Mini-review

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Progress and challenges associated with halal authentication of consumer packaged goods

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Abstract

Abusive business practices are increasingly evident in consumer packaged goods. Although consumers have the right to protect themselves against such practices, rapid urbanization and industrialization result in greater distances between producers and consumers, raising serious concerns on the supply chain. The operational complexities surrounding halal authentication pose serious challenges on the integrity of consumer packaged goods. This article attempts to address the progress and challenges associated with halal authentication. Advancement and concerns on the application of new, rapid analytical methods for halal authentication are discussed. The significance of zero tolerance policy in consumer packaged foods and its impact on analytical testing are presented. The role of halal assurance systems and their challenges are also considered. In conclusion, consensus on the establishment of one standard approach coupled with a sound traceability system and constant monitoring would certainly improve and ensure halalness of consumer packaged goods.

Keywords: halal; authentication; traceability; certification

INTRODUCTION

Consumer packaged goods are products consumed frequently in day-to-day life that include foods, beverages and cosmetics. From the consumers' perspective, it is very important to ensure that the products they consume are safe and authentic. Constitutionally, consumers have the right to protect themselves against abusive business practices. Systematic surveillance and testing by competent authorities ensure product safety and play an important role in timely recalls and withdrawal of potentially unsafe goods. However, concerns on authenticity are becoming a growing issue worldwide. For instance, food fraud involving cases of dilution, substitution and mislabeling continues to exist in the industry. The distances between producers and consumers are increasing as a result of rapid industrialization and urbanization. The incidences of economically motivated fraud are mounting and international trade is disrupted by frequent disputes.[1] Religious sentiments also play a crucial role in product selection, with a direct implication on consumers based on the faith they follow. For instance, the doctrines of the Quran forbid Muslims from consuming pork, alcohol, etc., while some Hindu sects predominantly shun most animal and fish products based on the doctrines of Hinduism.[2] Moreover, consumers have the right to be informed about the price, quality, quantity and ingredients of the products they buy. In Islam, specific guidelines have been laid down for its people on the type of food and drink to be consumed (halal).

Thus legitimate labeling has become an inevitable tool for consumers for decision making. However, labels lack sufficient guarantee about the true contents of a product. For instance, meat pies and pasties labelled as 'halal' were found to contain traces of pork,[3] which is forbidden in Islam. Surveys from Iran and Indonesia also revealed porcine contamination in hamburgers and meatballs respectively.[4,5] Market surveillance of pharmaceutical and cosmetic goods also exposed porcine DNA in Malaysian local markets, indicating the need for surveillance and analytical testing of consumer products.[6] The complex nature of the global supply chain also makes adulteration (both intentional and/or accidental) an emerging risk. Although significant progress has been made on the analytical side, the challenges associated with highly processed foods and cosmetics clearly raise concerns on fulfilling the religious sentiments of consumers. Furthermore, fraudsters also continue to take explicit measures to evade adulteration detection. A typical example of such economically motivated fraud is the removal of DNA and protein from pork before injecting it into chicken products, thus making protein and DNA analysis useless for species authentication.[7] Moreover, testing does not always reflect the true characteristics of a particular lot, as it involves only a small fraction of the sample.[8] Nevertheless, the advent of modern technologies continues to resolve complexities associated with analytical testing and traceability.

Given this background, this review article aims to discuss the progress and challenges associated with consumer packaged halal goods. The article begins with a definition of halal, followed by the progress made on analytical capabilities. It then explores the challenges of analytical methods, discusses the progress and challenges of halal assurance systems and ends with some concluding remarks.

WHAT IS CONSIDERED AS HALAL BY DEFINITION?

The word halal originates from the Arabic word حلال, حلي, حلا, which means to set free, to let go, to dissolve and to allow or to exit

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from something that is illegal.[9] It refers to commodities prepared, processed, transported or stored using any appliance or facility that is free from anything unlawful as per Islamic Sharia law.[10]

The expression of the term 'halal' is also associated with 'al-tayyib' or 'al-tayyibat' in the Quran, and hence halal foods must conform to the conditions expressed in the meaning of 'halal and tayyib' referring to goods that are permissible, safe and pure.[11] However, the significance of the 'tayyib' requirement is not being considered strictly as stated in the Quran. For instance, some foods may be halal but not safe for human consumption, i.e. food products that fail to preserve human life and health are also considered haram or unlawful. Similarly, the use of lard oil (pork fat) in foods and cosmetics has been recognized as safe but does not fulfill religious sentiments. In the general guidelines outlined by Codex Alimentarius, the definition is more towards the term 'halal' as quality attributes are framed and enforced by competing authorities. Nevertheless, countries such as Malaysia have adapted the 'halal and tayyiban' concept as the criterion for consumer products.[9]

PROGRESS ON ANALYTICAL METHODS

Analytical methods are increasingly becoming the focus of halal authenticity issues. Innovative analytical methods are being developed in response to emerging issues, as they remain the only means of confirmation for regulators to make sound scientific decisions. Although there is a plethora of articles describing various analytical techniques for speciation and halal authentication, our focus is confined to recent developments in the analytical methods covering both chemical and biological assays. The testing procedures commonly employed for halal authentication are either immunological or nucleic acid based. The advantage of immunological methods utilizing antigen–antibody interactions lies in their ability to produce rapid results at a reasonable cost, so they are among the most preferred methods in food testing. Methodological improvements have also led to the utilization of this technique in food testing, particularly for animal species adulteration.[12] For instance, it is difficult to identify animal species in processed foods, since factors such as high temperature may denature protein molecules, rendering them unsuitable for immunoassays. To overcome this, specific monoclonal antibodies recognizing thermostable muscle proteins have been introduced that are highly sensitive and specific for porcine detection in heat-treated products. A detection level of up to 1% was achieved for meat bone meal in soy products without the need for complicated sample processing steps.[13] Recently, a sandwich enzyme-linked immunosorbent assay (ELISA) utilizing a monoclonal antibody was developed for food ingredients derived from porcine blood with a detection limit as low as 0.03% (v/v).[14] A rapid lateral flow immuno-chromatographic assay utilizing thermostable meat protein for the detection of raw, cooked meat and gelatin samples was developed that was capable of detecting as low as 0.01% based on the sample matrix, with no cross-reactivity over related species.[15] Interestingly, the assay was able to detect gelatin residues where polymerase chain reaction (PCR) methods failed owing to their inability to recover DNA from gelatin. A lateral flow immunoassay was also applied successfully in fat detection by targeting muscle protein, suggesting the applicability of the technique in species authentication.[16]

Application of DNA-based detection methods in halal authentication has gained considerable attention in the recent past owing to their sensitivity and specificity over immunoassays.[17–19] This technique is capable of detecting highly processed matrices such as gelatin, which is a common ingredient in the food and pharmaceutical industries. Since gelatin is subjected to thermal and chemical treatments, the DNA is fragmented and inadequate for subsequent analysis. To overcome this, improved PCR assays targeting shorter fragments have been developed, as it is possible to recover fragments of up to 300 bp following sterilization.[20] Several PCR methods have been developed and validated for porcine detection in raw, processed and highly processed matrices.[21–24] Recently, a loop-mediated isothermal amplification (LAMP) method has been developed for pork detection in processed meat products. LAMP is a simple, rapid and cost-effective technique that employs DNA polymerase with high strand displacement activity and a set of four specially constructed primers (two inner and two outer primer) that recognize six distinct sequences on the target DNA. The technique is capable of producing high-level precision without expensive equipment.[25] The sample preparation steps are also easier compared with other PCR techniques. The detection limit of the assay is 1 pg for raw pork DNA and 0.01% of pork in beef/meat admixtures. The advantage of this method is that it can be used for rapid on-site detection of pork.[26]

One of the major challenges associated with highly processed food matrices is template concentration and DNA degradation, especially when the products are subjected to various chemical and thermal treatments.[27] Thus, to ensure successful PCR amplification, several factors such as copy number of the target gene, amplicon size and primer specificity should be considered, as they play a pivotal role in the subsequent amplification procedure. Recently, a novel double-gene detection method targeting mitochondrial DNA with two short amplicons (73 and 146 bp) has been evaluated on frankfurter products. The limit of detection of the assay is comparable (0.1%) to that in other published reports. The advantage of the assay is its ability to complement potential missing targets, as it amplifies two different genes simultaneously.[28]

Halal authentication is not limited to porcine detection alone. In general, products from animals with canine teeth or fangs, such as dog, cat, monkey and rat, are also considered non-halal according to Islamic laws. Nevertheless, cat and dog flesh can be found on the menu in countries such as China, Korea and Vietnam. Thus, in a globalized food market, it is not uncommon to find these species in the food chain accidentally or as potential adulterants for economic gain. In this context, a multiplex PCR assay that detects five haram meat species (pig, dog, cat, monkey and rat) in raw and processed meat products has been developed and evaluated. The multiplex PCR targets mitochondrial genes with short amplicons in the range of 108–172 bp. Multiple copies of mitochondrial genes coupled with amplification of shorter amplicons make the assay an ideal candidate for detecting highly processed and degraded food samples with a detection limit of 0.01 ng of DNA templates.[29]

Apart from immunoassays and nucleic acid assays, spectrometric, spectroscopic and chromatographic techniques are also used in halal authentication.[30–33] These techniques are usually combined with chemometric methods such as principal component analysis (PCA) or linear discriminant analysis (LDA) for analyzing the data obtained from the instrument interface. Of these techniques, Fourier transform infrared (FTIR) spectroscopy has shown promising results on complex matrices such as lard and gelatin from food and cosmetic samples.[34–37] Likewise, the fat components of biscuit formulations with lard and palm oil as fat source have been compared using reverse phase high-performance liquid chromatography (RP-HPLC). Based on their thermal profiles, lard

and palm oils were differentiated by the occurrence of excessive palmitic acid, a characteristic feature to identify pork fat.[38]

A paradigm shift in biosensor technology from theranostic to diagnostic applications has paved the way for generating nanoscale arrays for pathogen and food-associated toxin detection. An application of this technology to detect pork adulteration in meatballs has been developed by integrating a porcine-specific nucleotide fragment of 27 bp in 3 nm diameter citrate/tannate-coated gold nanocrystals. The assay was successfully applied to authenticate 1% pork adulteration in meatball preparations. This method is relatively cheaper than real-time PCR and can be applied effectively on highly degraded samples.[39]

Recently, a non-invasive sensing technology named hyperspectral imaging has received considerable attention for its application in quality and authenticity attributes.[40–42] Using this method, pork adulteration in beef with a detection limit of 10% was achieved.[43] Although this level is quite high, it is a promising and crucial step towards automated, non-invasive analysis where time is critical in monitoring food quality. Also, the technique empowers 100% sampling of the product with very low cost and time, a unique feature which is not possible with current methodologies.[44] Nevertheless, the technique should be refined further for low-level detection and quantification.

Applications of non-invasive electronic nose (e-nose) concepts have also gained considerable attention in recent years. This technology mimics the human sense of smell and analyzes food aroma by using sensors such as metal/oxide to discriminate complex vapor mixtures containing many different types of volatile organic compounds. For instance, aromas of different animal fats are sufficiently unique to discriminate them using zNose™.[45] The chemical signature of the aroma of a substance is used to build a model for prediction of the substance's content in adulterated meat mixtures. The method is useful for rapid identification of lard adulteration in relatively low concentration (1%) in food products.[45] Although the analysis is relatively rapid and low-cost, it requires specialized and time-consuming training.

Analytical methods applied in halal authentication are summarized in Table 1.

ANALYTICAL CHALLENGES

Whilst the development of new, rapid methods covering complex sample matrices is very encouraging, analytical methods are not free from challenges. Owing to the complexities in food processing and supply chain management, it is difficult to rely on analytical testing alone. Since most packaged foods contain many ingredients, it is very difficult to recognize them all using the targeted screening methods applied in food laboratories. For instance, ingredients such as emulsions or aromas can have unclearly defined origins which manufacturers are not obliged to declare on food labels.[46] Foods can also be contaminated with pork, added in the form of emulsifier or other substances such as gelatin, enzyme, glycerin and lecithin. Pork fat that may be used in bread as a substance of emulsifiers E471 and E472 is a typical example.

Lard (pork fat) has been well known for its use as a fat ingredient in certain types of biscuits[47] and cakes[48] owing to its functional properties and economic benefits. It is not easy to detect the origin of fat used during baking. Similarly, identifying the origin of gelatin is yet another gray area where reliable detection methods are not available. For instance, gelatin from pork skin is subjected to acid treatment during processing, and nucleic acids are degraded, hence it is difficult to apply nucleic acid-based extraction and detection methods,[49] which are regarded as sensitive and reliable methods for species identification.[50–52] Although DNA-based detection is the most appropriate method for animal species authentication in food and feed,[53] it has potential risks of cross-contamination and false-positive claims.[54–56]

In the case of infrared (IR) and other spectroscopic methods, the models developed for one formulation cannot be applied for all, as the spectra will be different.[36] Another limitation of FTIR for lard detection in food products is that the calibration model developed can only be applied to functional group characteristics similar to those of the standards used to derive the calibration model. These methods are also expensive, requiring highly skilled resources and consumables.

The application of newly emerging technologies such as hyperspectral imaging in halal authentication is still in its infancy. As of now, no single technique is capable of detecting all haram substances or their derivatives, and it is not practical to authenticate all ingredients in a sample.

Although technological developments and improvements are facilitating detection limits as low as possible, when it comes to halal goods, zero tolerance policy is strictly adhered to, which is in principle to eliminate undesirable products such as pork, dog, cat and their derivatives. However, detection methods are not capable of accurately measuring analyte concentrations down to zero. Since detection methods rely on instrument-based signals, there is no objective evidence to prove that a low concentration of analyte will indeed produce a signal distinguishable from a blank.[57] Therefore adhering to zero tolerance policy on halal goods is not practical as far as analytical methods are concerned, as absence of evidence cannot be considered as evidence of absence.

PROGRESS AND CHALLENGES OF HALAL ASSURANCE SYSTEMS

In order to assure 'halalness', products and processes must be either detectable/quantifiable or verifiable. Detection of haram substances such as pork and concentration of alcohol are typical examples of detection and quantification respectively, while processes such as raw material traceability, slaughtering method, storage and distribution are usually verified through auditing and certification. This is a process whereby a credible organization certifies that the services offered by a certification body meet the specified requirements of halal standard so that consumers can confidently make an informed decision during purchase. The certification bodies comprise both scientific technical members and religious leaders so that both aspects are fulfilled.

In Thailand, Indonesia, Singapore and the Philippines, institutions dedicated to halal certification have been established by the respective governments. It is noteworthy to point out the contribution of Malaysia to develop general requirements for firms operating halal product certification systems based on the international standard ISO/IEC Guide 65:1996, as well as to accredit laboratories through Skim Akreditasi Makmal, Malaysia. Similarly, the Gulf Cooperation Council (GCC) Standardization Organization (GSO) has developed standards for halal certification bodies (GSO 2055-2) and general requirements for halal accreditation bodies accrediting halal certification bodies (GSO 2055-3).

Theoretically, accreditation bodies are the topmost authorities responsible for assessing certification bodies to ensure compliance with recognized standards. National entities such as

Table 1. Analytical methods used in halal authentication and their limit of detection (LOD)

Method	Matrix	LOD (%)	Reference
Sandwich ELISA	Raw, heat-processed meat and feed	0.05 – 1	13
Lateral flow	Raw, cooked meat and gelatin residues	0.01 – 2.5	15
Conventional PCR	Gelatin mixtures	0.1	24
LAMP	Heated meat mixtures	0.01	26
Multiplex PCR	Meatball formulations	1	29
HPLC/MS/MS	Sausages, meatballs and canned meat	0.24	32
FTIR	Lard in vegetable oil, gelatin	1, 4	36,37
Biosensor	Cooked meatball formulation	1	39
Hyperspectral imaging	Raw meat	10	43
E-nose	Lard aroma	1	45

Malaysia (Department of Standards Malaysia), UAE (Dubai Accreditation Center), Pakistan (Pakistan National Accreditation Council), Indonesia (National Accreditation Body of Indonesia), Japan (Japan Accreditation System for Product Certification Bodies of JIS Mark), Australia and New Zealand (Joint Accreditation Service of Australia and New Zealand) and GCC countries (Gulf Accreditation Council) are signatories of the International Accreditation Forum with confirmed halal accreditation programs.

Members of the Organization of Islamic Countries (OIC) also have their own institution, with varying standards from one country to another.[58] In Europe, a comparison between different standards such as those of Malaysia, Indonesia and Turkey was carried out to formulate its own standards by avoiding conflicting issues.[59] As far as halal standards are concerned, Malaysian standard MS 1500:2009 serves as a global benchmark and basis for many other standards. It lays out comprehensive requirements for the food manufacturing and food servicing chain from processing to handling, distribution, storage, display, serving, packaging and labelling according to Sharia law. Aesthetic aspects – hygiene, sanitation and food safety – are also covered as part of the requirements.[60]

In order to fulfill the holistic approach of the halal concept from farm to fork, new developments such as Halal Compliance Critical Control Point (HCCCP), a synonymous system to Hazard Analysis Critical Control Point (HACCP), to cover halal compliance in industries have been suggested.[61] Similarly, the concept of Islamic Manufacturing Practice (IMP), 'a guideline intended to ensure quality, efficacy and purity during manufacturing for Sharia compliance', has been introduced in Malaysia.[62]

Even the distribution, storage, handling and procurement of halal products must follow the Sharia principle in order to be considered halal.[63] In this context, a strengths, weaknesses, opportunities and threats (SWOT) analysis has been done to introduce halal logistics in Malaysia.[64] These developments imply that commendable progress has taken place to develop, implement and ensure halal assurance at all levels of processing and distribution of consumer packaged goods. To facilitate halal integrity throughout the supply chain, various critical control checkpoints, including financial aspects, have been proposed,[65] as depicted in Fig. 1.

Nevertheless, there are many challenges to be addressed for effective utilization of these developments. For instance, from the halal standardization point of view, there exist many different standards conflicting the notion of removing technical barriers to trade among OIC member states.[66] Although the definition for halal and haram is very clear and accepted by all Islamic schools, consensus on what properties make a product/process halal is not yet reached. For instance, physiochemical alteration (Istihalah) is a widely accepted phenomenon in Islam. According to Maliki, al-Syawkani, Hanafi and Ibn Hazm al Zahiri schools, both natural and intentional physiochemical changes are accepted, while Hambali and Shafii schools consider only natural changes.[67] Products such as gelatin, food flavorings and animal enzymes fall under this category. According to the recommendations issued by the World Health Organization Regional Office for the Eastern Mediterranean, 'the gelatin formed as a result of transformation of the bones, skin and tendons of a judicially impure animal is pure, and it is judicially permissible to eat it'. These recommendations were endorsed by many Islamic scholars from Egypt, Tunisia, Saudi Arabia, Oman, Qatar, Lebanon, Pakistan and Kuwait.[68] It is not clear whether these recommendations are accepted and followed even among the endorsing nations. However, according to UAE standard 2055-1:2015, it is very clear that food additives derived from non-halal materials are also prohibited.

Likewise, issues related to stunning appear to be yet another major divergence among different Islamic groups. The technical specification of OIC states that stunning is permitted in poultry and was also adapted by Malaysian standard MS 1500:2009 under certain conditions.[69] However, as per the Standards and Metrology Institute for Islamic Countries (SMIIC), all forms of stunning and concussion are prohibited (OIC/SMIIC 1:2011) and the law is strictly enforced in countries such as UAE. It is also unclear whether the term 'halal and toyyiban' is to be applied together or independently. Although many scholars describe it as a combined approach,[9] usage of the term halal is being practiced more commonly. These differences create confusion for producers, who may not know which authority to consult in order to get their product certified for the right market.[70] Thus, in the absence of a unified standard, the process of halal certification is very challenging and may even misguide consumers.

CONCLUDING REMARKS

The present review was undertaken to assess the progress and challenges associated with halal authentication of consumer packaged goods. Undoubtedly, the halal concept serves beyond Islamic values, as it considers both religious and safety aspects.

Analytical testing plays a pivotal role in halal authenticity issues. Significant progress has been made in the sensitivity and specificity of analytical procedures regardless of the technique being applied. It is noteworthy to point out that each technique (ELISA, PCR, mass spectrometry (MS), etc.) has its own advantage and application based on specific needs and that they complement

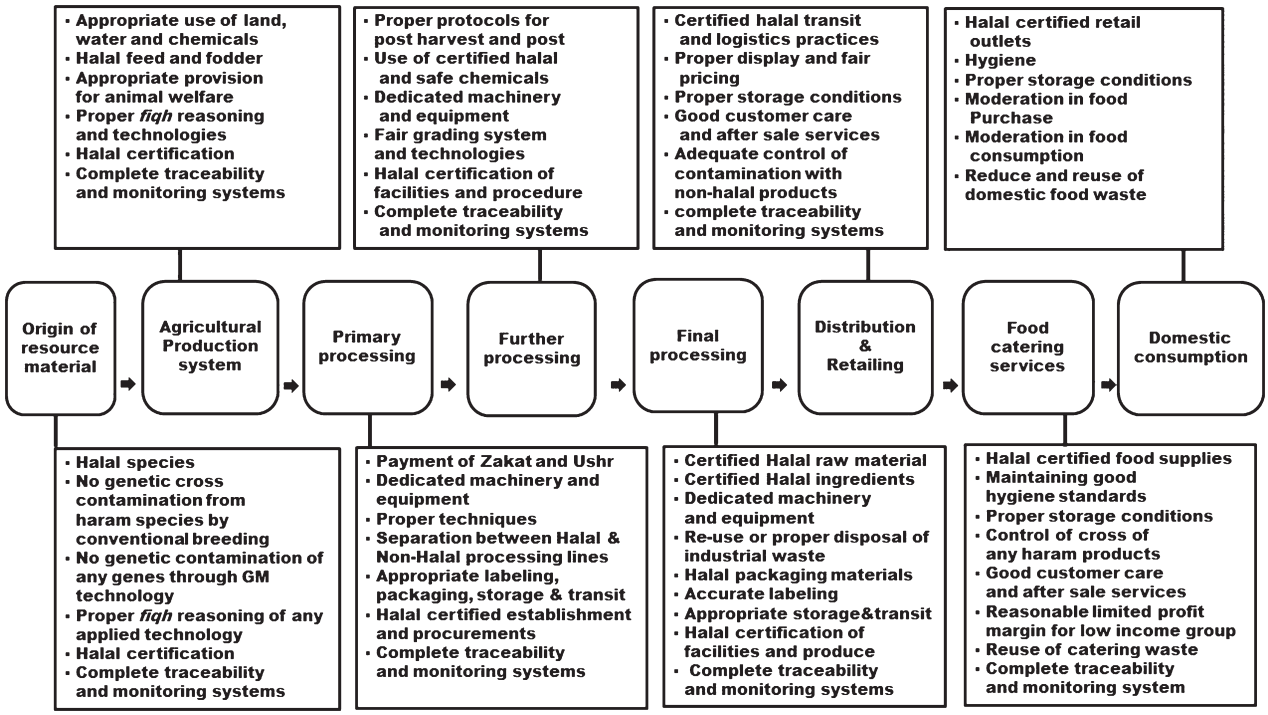

Figure 1. Halal assurance critical control check points.[65]

each other. For instance, rapid on-site detection of large samples may utilize immuno-chromatographic technique-based screening procedures, while complex samples may require ELISA and PCR methods. For cosmetic and pharmaceutical samples, FTIR and MS methods may be more suitable. New innovative methods are being developed for rapid on-the-spot detection with better sensitivity to assist and enable regulators to make sound scientific decisions. However, none of the analytical procedures is capable of confirming the absence of non-halal substances, as measuring analyte concentrations down to zero is not possible. In the case of genetically modified organisms, a certain percentage of allowances has been permitted for adventitious presence. Since Islam prohibits haram substances such as pork and its derivatives, it may not be appropriate to use such allowances when it comes to religious sentiments. However, knowing the technical limitations of the analytical methods, religious scholars across the globe should consider an Islamic ruling (Fatwa) to propose the lowest possible detection limits as allowances until new methods with improved detection limits are established. In addition to analytical testing, sound traceability systems with product identification, tracking and maintenance of information relating to the product and its movement can help improve halal assurance of packaged goods. The first step towards effective halal authentication lies in the unification of halal standards, for which consensus among different schools is undeniably essential. Since the basic principles of Islamic law remain unaltered, it is worthwhile to establish a common minimum program or at least mutual recognition among Islamic countries, which would in turn pave the way for the establishment of a single standard. Once this is achieved, monitoring becomes more practicable to ensure halalness. In conclusion, consensus on the establishment of one standard approach coupled with a sound traceability system and constant monitoring would certainly improve and ensure halalness of consumer packaged goods.

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