in processed or composite mixtures have emanated into appointment or formation of credible halal certification bodies like Halal Food Authority (HFA) in UK, Islamic Food and Nutrition Council of America (IFANCA), Halal Food Council International (HFCI), Australian Federation of Islamic Council (AFIC), Federation of Islamic Association of New Zealand (FIANZ), Islamic Religious Council of Singapore (MUIS), Ulama Council of Indonesia (MUI), Central Islamic Committee of Thailand (CICT) and Department of Islamic Development (Jabatan Kemajuan Islam Malaysia) (JAKIM) in Malaysia. Crucially, such bodies should endeavour to clarify which food is "authentic" or better still "halal" and ensure accurate labelling in order to protect Muslim consumers as well as promote fair trade.

This paper sets out to identify what makes meat halal, highlight the halal authenticity issues that occur in meat and meat products and provide an overview of the possible analytical methods for halal authentication of meat and meat products. For Muslim consumers, the major authenticity concerns in meat and meat products include pork substitution, undeclared blood plasma, use of prohibited ingredients, pork intestine casings and non-halal methods of slaughter. The analytical methods used for halal authentication of meat and meat products include polymerase chain reaction, enzyme linked immunosorbent assays, mass spectrometry, chromatography, electronic nose and spectroscopy. An overview of the analytical techniques is given in Table 1. In order to obtained halal meat, the animals must be of halal (acceptable) species and the animals must be slaughtered according to the Islamic method (halal slaughter), however, it is beyond the scope of this paper to review all the requirements for the Islamic method of slaughter. Additionally, contamination with haram meat should be avoided throughout the manufacture process and the product must not contain any haram ingredient.

2. Authenticity issues

2.1. Pork substitution

Religion is among the major factors determining food avoidance, taboos and special regulation with respect to meat (Simoons, 1994). Muslims follow strict dietary laws enshrined in the holy Quran. The Islamic law forbids Muslims from eating or using any product derived from pigs. Halal meat is the major concern for Muslim consumers (Murugaiah et al., 2009). The main authenticity issue which commonly arises among Muslim consumers is the need to determine whether meat products from halal species have not been mixed with similar material from a cheaper non-halal species. This is because in most countries, food manufacturers choose to substitute pork derivatives in food

Table 1
Summary of analytical techniques applicable in the halal authentication of meat and meat products.

Authenticity issue	Analytical technique	References
Pork adulteration		
Species identification	PCR–RFLP	Murugaiah et al. (2009), Aida, Che Man, Raha, and Son (2007), and Aida et al. (2005)
	Real time PCR	Martín et al. (2009), Kesmen, Gulluce, Sahin, and Yetim (2009), Tanabe et al. (2007), Fumière, Dubois, Baeten, von Holst, and Berben (2006), and López-Andreo, Garrido-Pertierra, and Puyet (2006)
	Species-specific PCR	Soares, Amaral, Mafra, and Oliveira (2010), Alaraidh (2008), Che Man et al. (2007) and Montiel-Sosa et al. (2000)
	RAPD	Martinez and Malmheden Yman (1998)
	PCR sequencing	Karlsson and Holmlund (2007)
Pork protein	ELISA	Chen and Hsieh (2000); Chen and Hsieh (2000)
	Chromatography	Chou et al. (2007)
	Peptide examination	Aristoy and Toldra (2004)
	Isoelectric focusing	Hofmann (1985)
Pork fat (lard)	FTIR spectroscopy	Rohman, Sismindari, Erwanto, and Che Man (2011a, 2011b), Che Man, Abidin, & Rohman, 2010, Rohman and Che Man (2011a, 2011b), Rohman and Che Man (2009), Che Man, Gan, NorAini, Nazimah, and Tan (2005), Che Man, Syahariza, Mirghani, Jinap, and Bakar (2005) and Che Man and Mirghani (2001)
	DSC	Marikkar, Ghazali, Man, and Lai (2003) and Marikkar, Lai, Ghazali, and Che Man (2001)
	Electronic nose	Nurjuliana, Che Man, and Mat Hashim (2011a), Nurjuliana, Che Man, Mat Hashim, and Mohamed (2011b), Che Man, Gan, et al. (2005), and Che Man, Syahariza, et al. (2005).
Blood plasma	Isoelectric focusing	Bauer and Stachelberger (1984)
	ELISA	Church and Hart (1995)
	Immunodiffusion	Price, Hart, and Church (1992)
	LC–MS/MS	Grundy et al. (2007) and Grundy et al. (2008)

products since they are cheap and readily available (Aida et al., 2005). Such pork derivatives may include; pork tissues like collagen and offal, porcine mechanically recovered meats (MRM) and pork fat (lard). Fraudulent substitution of meat tissue with collagen and offal may be profitable to the food industry (Ballin, 2010). If collagen and offal from pigs are used as ingredients in the manufacture of any meat product, then that particular product becomes haram (unacceptable for Muslim consumption). Animal fat from one species is often fraudulently used to substitute animal fat from another species (Ballin, 2010). If the substitution involves pork fat, then that particular product becomes haram. Cheap animal protein, particularly from pork might be fraudulently used to substitute more expensive animal proteins (Ballin, 2010). This also renders that particular product haram. Another main form of substitution of meat products is the use of mechanically recovered meat (MRM). MRM refers to the residual material off bones that is obtained by machines operating on auger, hydraulic or other pressure principles in such a manner that the structure of the material is broken down sufficiently for it to flow in puree form from the bone. The paste-like meat product is produced by forcing bones, with attached edible meat, under high pressure through sieves or similar devices to separate the bone from the edible meat tissue (Surowiec, Fraser, Patel, Halket, & Bramley, 2010). MRM offers the food industry a means of reducing cost through the incorporation of cheaper ingredients. MRM has been used in comminuted meat-based products such as meat pies, sausages and some burgers (Surowiec et al., 2010). MRM covers a wide range of product compositions (Crosland, Patterson, Higman, Stewart, & Hargin, 1995). MRM are often used in meat products due to their high calcium and iron but low collagen content (Hargin, 1996). Chicken and pork carcasses are the most commonly used materials for MRM production to date (Surowiec et al., 2010). If pork carcasses are used, then the particular products are considered haram and condemned for Muslim use.

2.2. Blood plasma

Blood plasma has been included in meat products due to its excellent gellation and emulsification properties (Hargin, 1996; Herrero, Cambero, Ordóñez, Hoz, & Carmona, 2009). The food industry is currently using porcine blood and its derivatives — plasma and red cells as food ingredients, which are frequently sold as spray-dried powders due to their high biological value and excellent functional properties (Dailloux, Djelveh, Peyron, & Oulion, 2002; Saguer et al., 2007). Dehydrated blood plasma is useful as a protein ingredient owing to its gellation properties in some foods, particularly meat derivatives (Dailloux et al., 2002). Plasma proteins contain a complex mixture of important proteins such as serum albumin, globulins and fibrinogen (Herrero et al., 2009). The main functional properties of plasma proteins are the ability to produce and stabilize foams and emulsions, and the ability to form heat-induced gels, which properties are comparable to those of other functional ingredients widely used in commercial applications (Dailloux et al., 2002; Howell & Lawrie, 1984; Raeker & Johnson, 1995; Saguer et al., 2007). Heat treatment of plasma proteins induces denaturation and aggregation resulting in a three-dimensional network forming consistent gels (Dàvila, Parés, Cuvelier, & Relkin, 2007; Herrero et al., 2009). The food processing industry takes advantage of these gel-forming plasma proteins for structuring and controlling the texture of cooked meat products (Cofrades, Guerra, Carballo, Fernández-Martín, & Colmenero, 2000; Herrero et al., 2009; Pietrasik, Jarmoluk, & Shand, 2007). The meat industry may also produce texture modifications by using cold binding agents especially fibrinogen and thrombin (Herrero et al., 2009). Such agents offer many advantages as they can be used in the chilled and raw state with minor effects on technological meat characteristics (Boles & Shand, 1998; Herrero et al., 2007; Herrero et al., 2009; Motoki & Seguro, 1998). Recently, blood clotting enzyme thrombin has been used together with blood plasma to obtain meat binders for incorporation in meat cuts or minced meat to be cut into desired mass and shape (Grundy et al., 2007, 2008). The use of blood plasma, irrespective of the source is considered haram and therefore prohibited for Muslim consumption. Any product in which blood is added is henceforth unacceptable for Muslim consumers.

2.3. Casings

Casings are generally used to determine size and give shape to meat products, particularly sausages. They also serve as processing moulds, as primary packages during handling and shipping, and as merchandizing units during display (Kramlich, Pearson, & Tauber, 1973; Pearson & Gillett, 1996; Savick, 1972). Sausage casing is obtained from collagen and cellulose. There are four specific types; (1) animal, (2) regenerated collagen, (3) cloth, and (4) cellulosic casing which are produced from these basic materials (Kramlich et al., 1973; Pearson & Gillett, 1996). Cellulose casings are not edible and must be peeled off the product after cooking. Cellulose casing is considered halal as they are obtained from plant material. On the other hand, animal casings are obtained from intestines of animals. The intestines can be obtained from sheep, goats or pigs (Pearson & Gillett, 1996). Casings obtained from sheep or goats are halal. However, those obtained from pigs are haram and thus condemned for Muslim consumption. Equally, casings from sheep and goats only become halal when animals are slaughtered by the halal slaughter method. If non-halal slaughter methods are applied, the casings undoubtedly become haram. Collagen casings are also edible casings which can be made from either finely ground cattle skins or pork skins (Riaz & Chaudry, 2004). Collagen casings for halal use must be obtained from halal slaughtered animals.

2.4. Sausages

Sausage is a meat product made by stuffing ground meat that is often mixed with salt, herbs and spices into a casing that may either be traditionally made from intestine or obtained synthetically. Sausage is a very popular and highly relished meat product world over (Sachindra, Sakhare, Yashoda, & Narasimha Rao, 2005). Sausages can be prepared using beef, mutton, chicken or pork. Because the ancient Chinese made sausages from pork, there has been a misconception that Muslims do not consume sausages (Savick, 1972). However, beef sausages are popular in Muslim countries. In Turkey as well as some countries in the Middle East, a special name “soujouk” is used and different kinds of “soujouk” have been manufactured for a very long time. “Merguez” which is made from beef stuffed in sheep casing is another pure beef sausage popular in a number of Muslim countries (Savick, 1972). Unlike pork sausages which are haram, beef, mutton and chicken sausages are halal for as long as they are stuffed in cellulose casings or animal (sheep, cattle and goat) casings obtained from animals that have been slaughtered by the halal method.

2.5. Non-meat ingredients

There are a number of organic or synthetic compounds which may be added to meat products to act as colourants, aromas, preservatives, flavour enhancers, binders, thickeners or stabilizers. It is important to ensure that prohibited materials are not used in halal meat products. The commonest haram ingredients on market include gelatine that is classified as food according to EEC's Codex Alimentarius and derived from animals unless the label says “Halal gelatine”, glycerine and lecithin from animal fat, alcohol, ingredients made from pork fat such as lard, mono & diglycerides, sodium stearoyl lactylate, and polysorbate 60 or 80, enzymes derived from haram animals, grain/plant based ingredients with pig based carrier such as Beta carotene (pig Gelatin) and butylated hydroxyl anisole/butylated hydroxyl toulene (pig based carrier) (Riaz, 1999), blood plasma enzymes (Grundy et al., 2007, 2008), blood plasma

and bacon or natural bacon flavour (Riaz & Chaudry, 2004). There are also other ingredients which are classified as doubtful, for example yeast extract from brewer's yeast and cochineal/carmine colour. These should be avoided too. In order to avoid doubt about the halal status of ingredients, meat processors are advised to ask their suppliers for halal certificates for the different ingredients.

3. Authentication techniques

With the current advances in food processing technology, food safety has become a major problem worldwide. Countries like USA, EU, Canada, Japan, Austria, Brazil and Argentina have imposed the requirement for food traceability as a food safety tool that can effectively trace quality and reduce false information on labels (Zhang, Zhang, Dediu, & Victor, 2011). In the Middle East and other Islamic countries, especially in East Asia, halal certification has been made mandatory for all meat and meat based imported food products. The production and consumption of halal meat have increased over the last two decades (Bergeaud-Blackler, 2007). Gregory (2008) argues that this increased consumption of halal meat among consumers, both Muslim and non-Muslim especially in the UK is attributed to its perceived quality and less risk of transmitting bovine spongiform encephalopathy (BSE). Detection and quantification of adulterants have thus become vital for the protection of consumers. Identification of ingredients in processed or composite mixtures and verification that the components are authentic and from sources acceptable to consumers have become necessary (Lockley & Bardsley, 2000). Authentication is the process by which a food is verified as complying with its label description (Dennis, 1998). Authenticity testing and analytical techniques have been developed, each appropriate and specific to deal with a particular problem. The most suitable technique for any particular sample is often determined by the nature of the sample itself, for instance whether it is raw or cooked, whole muscle or comminuted (Hargin, 1996).

3.1. Pork detection

The analytical methods currently used to detect pork adulteration rely on either protein or DNA analysis. Protein based methods include; Fourier transform infrared (FTIR) spectroscopy (Rohman & Che Man, 2009; Rohman et al., 2011a, 2011b), near-infrared spectroscopy (Fan, Cheng, & Xie, 2010), electronic nose (Che Man, Gan, et al., 2005; Che Man, Syahariza, et al., 2005), chromatography (Chou et al., 2007) and electrophoresis (Montowska & Pospiech, 2007). DNA based methods include; polymerase chain reaction (PCR) amplification of mitochondrial DNA (Che Man, Aida, Raha, & Son, 2007; Montiel-Sosa et al., 2000), PCR–restriction fragment length polymorphism (RFLP) analysis (Aida et al., 2007; Aida et al., 2005; Chen, Liu, & Yao, 2010; Murugaiah et al., 2009) and PCR sequencing(Karlsson & Holmlund, 2007; La Neve, Civera, Mucci, & Bottero, 2008). Rapidly evolving DNA-based methods have led to a change from protein to DNA analysis due to the advantages DNA based techniques have over protein based techniques. Protein based techniques have a number of limitations. They are limited when assaying heat treated products due to denaturation of proteins during thermal processing (Fajardo, González, Rojas, García, & Martín, 2010). Additionally, analyses of immunoassays, which rely on the use of antibodies raised against a specific protein, are often hindered by cross-reactions occurring among closely related species (Fajardo et al., 2010). On the other hand, degeneracy of DNA offers the advantage of differentiating among different animal species solely using DNA analysis (Ballin, 2010). Additionally, DNA is a stable molecule that allows analysis of processed and heat treated products (Aida et al., 2005), it is present in majority of cells and the information content of DNA is not only greater than that of protein but it can also be extracted from all kinds of tissues (Lockley & Bardsley, 2000).

3.1.1. PCR-based techniques for pork detection

PCR is capable of amplifying very few copies of DNA and its detection limit is much lower than what is observed with protein based assays. PCR amplification is based on hybridization of specific oligonucleotides to a target DNA and synthesis of million copies flanked by these primers. The simplest PCR strategy applied to evaluate presence of any species in a meat product is the amplification of DNA fragments, followed by agarose gel electrophoresis for fragment size verification. To successfully detect a species with PCR, adequate genetic markers are chosen to develop the assay. Either nuclear or mitochondrial genes can be targeted (Fajardo et al., 2008). However, the use of mitochondrial DNA (Mt DNA) offers a series of advantages over cell nucleus DNA. Mitochondrial DNA facilitates PCR amplification even in cases where the availability of DNA template after its extraction is insufficient for detection (Murugaiah et al., 2009). This is attributed to the fact that Mt DNA is several fold more abundant than that of nuclear genome; each mitochondrion is estimated to contain 2 to 10 Mt DNA (Murugaiah et al., 2009). Furthermore, Mt DNA evolves much faster than nuclear DNA and henceforth contains more sequence diversity facilitating the identification of phygenetically related species (Fajardo et al., 2010; Girish et al., 2005; Murugaiah et al., 2009). Among the mitochondrial genes, cytochrome *b* (cyt *b*) (Aida et al., 2005; Murugaiah et al., 2009) and 12S rRNA (Chen et al., 2010; Girish et al., 2005) are the most commonly used markers in the development of DNA methods for meat species authentication.

PCR–RFLP is one common technique that has been widely used to detect pork adulteration for halal authentication. Murugaiah et al. (2009) used PCR–RFLP analysis of cytochrome *b* gene of mitochondrial DNA to trace adulteration present in mix meat. Aida et al. (2005) had earlier used PCR–RFLP of cytochrome *b* gene to detect pork adulteration in raw meats. PCR–RFLP technique presents the advantage of being cost friendly, simple and especially adoptable for routine large scale studies like those required in inspection programmes (Pfeiffer, Burger, & Brenig, 2004). However, PCR–RFLP has a shortcoming of not being applicable in processed foods due to DNA destruction as amplification of large DNA fragments which are required for enzymatic restriction is impeded by thermal DNA degradation (Fajardo et al., 2010).

PCR using species-specific primers is yet another method that has been used to detect pork adulteration for halal authentication. With PCR using species-specific primers, a target sequence can be amplified very sensitively from a food matrix containing a pool of sequences, avoiding subsequent sequencing or RFLP. Studies using species-specific PCR to detect pork adulteration have been documented (Alaraidh, 2008; Che Man et al., 2007; Montiel-Sosa et al., 2000; Soares et al., 2010). Che Man et al. (2007) successfully detected pork adulteration in sausages, bread and biscuits though did not extract genomic DNA for casings, which can be attributed to the casings having been artificial (synthetic). Species-specific PCR has a number of advantages; it offers simple, fast, specific and high sensitive species identification. The technique can be used to analyse cooked or processed products despite the highly damaged DNA. Species-specific PCR presents a simple and promising method for the detection of pig derivatives that can be adopted by research bodies and quality control laboratories for halal authentication and verification (Che Man et al., 2007).

Real time PCR has also been used to detect pork adulteration. Real time PCR is the process where the production of amplification products is directly monitored during each amplification cycle and can be measured when the PCR reaction is still in the exponential phase and none of the reaction components is limited, which allows quantitative results to be obtained. Although real time PCR has traditionally been used for gene expression analysis, identification of microorganisms and detection or quantification of genetically, modified organisms, recently it has been suggested for animal species (Hanna,

Connor, & Wang, 2005). Martín et al. (2009), Kesmen et al. (2009), Tanabe et al. (2007), Fumière et al. (2006) and López-Andreo et al. (2006) have successfully used real time PCR for species identification. Real time PCR has numerous advantages. The method has the potential to quantify measurements at an early stage in the PCR process, which makes it more precise than end point analyses. The method discriminates the origin of DNA without the need for any time consuming and laborious steps like sequencing, enzyme digestion or confirmation analysis. In real time PCR, fluorescence data can be collected directly from the real time instrument, avoiding the need for electrophoresis. The assays are rapid, which allows routine high-throughput screening of multiple samples. Lastly, the method offers great reduction of the potential of contamination of the PCR mixture as the reaction tubes remain closed throughout the assay (Fajardo et al., 2010). Real time PCR is a promising technique for pork detection for halal authentication. However, its application may be hindered by the cost derived from the specific fluorescent probes (Martín et al., 2009).

Another common PCR based technique that can be used to detect pork adulteration is random amplified polymorphic DNA (RAPD) analysis (Martinez & Malmheden Yman, 1998). RAPD analysis consists of the analysis of amplification of DNA fragments using short arbitrary primers that tie multiple locations on the genomic DNA, followed by separation of amplified fragments based on their sizes using gel electrophoresis. RAPD is a powerful technique in instances where little or no information on the DNA sequence is available (Ballin, 2010). RAPD is a simple and fast method that can be used for halal authentication of meat without complex analytical steps like DNA restriction, sequencing or hybridization. However, its disadvantage is the difficulty of obtaining reproducible data as PCR amplifications have to be developed under strictly controlled and standardized conditions such as temperature, number of cycles and reagent concentration. RAPD also requires high quality starting DNA in order to achieve reproducible RAPD profiles, which limits its application in highly processed meats with excessively degraded DNA. Additionally, RAPD analysis is not suitable for identification of a target species in admixed meats consisting of more than one species due to the non-specific nature of the PCR reaction (Fajardo et al., 2010).

Pork adulteration can also be detected using PCR-sequencing. PCR-sequencing is the most direct means of obtaining information from PCR products (Lockley & Bardsley, 2000). Amplification of DNA mitochondrial sequences, particularly the cytochrome b gene (La Neve et al., 2008), 12S and 16S rRNA genes (Karlsson & Holmlund, 2007) has been used to obtain information for identifying the animal origin of meat due to the several advantages possessed by mitochondrial DNA (La Neve et al., 2008). Characterisation of animal species by PCR sequencing relies on the availability of known sequences for comparison. Such sequences are available and can be downloaded from databases like Gen Bank and National Centre for Biotechnology information. PCR sequencing is a potential tool for detection of pork for halal authentication. However, the method may present constraints in cooked or processed samples with degraded DNA and it is further restricted in the analysis of mixed-species meats as the heterogeneous amalgam of sequences from different species hinders result interpretation (Fajardo et al., 2010).

3.1.2. Protein based techniques for pork detection

Pork protein, due to its being cheap and readily available, might fraudulently be used to substitute other animal proteins. ELISA is the most commonly used method to detect animal proteins and a number of commercial immunoassays are available. Chen and Hsieh (2000) were the first ones to develop an enzyme-linked immunosorbent assay (ELISA) using a monoclonal antibody to a porcine thermal-stable muscle protein for detection of pork in cooked meat products. The assay was able to detect porcine skeletal muscle, but not cardiac muscle, smooth muscle, blood, and non-muscle organs. They observed no cross-reactivity with common food proteins. Ayaz, Ayaz, and Erol (2006) were also able to detect species in meat and meat products using ELISA. Detection of pork protein is not limited to ELISA. Chou et al. (2007) was able to qualitatively detect a variety of meats, including pork using liquid chromatography methods that focus on protein profiles. Aristoy and Toldra (2004) used the examination of dipeptides, carnosine, anserine and belanine to qualitatively identify pork. However, the method was only applicable when different species were not mixed. Hofmann (1985) employed isoelectric focusing on the polycrylamide gel for identification of muscle derived from pigs. Species identification of meat using electrophoresis has been reviewed (Montowska & Pospiech, 2007). Detection of animal protein depends on the nature of the protein. Pork protein detection might be impossible, particularly if proteins are degraded or severely or altered during processing. In such a case, DNA based methods like PCR can be employed to detect pork protein adulteration in meat products.

3.1.3. Analytical techniques for lard detection

To gain economic benefit, animal fat from pigs might fraudulently be used to substitute fat from other species due to its being cheap and readily available. For Muslim consumers, the presence of lard in food products is prohibited as lard is not permissible for consumption by Muslims (Regenstein, Chaudry, & Regenstein, 2003). This has prompted a number of studies aimed at the detection of lard in different food products for halal authentication. Animal fat contains species-specific relative amounts of fatty acids (Precht, 1992) and methods based on these relative amounts of fatty acids can be used to identify foreign fat in meat and meat products. Fourier transform infrared (FTIR) spectroscopy is among the most widely applied method to detect lard adulteration (Che Man et al., 2010; Che Man, Gan, et al., 2005; Che Man & Mirghani, 2001; Che Man, Syahariza, et al., 2005; Rohman & Che Man, 2009; Rohman & Che Man, 2011a; Rohman & Che Man, 2011b; Rohman et al., 2011a, 2011b). Differential scanning calorimetry (DSC) has also been widely used to detect lard adulteration (Marikkar et al., 2003; Marikkar et al., 2001). Electronic nose has also been successfully used to detect and discriminate lard from other types of animal body fats and samples containing lard (Che Man, Gan, et al., 2005; Che Man, Syahariza, et al., 2005; Nurjuliana, Che Man, & Mat Hashim, 2011a; Nurjuliana, Che Man, Mat Hashim, & Mohamed, 2011b).

For monetary benefits, meat processors, use mechanically recovered meats (MRM) in comminuted meat-based products such as meat pies, sausages and some burgers. MRM from bovine have been banned internationally due to the associated risk of transmitting BSE (Surowiec et al., 2010). MRM from sources other than pork are authentic for Muslim consumption. In case of adulteration with porcine MRM in meat products, the methods mentioned above for pork detection can be applied for halal verification. In order to authenticate animal casings for consumption by Muslims, DNA-based polymerase chain reaction methods are reliable. The fact that Che Man et al. (2007) failed to extract genomic DNA from casings can be attributed to the casings having been artificial (synthetic).

In the near future, we are more likely to see development of new techniques to detect pork adulteration in products for the ever growing halal market. One such promising technique is the use of pork detection kits that were first developed in Japan in 2010. Pork detection kits are immunochromatographic assays using nano-sized colloidal gold particles to detect adulteration of pork in food samples. The assays can detect pork in both raw and cooked food. These assays allow rapid detection of pork in food samples at low cost without using any special equipment or requiring skilful techniques (Ali, Hashim, Mustafa, Che Man, & Islam, 2012). Unlike the existing testing methods such as PCR, which require special equipment and laborious procedures involved in the identification of specific sequences within it by RFLP analysis, southern blotting or sequencing, gold nanoparticles can be used to detect target sequences just by observing colour change. Ali et al. (2012) have pioneered the identification of pork adulteration

using gold nanoparticles. They have successfully identified pork adulteration in beef and chicken meatballs using 20 nm gold particles as colorimetric sensors. The method is thus suitable for conducting preliminary screening of large numbers of routine samples before using an existing method for confirmation, which can enable an enhanced surveillance programme of the halal meat products supply.

3.2. Detection of blood plasma

The food industry is currently using blood plasma as a binding agent in meat products. However, the consumption of blood is prohibited according to the Islamic dietary law. This necessitates techniques to detect blood plasma in food for halal authentication. Bauer and Stachelberger (1984) successfully detected blood plasma in heat-treated meat products using ultrathin-layer isoelectric focusing. To overcome the challenge of identification of blood plasma in meat products, the UK Ministry of Agriculture, Fisheries and Food (MAFF) commissioned research using immunodiffusion and ELISA (Church & Hart, 1995 as cited by Hargin, 1996; Price et al., 1992 as cited by Hargin, 1996). The immune double diffusion in agar-gel was only able to detect 8% antibody in cooked beef and 1% in raw pork. The ELISA protocol was more successful, detecting 0.2% m/m as dried plasma. Although these two techniques could not differentiate species origins, they are sufficient for halal authentication because the requirement is to verify presence or absence of added blood plasma in products. Blood plasma contains enzymes; thrombin and fibrinogen which are applied to meat as thrombin transforms fibrinogen to fibrin that interacts with collagen enabling binding of meat pieces (Grundy et al., 2007). In the process, blood protease thrombin cleaves fibrinogen to its constituent fribrinopeptides A and B (Grundy et al., 2007). Liquid chromatography triple quadrupole mass spectrometry has been successfully used to screen for addition of bovine (Grundy et al., 2007) and porcine (Grundy et al., 2008) blood-based binding agents in meat products.

3.3. Identification of non meat ingredients

The vast number of organic and synthetic compounds added to meat products as colourants, aromas, preservatives, flavour enhancers, binders, thickeners or stabilizers make it difficult to present a detailed description of each. In order to avoid the use of prohibited or doubtful ingredients, manufactures should ask their suppliers for halal certificates of the particular ingredients. The halal certificate confirms the authenticity of the ingredients.

4. Requirements for halal meat processing

Halal is an Arabic term which means permitted, allowed, authorised, approved, sanctioned, lawful, legal, legitimate or licit. Guidelines for halal are given by Allah in the Holly Quran; “Forbidden to you (for food) are: *Al-Maytatah* (the dead animals — cattle-beast not slaughtered), blood, the flesh of swine....” (Surah Al Maidah, verse 3).

Halal meat must be obtained from halal species only. All land animals are halal except pigs, dogs, carnivorous animals that slash and kill such as tigers, lions, bears, cats and similar animals, animals with tusks such as elephants, and animals which are permitted to be killed in Islam such as rats, centipedes, scorpions and other similar animals. Equally, all birds are halal except scavengers and birds of prey, that is, those with claws and those that feed by snatching and tearing like eagles and birds that are forbidden to be killed in Islam such as woodpeckers (Codex Alimentarius Commission, 1997; Department of Standards Malaysia, 2004, 2009; Wahab, 2004). Although much attention has been given to pork detection and numerous papers have been published in this area, verification of other species can be carried out using different DNA and protein based speciation techniques. To obtain halal meat, halal species must be slaughter using the halal slaughter method. To the best of our knowledge, no analytical method that differentiates meat obtained by halal slaughter methods from that obtained by non-halal slaughter methods has been published. In future, research should be carried out to verify halal versus non-halal slaughtering.

Although the halal status of meat is often believed to be equivalent to the application of halal slaughter, additional conditions, particularly during the various processing unit operations should be taken into account to avoid contamination of halal meat with non-halal meat or unacceptable ingredients. The meat chain conforming to all halal requirements is very complex and the risk of cross-contamination is substantial (Bonne & Verbeke, 2008). This calls for critical control points to be identified and carefully monitored. Great care should be taken during cleaning, deboning, carcass fabrication, mincing, mixing, packaging and cold storage. All halal meat products should be packaged in clean containers and proper labels affixed to identify the halal markings. During storage and display, halal products must be segregated from non-halal ones so as to prevent cross contamination (Wahab, 2004). At cold stores, all incoming halal load should be received by a Muslim inspector and halal products must be segregated during freeze storage. All halal products transported out of the cold store should be accompanied by a transfer certificate (Riaz & Chaudry, 2004). Different countries and halal certifying bodies have different symbols. Fig. 1 shows halal certification symbols for different countries. The certification attests that the product adheres to halal manufacturing procedures. Halal certification gives evidence and provides assurance that your product is halal and free from non halal products thus it is safe for Muslim consumption.

5. Conclusion

Every country has specific concerns and wishes to determine its own particular priorities for targeting authenticity issues, labelling and compositional regulations. However, the Islamic dietary law is

Fig. 1. Halal certification symbols for different countries.

universal and derived from the holy Quran, which makes it similar in all nations of the world. Halal status of meat is a credence attribute that cannot be ascertained by the consumer, even upon consumption of the meat. The halal meat chain begins from the farm to the table. Halal encompasses origin, species, production system, slaughter procedure and the processing method of meat. All these characteristics are not visible and cannot be verified by the consumer during the pre-purchase stage. Henceforth, halal certifying authorities require quick, reliable and cost friendly analytical techniques to authenticate halal meat. This will not only protect Muslim consumers, particularly Muslim minorities in secular states but it will also promote fair trade.

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