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THREE-DIMENSIONAL (3D) PRINTED FOOD PRODUCTS FROM HALAL FORENSIC PERSPECTIVE: A PRELIMINARY REVIEW¹

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ABSTRACT

The emergence of three-dimensional printed (3DP) technology in the food industry is one of the possibilities for a source of global halal food supply in the future. Producing individualized nutritional meals, food sustainability, and developing new solutions worldwide are just a few of the benefits of using 3DP. However, there are still issues with 3DP, especially regarding safety issues and all the risks to the consumer that needs to be overcome. Besides, it will safeguard each essential component of food production for commercial purposes and acceptance by the public. The objective of this study is to gather information regarding the potential of 3DP as well as its availability in the halal market. This study revolves around the five main pillars of halal forensics for halal-based products. This qualitative study employs library research as the data collection method. Data were analysed using content analysis method. Based on this study, a new regulatory framework for halal 3DP food products can be suggested through the halal forensics concept. This allows the authenticity of halal 3DP food products to be certified to safeguard consumers when consuming especially the Muslim community.

Keywords: *Three-Dimensional (3D), regulatory framework, 3D Printing, Halal Forensics.*

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Introduction

Science and technology have transformed the world in ways it has never been changed before. Technology has become an inevitable part of the world ecosystem where technology creates a profound impact on human life and the surrounding environments. This is even more so with the rise of Industry 4.0 where the growth of technology has altered the landscape of the manufacturing industry. Technologies such as robotics, the Internet of Things (IoT), big data, cybersecurity, augmented reality (AR), cloud computing, and additive manufacturing (three-dimensional (3D) printing) (Alcacer, V., Cruz-Machado, V., 2019; Pereira, A. Romero, F., 2017) have been integrated with a plethora of applications in the manufacturing sector.

One manufacturing sector that has integrated such technology is the food industry (Dick, A. et al., 2019). The development of the food industry ranges from materials, processes, packaging, and manufacturing equipment which utilized technologies for such purposes (Malagie, M. et al., 2018; McKinsey, 2018). One of the technologies from Industry 4.0 used in the food industry is 3D printing (3DP). The capability of 3DP provides a fresh alternative to the production of food by reducing the usage of the workforce, timing saving, and affordability. For example, in the 3DP world, 3D meat printing creates a cross-sectional slice that can imitate the structure of the conventional slices. Such accomplishment is done by aligning the content of protein, fat, and other nutrients while maintaining the food's original texture and taste (Handral, H. K, et. al., 2020). This 3DP meat can provide the right balance of nutrients that are beneficial to human health, in addition, generate value for consumers and the food industry. This advantage can largely be highlighted in countries with the lowest gross income. Moreover, the usage of 3DP food can save thousands of lives, particularly children, from being a victim of malnutrition and starvation. Also, it helps patients and the elderly when it comes to chewing and swallowing difficulties.

The absence of a halal regulatory framework for halal 3DP food products will lead to risks and harm to consumers. As for now, little research has been done on the relevant studies discussing 3DP food products from a religious and legal perspectives. Therefore, this study reviews the elements of Islamic jurisprudence in halal forensics concept to suggest for a regulatory framework for halal 3DP food products.

Methodology

This qualitative study was conducted using the armchair research method of library research and consists of two phases. The first phase is the data collection phase, which refers to and examines the primary and secondary data. This also involves Quranic verses, Sunnah, classical books of *turath*, journal articles, books, papers, electronic publications, and other related documents. It focuses on the field of halal forensics, fiqh forensics, 3DP technology, legal rules and regulation, documentary, and others. The second phase is the data analysis phase where content analysis method has been used to analyse the data. Content analysis is a method of communication message processing that comes in the form of written, oral, or visual messages (Mohajan, 2018). In this research, deductive and inductive approaches have been used to achieve the research objectives. Inductive analysis is described as the process of using raw data to specify themes, models, concepts, or parameters through the understanding of gained data. In simple words, it refers to the process of concluding specific-complicated data into a general conclusion and generating new knowledge, while the deductive approach is vice-versa (Alias et al., 2010; Hashim & Qadous, 2014).

Discussion

3DP in The Food Industry

3DP of food is the process of manufacturing food products using various techniques, and it is also known as Additive Manufacturing (AM) (Handral, H. K. et al., 2020) or Rapid Prototyping (Gross, B. C et al., 2014). These food printers allow consumers or users to create the desired food by modifying

and controlling the shape, colour, texture, taste, or nutrition using a computer, a telephone, or some other devices (Dick et al., 2019).

The first published work on 3D meat printing was when a researcher demonstrated 3DP turkey puree for sous-vide cooking methods. Turkey paste was added with transglutaminase enzyme as a binder and bacon fat as seasoning. It was printed in hemispherical cut using a home extruder-type 3D printer. Multi-material food printing with a complex internal structure is suitable for conventional post-processing. So, starting from that moment, the study of 3D printing in the field of food has grown (Matias, E., & Rao, B. P. 2015; Noorani, R. I. 2017; Gross, B. C. et al., 2014).

New technological innovations were developed and have successfully printed alternatives using 3D printers. This meat has the same quality, taste and texture as real meat. Two Israeli companies pioneered this technology, namely, Redefine Meat and MeaTech. Redefine Meat has successfully printed plant-based meat consisting of beans, soy, sunflower oil, coconut fat, and flavors. The end of a product is a plant but tastes like meat. While MeaTech prints meat based on cultured cells. Cultured cells are taken from non-slaughtered cattle. Then, the cultured cells were used as material for printing the meat. There are other companies such as NovaMeat and Natural Machines that are now currently on the wagon for 3DP of food with more advanced products and printers.

The Marketability Potential of 3DP Food Products

Today's market is flooded with various food due to advances in the food technology industry. Some are self-beneficial and healthy, and some are foods that are harmful to human life. The technology of 3D printing can be used as a solution platform for several of the problems that the industry needs to face, including human beings as consumers, or the environment (Lipson, H., & Kurman, M., 2013). The development of 3D printing for example 3DP meat is increasingly being touted and has gained the public's attention in the market. It is emerging as one of the most exciting and promising future technologies in this area (Alcacer, V., Cruz-Machado, V., 2019). Based on statistics recorded by online content writers, Silicon India notes that the worldwide 3D Food printing industry has grown from USD 3 billion in revenues back in 2013 to USD 21 billion in 2020 (Rajan Sarma, 2020). In addition, based on a global market scale, 3D printing products and services are anticipated to have a yearly growth rate of about 26% and are envisaged to be worth USD 40 billion by 2024 (Kewuyemi, Y. O. et al., 2021). Besides, Antonietta Baiano (2020), in her study highlighted possible opportunities for 3D business expansion whereby in their opinion, 3D food printing can be used as an avenue to build innovative market models as well as to improve the sustainability of the food supply chain. In conclusion, based on the statistics and prediction of the researchers about the potential and advantages of this 3DP food product, it is estimated to further create a potential market and demand for food printing.

Five Main Pillars of Halal Forensic Concept

The definition of halal is 'allowed' or 'not forbidden' intake in Islam. According to the Quran, all good and clean food is halal. Muslims are required to make food choices based on two criteria that must be met, namely halal and *tayyib*. As Allah SWT said:

Translation: "They ask you, 'O Prophet,' what is permissible for them 'to eat.' Say, "What is good and lawful."

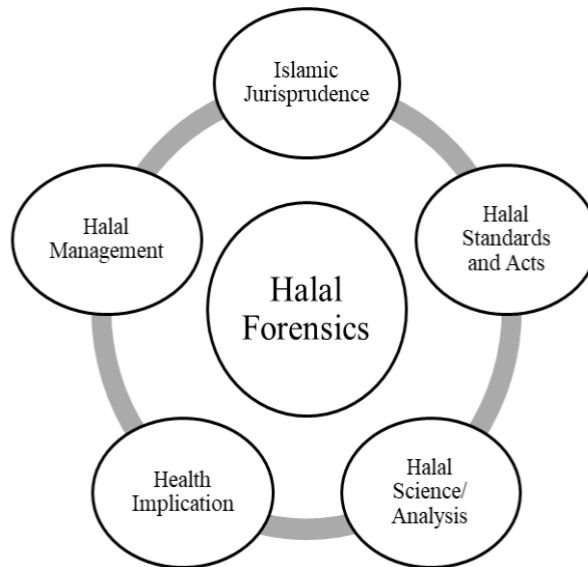
(Surah Al-Māidah 5:4)

According to Ibnu Kathīr (1999) and Al-Sābūnī (1980), the term 'halal' refers to what is permissible by Allah s.w.t. while 'toyībān' is something that is legalized and taken according to one's state of health.

On the other hand, the definition of forensic is the debate and discussion in the trial or judgment taken from the Latin language that is from the word 'forensic' and 'forum' (Crispino, 2013). In terms of terminology, it is to apply scientific methods to solve an investigation case that includes the application of the law, chemistry, biology, information technology, and so forth (Baharuddin et al., 2015). Halal

forensics concept (HFC) was introduced by Hassan (2018) that consists of Islamic jurisprudence, Halal Standards and Acts, Halal Science, and Halal Management elements. Islamic jurisprudence is the first element encountered in the halal forensics model. It is based on Islamic law that explained in detail permissible and prohibited things in every aspect of human life. Baharuddin A. S. *et. al.* (2019), later added the fifth element which is health implication as another important element in HFC. This aspect concerns the safety of food and good for human health that can be divided into three categories, physical health, mental health, and spiritual health effects that embody long-term and short-term effects of human consumption on certain products. The abundance of foods and goods products can expose consumers to many health risks if wrongly consumed. So, the role of health in this model helps to expand the knowledge regarding the safety and risks of consuming food and goods. The overall concept of HFC can be viewed in Figure 1:

Figure 1: Halal Forensic Concept (HFC)



Advantages, Challenges, and Issues of 3D Printed Food Products

Based on recent data obtained from scientific journals, 3DP food especially meat provides a variety of advantages and benefits. Numerous advantages arise from the usage of this new science and technology by increasing the positive impact on any area of health, economy, and others. Besides, we can see this technology founded to stand as a platform to improve the nutritional value as in the study that has been discussed (Dick, A. *et al.*, 2019). This technology can improve the texture and value of food for a new food product through this printing by combining various food ingredients. Besides, this technology can reduce waste and improve environmental sustainability, increasing convenience and efficiency, ensuring human health, and helping the world face food shortages (Lupton, D., & Turner, B., 2017). Similarly, Jasper's study supports that 3D printed meat can fix food scarcity problems in some areas and countries, solve the problem of nutrient-containing foods that have been limited, resolve the issue of food shortages faced by astronauts and military forces, and climate change mitigation (L. Tran, 2016).

However, some researchers have raised the challenges and issues detected in 3D-printed food products. L. Tran (2016) focused his research on the legal concerns of 3D printed food labelling in terms of product content. This includes probable allergies and adulteration, both of which could pose a health risk to consumers. As a result, he advocated for the implementation of legislation governing the labelling of 3D printed food products. Meanwhile, Ismail, Hwang, and Joo (2020) opined that regulations and laws are needed to preserve human life, consumer interests, and health in using 3DP food product. This is also to ensure that the food trade is conducted fairly. On the other hand, Antonietta Baiano (2020) provides an extensive overview of safety standards for 3D-printed foods. While Dankar, Haddarah, Omar, Sepulcre, and Pujola (2018) emphasized the importance of enacting clear laws for 3D

food printing facilities and employees. They also stated that the printing process has four significant challenges: rules and guidelines, food shelf life, ingredient restrictions, and post-processing. In addition, the issue that needs to be highlighted is related to the food status of the technology from the Islamic view to match with the *halalan toyyiban* principle. This is crucially related to the life of a Muslim and will have a profound effect on daily life. The fatwa or law on consuming food additive manufacturing needs to be issued and gazette for the benefit of the Muslims community.

Halal Regulatory Framework for 3DP food product based on Halal Forensic Concept

The presence of 3DP food products on the market has prompted the emergence of new market players, as well as consumers from various levels and demographics, including Muslims. However, based on preliminary studies conducted, a regulatory framework for 3DP food products has not yet been established. This can lead to risks and harm to consumers especially Muslims for halal products. Therefore, it is important to build a regulatory framework for halal 3DP food products in ensuring food safety, security, and sustainability. This study suggests HFC as a foundation for building the regulatory framework of 3DP food products. This is because the existence of halal forensics can be a good solution to overcome crimes related to consumer products. This approach is significant in helping to combat the criminal actions of entrepreneurs as well as convicting offences and appropriate punishment. This is because such criminal acts not only involve the content of illegal products but can also pose a risk to the lives of consumers as well as a threat to the halal industry. Hence, a halal regulatory framework for 3DP food products can be suggested to be built based on the HFC. The five main elements of halal forensics as noted in the previous discussion are Islamic jurisprudence and fatwa, halal standards and acts, halal science/analysis, health implications, and halal management. This study will only focus on the element of Islamic jurisprudence or fatwa to determine the halal status of 3DP food product products.

Islamic Jurisprudence / Fatwa

An explanation of the obligation or prohibition for a product must be considered from a shariah perspective. Nowadays, various new things arise, and their status is not explained in detail and directly. So, it needs to be discussed and explained based on the evidence of the Qur'an and Sunnah to determine the law on an issue. With the development of new technology 3D printed products have become the new products for producers and buyers. Even still, practically all Muslims in Malaysia were concerned about ijihad and fatwa on 3D printed technologies. The lack of state or national fatwas has hampered the manufacturing of this commodity in Malaysia and other countries until present. In early December 2020, the Malaysian government sent a representative from the Jabatan Kemajuan Islam Malaysia (JAKIM) to Singapore to obtain information and clarification from the Singapore mufti on the topic of cultured meat developed using bioreactors. This is due to the permission given by the Singapore Food Agency (SFA) for the adoption of new technology-based meat. It is also intended to perform an in-depth study before issuing any fatwa on whether Muslims are allowed to eat it or not (Faebaderolhesam, 2020). Hence, building a regulatory framework on 3D printed food products requires cooperation with members of the fatwa congregation as well as relevant parties to discuss all the rules of obligation or prohibition and fatwas related to this 3D food product technology. Therefore, this study proposes a regulatory framework from a view of the shariah point as a proposed solution to the issues that arise in 3D food product technology.

a) Ingredients/raw material

The materials or ingredients used in producing 3D food or additive manufacturing are the most important aspect and need to be emphasized. The main thing to consider is the obligation to ensure that it is from a halal source and free from anything that poses a risk to health, mental and physical. This is because this technology uses either animal or plant-sourced materials. As a method of producing this

product, Islam requires its people to choose good materials. Therefore, as a guideline to ensure that 3DP food product technology is in line with Shariah requirements, it must comply with the following:

- i. Halal and pure ingredients.
- ii. Substances that do not harm the human soul and mind.
- iii. Materials that go through the production process also do not harm humans and the environment.
- iv. Use of good plant material and far from toxic.
- v. The use of prohibited substances is prohibited
- vi. The use of halal animals is allowed if the animals are slaughtered according to Islamic rules.
- vii. Limbs or cells that are separate from the body of an unslaughtered animal are prohibited because they are a carcass. Most scholars' opinion is that meat or limbs that are separated from an animal while it is still alive are unclean and forbidden to be eaten.
- viii. Free from pork, poison, and *khamr*-based sources

Therefore, it is necessary to thoroughly examine all the materials used during processing to comply with the order and avoid Shariah prohibitions.

b) Packaging and labelling process

The next issue highlighted for 3DP food products is related to food labelling and packaging. One of the methods to ensure that a product is halal is by reading the packaging label to ensure that the ingredients and halal logo are recognized. Food labels are very important, moreover, we are now in an era that requires sensitivity to the production and nutrition, and content of a food. It is one of the precautions to prevent artificial foods and misuse of labels about the contents of the product. The halal law on a product is also one that does not give harm and risks the consumer. But there are issues with 3DP food product regarding consumers' potential to be food-poisoned (L. Tran, 2016). This thing happens to some consumers who are allergic to certain foods. The manufacturer also needs to consider the standard packaging and labeling procedures by stating the package's food allergen. It is one of the actions that consumers who are allergic to certain substances can avoid harming and labeling the product will determine its status (Baharuddin et al., 2020). Avoiding harm by addressing issues that arise is also one of the *toyyib* things. In conclusion, a more careful emphasis on the principles of Maqāsid Shari'ah as well as eating halal and good food from all aspects helps a person perform good deeds as well as be able to preserve religion and morals (Surah Al-Mā'idah 5: 1, 5: 4–5, 5: 87–88, 5:96). So, one of the standards that must be considered by all parties of 3DP food product production is during the packaging and labeling process. Manufacturers must comply with the instructions stating the food allergy on the packaging.

c) Printing process

As we know 3DP food product has various benefits, but it must be ensured to achieve *halālān toyyibān* status, in each food manufacturing chain including all processing activities and operations. As a method of producing *halal toyyiban* products, the whole process must be based on shariah for the good and *maslahah* of human beings. So, the status of eating food that is good for human beings is justified. This study also suggests that special Standard Operating Procedures (SOP) be prepared for the use of 3DP food technology because it is a technology that can print food industrially or privately according to their tastes. Therefore, all rules, guidelines, and SOPs must be followed by all parties during the printing process in order to avoid potential pollution that may occur during the processing of the food.

d) Facilities and employees

Among other issues that need to be considered in the 3DP food product manufacturing process is that it should scrutinize a perfect assessment in a wide range in terms of facilities and employees to ensure that this technology does not conflict with religious practices. This step can avoid all adverse effects on humans and the environment. It means that 3DP food product must be produced with full honesty and use clean and pure equipment. As per the definition of halal stated in the *Perintah Perihal Dagangan (Takrif Halal) 2012* it is “not prepared, processed or manufactured using any equipment contaminated with ‘najis’ in accordance with Hukum Syarak and Fatwa”. Thus, as a suggestion, prevention through legislation should be done to maintain the authenticity of the food. It is also to prevent cases of deliberate contamination with the aim of profit by one party and endangering the lives of consumers.

Conclusion

In conclusion, the presence of halal regulatory framework for 3DP food product based on halal forensics concept would greatly benefit the future. This 3DP food product innovation and revolution is a new issue in the food manufacturing sector. Hence, before it is genuinely commercialized, especially in Malaysia, research efforts need to be intensified. So that these efforts can address the unresolved existing issues of 3DP food product that need to be overcome. Therefore, to achieve good impact, the halal forensics concept, should be made the key policy in parallel with the development of science and technology. Likewise, if human beings use their intelligence well by following the rules of the principles of Shariah, they can reject all negative things. The development of science and technology that is not guided by religion will be led to various problems, issues, and risks. Therefore, Islam always welcomes the development of new technology, but it should be following the guidance of the Qur'an and Sunnah. Therefore, this study suggests should further research to be done from other halal forensic elements in order to establish the regulatory framework.

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