

The Recombinant Collagen-Like Protein as Animal-based Collagen Substitution: A Qualitative Study

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ABSTRACT

Collagen has been used widely in food, pharmaceutical, cosmeceutical, biomedical, tissue engineering and film industries. The surge concern on the halal issues of Collagen, which mainly originates from porcine or pork as well as bovine, leads to the development of the recombinant collagen-like protein as an alternative of animal-based Collagen. It can be a substitution for halal and vegetarian industries. The aim of this study is, therefore, to discuss on the issue of halal Collagen and the experts' opinion on the new technology of the recombinant collagen-like protein to substitute non-halal and doubtful sources of Collagen. The study is carried out by holding an in-depth interview with the experts who are from various areas of expertise and different academic background. These experts concur similar definition of Collagen. Even though they had different opinions on the suitability of bacteria-based Collagen to be used in production, they mutually agreed that the bacteria-based Collagen has a massive prospect in Malaysian industries. Thus, companies should produce final products that use bacteria-based Collagen as it may tempt a lot of consumers who concern about the resources used in the product produced. The experts also agreed that halal certification on the alternative source of Collagen could boost confidence among consumers on the final products produced.

Keywords: Collagen, Recombinant Collagen-Like Protein, Halal, Malaysia

1. Introduction

The halal issues on Collagen aroused since the source of Collagen are mostly from an animal such as pork, especially in gelatine, which always used in the food industry. The gelatine generally comes from swine skin because it is the quickest way to produce the gelatine, and it is least expensive (Batu et al., 2015). Aside from that, in the pharmaceutical industry, the halal issues also come to light. Still, it is considered as a minor concern as compared to halal issues in the food industry (Tumkur, 2010).

Since the surge concern on the halal issues of Collagen, which mainly comes from porcine or pork as well as bovine, it leads to the existence of the recombinant collagen-like protein as the substitution to the animal-based Collagen for halal and vegetarian industries. Moreover, gelatine, which is known in the food industry, mostly sourced from bovine or porcine. As reported, 41% of gelatine produced in the world made out of swine skin, 28.5% from bovine hides and 29.5% from bovine bones (Lestari et al., 2019). Due to the growing fret on the Bovine Spongiform Encephalopathy (BSE) or mad cow disease, it has affected the gelatine market. The manufacturers have tweaked the market into porcine gelatine, which is a by-product from pork. Hence, it resulted in 90-95% of global gelatine production are sourced from non-halal sources (Lestari et al., 2019). Gelatine made of marine sources is halal and can substitute the animal-based gelatine. However, the production of marine gelatine is minor (M^a C Gómez-Guillén et al., 2002; Lestari et al., 2019).

Nevertheless, the growing demand from vegetarian food groups thrives the interest in "veggie gelatine" which can replace the animal-based Collagen (Lestari et al., 2019). Initially, the plant-based Collagen was nowhere to be found. Fortunately, the plant-based gelatine replacers were found, and they are

typically developed from plant hydrocolloids (Lestari et al., 2019). However, the physicochemical characters of Collagen in plant and animal are different. Thus, not all plant-based Collagen is being able to substitute the animal-based Collagen. Therefore, the recombinant collagen-like protein has the potential to replace the animal-based Collagen. This paper thus discusses the halal Collagen and the experts' opinion on the new technology of the recombinant of collagen-like protein to substitute non-halal and doubtful sources of Collagen.

2. Literature Review

2.1 Introduction to Collagen

Collagen has been extensively studied in research laboratories at the beginning of the 20th century (Sandhu et al., 2012). It is widely used in various industries, especially foods and cosmetics. Scientifically, Collagen presents mainly in connective tissue found in skin, tendon, bone, and cartilage (Hashim et al., 2015; Raman & Gopakumar, 2018). Collagen can be found not only in the animal but also in human. It represents one-fourth of total animal protein while, in the human body, Collagen is the source of protein, which total up to 30% of dry weight (Raman & Gopakumar, 2018; Sandhu et al., 2012).

Collagen in animal mainly processed and useful in a variety of product and it has been one of the significant interests in science because of its features as gels and edible films. One of the uses of Collagen is in the processed meat, poultry, and seafood products which can slow down the moisture loss, reducing lipid oxidation and discoloration. Besides, the edible coating is also enhancing product appearance in retail packages by eliminating dripping, sealing subtle flavours, functioning as carriers of food additive (Maroušek et al., 2015). In the human body, Collagen naturally exists in connective tissue such as skin, bone, cartilage, smooth muscle, and basal lamina. Moreover, Collagen provides rigidity, elasticity and strengths. Besides, Collagen imposes a significant impact on human well-being. Since Collagen is the basic building block of the extracellular matrix in native tissue, it is an ideal material for regenerative medicine (Pawelec et al., 2016). Regenerative medicine mainly focuses on human cells and focuses on restoring the tissues' native function (Mason & Dunnill, 2008; Pawelec et al., 2016). For example, the patients with the malignant tumour for the thyroid gland, larynx or trachea are required to go through the tracheal resection. Thus, the procedure has caused the failure for the trachea to function fully like it used to be (Cotton, 2000; Marino et al., 1961). Due to the implication, the development of artificial trachea emerged since 1995 (Nakamura et al., 2000; Tada et al., 2012). The artificial trachea was constructed with conventional collagen sponge, and it has shown good progress with no restenosis, which is an occurrence of post-operation (Omori et al., 2005; Tada et al., 2012). Nevertheless, Collagen also widely used in food and beverages (Hashim et al., 2015). In particular, the fish collagen used in food and pharmaceuticals (Raman & Gopakumar, 2018) and it is also used in nutraceuticals product particularly for geriatrics or older patients (Gupta & Prakash, 2015).

2.2 The overview of *Halal* products in Islamic points of view

As Muslims, we believe in al-Quran and al-Sunnah which guide us on the *halal* and haram act. Like our daily consumption, there are various verses in the Quran that taught Muslims what is right to consume as well as what is prohibited to consume. Any source of food from swine is highly prohibited, and it was mentioned in the Quran, Sunnah, and the consensus of Muslim jurist (Fadzlillah et al., 2011). The verses in the Quran clearly stated about the prohibition on swine and all products made from it. Allah say:

He has forbid you what dies of itself, and blood, and flesh of swine, and that over which any other name than that of Allah has been invoked; but whoever is driven to necessity, not desiring, nor exceeding the limit, no sin shall be upon him; surely Allah is Forgiving, Merciful.
(Al-Baqarah 2:173)

Other than swine, Muslims also prohibited to consume any foods and goods sourced out from carrion. Previously, this article define that natural Collagen came from an animal, usually swine and cattle since there are several of by-product from these animals in the market. Even though the production of Collagen is from cattle, it is still doubtful because, in Islam, the animal should be slaughtered properly. Otherwise, it is considered as carrion and strictly prohibited to be consumed; Allah say:

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 invoked, and the strangled animal and that 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, and what is sacrificed on stones set up (for idols) and that you divide by the arrows; that is a transgression. This day have those who disbelieve despaired of your religion, so fear them not, and fear Me. This day have I perfected for you, your religion and completed My favour on you and chosen for you, Islam as a religion; but whoever is compelled by hunger, nor inclining wilfully to sin, then surely Allah is Forgiving, Merciful. (Al-Ma'idah 5:3)

Owing to the above statements, we know that it is crucial to ensure that a product produced is using halal materials before it can be consumed by Muslims. There are various methods in the production of halal products either in food, cosmetics, nutraceuticals or even medical supplies from Islamic and science perspective, which one of them is *istihalah* (Jamaludin et al., 2011). *Istihalah* refers to "substantial change" or "complete process" of transformation from one substance into another substance (Jamaludin et al., 2011; Zarmani et al., 2016). *Istihalah* is a transformation of offensive or *haram* materials to other materials which include physical appearance and its properties such as name, odour, taste, colour and nature (al-Khatib, 2004; Jamaludin et al., 2011). Therefore, two opinions emerged in the application of *istihalah*. The first opinion was mutually agreed by Hanafi, Maliki, Ibn al-'Arabi, Ibn Taymiyyah, Ibn al-Qayyim, al-Syawkani and Ibn Hazm al-Zahiri school of thought. They suggested that application of *istihalah* can be applied to the various situation such as the fermentation of wine to vinegar, and it is considered *Halal* whether it undergoes the natural or synthetic process. The second opinion suggested by Syafi'i and Hanbali school of thought, which they limit the application of *istihalah* in specific issues only, where they only accepted the natural process of transformation without any intervention of synthetic process (Jamaludin et al., 2011; Ibn Taimiyyah, 2005).

In the research conducted by Jamaludin et al. (2011), as previously cited, they used the *istihalah* application suggested by the first opinion on the issue of gelatine-based products. They applied *istihalah* to determine the *halal* status in gelatine process. *Istihalah* process has three elements; raw materials, conversion agents, and finish products. The mixing process occurred as a result of the interaction between raw material and conversion agent, naturally or synthetically. Later, the finished product will undergo a conversion process, which is differed physically and chemically from the original material (Jamaludin et al., 2011). The study reported that collagen-based from a swine or non-slaughtered animals are prohibited owing to the characteristics of gelatine itself, which are not changing chemically.

Other than *istihalah*, there is also another instrument known as *istihlak* or "extreme dilution". This is when a prohibited substance is diluted in a lawful medium to the extent that none of the known properties of the prohibited substance is noticeable in the lawful medium (Zarmani et al., 2016). *Istihlak* theory refers to the state of a substance that breaks down after stages of the process. For example, when water accumulated faeces more than two tanks, the nature of the *najasa* is decomposed into absolute water. Moreover, according to Ibn Taymiyyah (2005), if a little or a lot of material that is illegal or faeces mixed *halal* permitted, and it gets rid of the smell, colour, and taste, the result is permissible as accord to the Islamic perspectives (Taymiyyah, 2005) (Ibn Taymiyah, 2005; Improper citation).

However, the knowledge of *istihalah* still lacks among science students as stated by a study on the indication of the alertness of Muslim Malaysian students by Universiti Sains Malaysia on *istihalah* in daily life (Aris et al., 2012). The development of technology nowadays is expected to lead to the growth of

knowledge on this method. In science research, fiqh *istihalah* can be applied in the determination of the *halal* status of a product (Jamaludin et al., 2012).

Other than the Islamic perspective in food and science, there are several theories involved in the acceptance of the consumers on the halal product, which is the theory of reasoned action and theory of planned behaviour. The latter is an extension to the former theory where according to the theory of reasoned action (TRA), the intention of appropriate behaviour is an immediate behavioural predecessor, which is the consequence of a collective attitude toward behaviour (Ahmed et al., 2019). Meanwhile, the theory of planned behaviour (TPB) explains that an individual's performance of a behaviour determined by his or her intent to perform that behaviour. For TPB, attitude towards the target behaviour and subjective norms about engaging in the behaviour are the factors influencing intention and purchasing behaviour (Alam & Sayuti, 2011). Both studies used to determine the consumer willingness (Ahmed et al., 2019) or consumer behaviour (Alam & Sayuti, 2011) and predict consumers' intention (Lada et al., 2009) on the halal products in the market.

2.3 Halal Collagen-Based Products

Nowadays, people urge for halal products, and they are not only demanded by Muslims but also by Jews who are also strictly consumed the halal products (Batu et al., 2015; Sugibayashi et al., 2019). The concept of halal itself has attracted consumers to shift their consumption from non-halal to halal. The attraction is owing to the benchmark of halal that focus on the safety, hygiene and quality assurance thus made the product in-line with halal prescriptions are acceptable to Muslim and non-Muslim around the globe (Ambali & Bakar, 2013).

Most Muslims are aware of the halal products and how to choose them. For example, a study conducted in Shah Alam, Malaysia, where the most population are Muslims, found that the factors determine the consumers' awareness on the halal products were religious belief, exposures, the role played by halal certification via halal logo or label and health-related reasons (Ambali & Bakar, 2013). Health issues also related to religious identity and degree of acculturation in whatever people consume (Bonne & Verbeke, 2006). Besides, the ill-health in these modern days attributable to poor nutrition and unhealthy state of what consumers take daily (Ambali & Bakar, 2013; Rice, 1993). Nonetheless, halal cosmetics also increasingly demanded worldwide, but the development of the halal cosmetics production still in nascent stage (Sugibayashi et al., 2019).

As previously mentioned, Collagen is used in various industries; food and beverages, cosmetics, nutraceuticals, pharmaceuticals and even in medical supplies. In foods, the concept of halal does not mean by the food is 'swine-free' (Majid et al., 2015). But we also need to ensure that other contents used to cook the ready-to-eat foods are from halal sources—for example, gelatine, enzymes, lecithin, and glycerine, which act as emulsifiers. Similarly, flavourings, colourings, breadcrumbs and other related materials must be from the halal sources (Zakaria, 2008). Usually, the halalness of gelatine has been doubted due to its sources from swine, which is indeed non-halal. Gelatine is also sometimes sourced from cattle hide, but, the halal status is also questionable. Another issue in the foods industry includes the slaughtering of poultry and meat must be consistent with the religion requirement. The poultry and meat must also not be engaged with other non-halal materials; for example, the cutter used to slaughter must be cleaned thoroughly (Majid et al., 2015).

Other products that are quite demanding are pharmaceuticals and cosmetics product. Around the globe, almost 2.4 billion Muslims demand halal pharmaceuticals and cosmetics products, which do not contain an ingredient derived from swine, carrion, blood, human body parts, predatory animals, reptiles, and insects among others (Sugibayashi et al., 2019). Halal products are quite appealing even among non-Muslim consumers who are strictly demanding safe and hygiene products since one of the halal concepts is hygiene. Moreover, for non-Muslim consumers, halal products can be a benchmark of accepted conformance and quality in trade dealing with Muslims (Haji-Othman et al., 2017; Jamaludin et al., 2011). Research regarding the attempt to discover healthy and halal Collagen is surging. The source of Collagen

that is healthy and halal is from bone, skin and fish scales (Abdul Jabar, 2011; Kittiphattanabawon et al., 2010; Mahboob et al., 2014; Nagai et al., 2004; Okazaki & Osako, 2014; L. Wang et al., 2008).

Usually, marine Collagen is the source of Collagen to replace the animal collagen that has been questionable in terms of their safety, hygiene, and well-being of the animal itself. Those are some basic requirements in the halal concept (Ambali & Bakar, 2013; Sugibayashi et al., 2019). For the fish by-products, not all types of fish have a good source of Collagen. Several fish such as Japanese sea bass skin, clown feather back skin, yellow fin tuna bladder, Japanese seer fish skin and bone, Japanese sturgeon cartilage, and fins, scales, skin, bones, and swim bladder from bighead carp are considered as most excellent alternatives for collagen extraction (Schmidt et al., 2016). The extraction of Collagen from fish can solve the management of fish waste country. As in Indonesia, fish waste is abundant, and the alternative to efficiently manage this waste is the alternative of collagen extraction. Besides, this is an alternative to replace the doubtful sources of Collagen which are from swine, cattle, horses and others (Susanti et al., 2019).

Scientifically, the extraction of Collagen from fish sources is relatively easy and safe. However, there are limitations in the production where the most promising process in getting the high nutritional and functionality outcome is quite expensive. Moreover, the costly process also can reduce the processing time (Schmidt et al., 2016). Fish collagen can be applied to various products in pharmaceutical and food (Raman & Gopakumar, 2018). The medical treatment such as collagen dressing which commonly used in dentistry and surgery also contain fish collagen (Avila Rodríguez et al., 2018; Mahesh et al., 2015) as well as the medication for wound healing treatment (T. Wang et al., 2015; Zhou et al., 2015).

For over ten-years, collage-like proteins have been identified from numerous bacterial genomes database (An et al., 2014). Those bacterial collagens share the similar physicochemical properties of animal collagen. However, some chemical structure in bacterial collagens lacks unlike the structure of the animal collagen. Despite lacking in chemical structure, the bacterial collagens studied in research for bacterial collagen exhibit high thermal stability, which close to that seen for mammalian collagens. This bacterial collagens are readily produced in large quantities by recombinant methods, either in the original amino acid sequence, which is the main physicochemical in Collagen or genetically manipulated sequences (Yu et al., 2014). The research on the bacterial Collagen is purposely to replace the extracted mammalian Collagen and may open a new pathway for collagen production (An et al., 2014). Fortunately, this recombinant of collagen-like proteins also may replace the doubtfulness in the halal status of collagen-based products in the market nowadays. Since this type of research is still in study, experts' opinion in halal products is needed. Therefore, this article discusses on the experts' view on the recombinant collagen-like proteins to substitute the mammalian Collagen in most products in the market today.

3. Research Methodology

3.1 Research Design

The study adopts qualitative research method. It explores views and perspectives of experts in various field related to Collagen and the development of bacteria-based Collagen. A semi-structured face-to-face interview is the primary source of data collection used in this study.

3.2 Sample selection

The study used the judgemental sampling method in selecting the respondents that are suitable for the interview. Those who possess knowledge, exposure and expertise in the related field are chosen. This research thus chooses six experts in various fields of academics and industries. Table 1 records the experts who participated in the interview session.

Table 1: Interviewee's description

Interviewee	Background of interviewee
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Interviewee 1	Head of International Institute for <i>Halal</i> Research and Training (INHART) Area of expertise <ul style="list-style-type: none"> - Natural Science - Chemical Sciences - Analytical Chemistry - Instrumental Sciences
Interviewee 2	Researcher at INHART Area of expertise; <ul style="list-style-type: none"> - Social Science - Syariah Law - Islamic Jurisprudence - Fiqh Halal and Consumerism
Interviewee 3	The Senior Professor in University Kuala Lumpur (UniKL) Area of expertise; <ul style="list-style-type: none"> - Food Technology - Food Biotechnology
Interviewee 4	Academician in University Sultan Zainal Abidin (UNISZA) Area of expertise <ul style="list-style-type: none"> - Functional Food and Nutraceuticals - Hazard Analysis and Risk Assessment - Halal Products - Entrepreneurship - Food Safety - Food Chemistry - Nutritional Sciences - Community Nutrition
Interviewee 5	Academician in Universiti Sains Malaysia (USM) Health Campus Area of expertise <ul style="list-style-type: none"> - General Hispathology with a particular interest in Soft Tissue and Bone Pathology
Interviewee 6	Malaysia Halal Analysis Centre, JAKIM Area of expertise <ul style="list-style-type: none"> - Food technology

While other interviewees were interviewed verbally, the interviewee from Pathology decided to give written interview owing to her limited time to spend for verbal interview.

3.3 Research Questions

The questions were divided into three themes, as outlined in Table 2 below:

Table 2: Interview's themes and questions

No	Themes	Questions
1	Information on the Collagen	<ol style="list-style-type: none"> 1. Do you know what Collagen is? Could you explain Collagen from your understanding 2. Could you please explain the usage or benefit of the Collagen 3. Do you know what the sources of Collagen are?

		4. What are the debatable issues pertaining to these sources, if any? Do you know why a particular group of people does not prefer animal-based Collagen?
2	Information on the suitability of the recombinant of collagen-like protein (bacteria-based Collagen)	<ol style="list-style-type: none"> 1. A new source of collagen extraction that is based on the bacteria has been discovered. Do you well aware of this? 2. What do you think of this new source in term of its suitability? 3. Do you think bacteria-based Collagen is suitable to be used in lab experiment only or it is suitable to be produced in mass production? Could you please explain the reason? 4. Do you think bacteria-based Collagen is suitable and safe to be used by the public? May I know why 5. Do you think bacteria-based Collagen is suitable to be produced in Malaysia? 6. Do you think bacteria-based Collagen is halal? Why? 7. What do you think of the prospects of the bacteria-based Collagen in Malaysia
3	Information on the viability of the recombinant of collagen-like protein (bacteria-based Collagen)	<ol style="list-style-type: none"> 1. Do you think producers or manufacturers are interested in producing Collagen that is based on bacteria? 2. Do you think the producers or manufacturers are interested in investing in the production of Collagen that is based on bacteria? 3. Does bacteria-based Collagen profitable to manufacturers? Why? 4. Will bacteria-based Collagen boost production and increase the demand for Collagen-based products? 5. Will bacteria-based collagen industry stay longer in the economy? 6. From your understanding, what is/are the factor(s) that can make a company stay longer in the industry and remain relevant? 7. In Malaysia, is halal certification is important? Why? 8. Will halal certification guarantee the place of the company in the industry? 9. Some collagen product in Malaysia stated the ingredients coming from natural ingredients without halal certification, is it safe for Muslim consumers to ingest that product? 10. Is Collagen considered well-accepted among Muslim in Malaysia nowadays? 11. If this product complies to the halal requirement, are you there to consume this product from bacteria? 12. Do you know what collagen-like protein? 13. Do you aware of collagen-like protein as new things? 14. As a Muslim, would you consume this product if it is commercialized and certified as halal?

3.4 Data analysis

The qualitative content analysis adopted in this study to analyse the outcome. Qualitative content analysis is an act of transcribing the interview texts. Its objective is to systematically transform the

transcriptions into a structured and concise results' summary (Erlingsson & Brysiewicz, 2017). The process in qualitative content analysis begins by listening and recording the interviews, and later the speeches are typed written. The statements from the expertise were improvised into a formally structured phrase as long as it did not stray away from their point of views. The interviews are recorded using the iPhone 8Plus. The answers are organized accordingly to the themes in the research question as described previously.

4. Results and discussion

The in-depth interview fetched on various answers and perspectives from the experts. As mentioned before, three themes are reported here:

4.1 Information on the Collagen

All five experts gave similar opinions on the meaning of Collagen according to their perspectives.

"...you must understand what collagen is. It is a natural product, is extracted from the animal. Mainly from the thigh, bones ... collagen is essential amino acid ... from protein" (Food Technologist, UniKL)

"Collagen is part of a protein, and you can get from different types of sources of animal and different part. You can get from many of their joints, bones, something like that. It is a combination of animal acids" (INHART officer)

"collagen comes from an animal, and none come from plants. It is because collagen has two typical components, hydroxyproline and proline. These two components must have in collagen." (Food Science Officer, JAKIM).

JAKIM officer who has experience in collagen research during her study also said;

"plant is not a source of Collagen. For example, in the current industry, there is also a company that used seaweed, plant-based such as pectin, carrageenan. Those are plant-based, but they did not contain hydroxyproline and proline compound. Besides, the contains of amino acid in the plant are little, while the amount of protein in Collagen and gelatine are more than 80%."

However, a different answer comes from an expert in the pathology field:

"collagen is produced from fibroblast which is mesenchymal cells created by God to secure our body to function beautifully" (Pathologist, USM)

The usage and benefit of Collagen also emphasized in food product aside from cosmetics and pharmaceuticals.

"well, the application mainly in foods. They served as a stabilizer, as well as a sweetener. Lately, a lot of collagen used in cosmetics, pharmaceutical products" (Food Technologist, UniKL)

"its (collagen) benefit for all products because it can upgrade the products' quality to support the food or cosmetics production" (INHART officer)

"if for gelatine, it is mainly used in the food industry, it is because the texture of gelatine itself is like jelly. Gelatine has a reversible function, unlike starch (carrageenan) ... Collagen currently mainly used in cosmetic products, other than cosmetics, Collagen also used in nutraceuticals." (Food Science Officer, JAKIM)

"normally collagen used in pharmaceuticals and beauty product"

(Halal Expert, UNISZA)

The sources of Collagen were said mostly from the animal, either bovine or porcine.

"... normally, the collagen in the industrial market come from swine and pork" (Halal Expert, UNISZA)

"you can have from, as far as I know, most of it is from animals. I am not sure about plants but, since it is a protein-based, they can have from a plant, but most of it is from animal" (INHART officer)

"the source of Collagen is from animals such as bovine, porcine, also can be found in buffalo and horse. In the global market, porcine has been commonly used in collagen-based products. I am telling you this because the producing cycle only took three to six months if the company use porcine. Meanwhile, for bovine, a company may need to take a year producing cycle" (Food Science Officer, JAKIM).

Due to the sources, the debatable issues exist. The debatable issues are not confined in the *halal* status per se but also the other issues such as diseases on the animal.

"two issues from these sources are the halal status and the general animals since there are a lot of animals, we do not know they may have contracted with foot and mouth diseases, or mad cow disease" (Food Technologist, UniKL)

Consumers switched their demand from animal-based Collagen to marine-based Collagen owing to the issues on doubtfulness of the halal status based on religious beliefs, and the well-being of the animal. However, other issues aroused.

"There are consumers who demand marine Collagen, which is from fish skin. Somehow, the contamination issue arose. There was this case; a company claimed that their product is based on marine Collagen, but, they discreetly contaminated the product with other sources of Collagen." (Food Science Officer, JAKIM).

4.2 Information on the suitability of the recombinant of collagen-like protein (bacteria-based Collagen)

The outputs of the interviews under this theme are outlined in Table 3.

Table 3: Interview's output

Questions	Description
<p>1. A new source of collagen extraction that is based on the bacteria has been discovered. Do you well aware of this?</p> <p>2. What do you think of this new source in term of its suitability?</p>	<p>Due to the issues on the general health of the animal as well as the <i>halal</i> status issues, the bacteria-based Collagen discovered. The experts were aware of this type of Collagen. The bacteria-based Collagen used media to grow the microorganism for them to become the bacteria for Collagen.</p> <p>Since the new source of Collagen was based on bacteria, the experts in food technologist and food chemistry gave their opinion as well as briefly explained the recombinant process of bacterial Collagen.</p> <p><i>"as far as I am in the industry, I am still not found this type of collagen. Maybe it is produced in the lab but not in manufacturing company"</i> (Food Science Officer, JAKIM)</p> <p><i>"Collagen has its properties. Through DNA engineering, when you apply in certain products, it requires certain specific properties. We can produce Collagen of specific properties through DNA for a particular purpose, but, we have to be careful in producing this kind of Collagen. It is because, during the cultivation, the media where we propagate the bacteria may not be halal."</i> (Food Technologist, UniKL)</p> <p><i>"It is safe if it is from the halal sources."</i> (INHART officer)</p>
<p>3. Do you think bacteria-based Collagen is suitable to be used in lab experiment only or it is suitable to be produced in mass production? Could you please explain the reason?</p>	<p>The bacteria-based Collagen, from the perspective of several experts, it is suitable to be produced in mass production.</p> <p><i>"We can do it (bacteria-based Collagen) in the lab as well as in mass production because now we have the technology, we call it bio-reactor, for example. So, in this bioreactor, bacteria can be grown in a mass and then you can extract a high amount or high content of Collagen from these bacteria."</i> (INHART Officer)</p> <p><i>"It is much easier to use bacteria-based collagen through mass production because you can control them."</i> (Food Technologist, UniKL)</p> <p>However, there was also an expert who disagreed with the production of bacteria-based Collagen in mass production.</p> <p><i>"For the current situation, you can use that one (bacteria-based collagen) for the lab experiment but, I doubt it to be produced in mass production. It incurs a high cost"</i> (Halal Expert, UNISZA).</p> <p>As from JAKIM officer's perspective, she explained the recombinant process. To be short, from the process, she clarifies that the recombinant process may minimize the cost because the bacteria may multiply exponentially.</p>

	<p>"... but, to answer either it is suitable to be produced in lab or mass production, I am not sure because I did not found any prove and one more thing, we are Muslim country thus, we have an issue in halal certification process" (Food Science Officer, JAKIM).</p>
<p>4. Do you think bacteria-based Collagen is suitable and safe to be used by the public? May I know why?</p>	<p>In the concept of halalan toyyiban, the products consumed should also have the characteristics of safe and from the experts' perspective, it is safe to be consumed by the consumers especially Muslims consumer if it is controlled adequately during its cultivation and production.</p> <p>"It can be said, yes (safe) ... we should first, test the toxicity before expose by the public" (INHART Officer)</p> <p>"It is safe if it is properly controlled and screened. We are worried about the recombinant process. Because some changes may take place and it produces some effect." (Food Technologist, UniKL)</p> <p>About the <i>halal</i> status on the bacteria-based Collagen, the experts explained that if the media and microorganisms are taken from the safe and <i>halal</i> sources, it will be considered <i>halal</i>.</p> <p>"If the sources of the bacteria per se are from halal sources, then, it is halal." (INHART Officer)</p> <p>"in the recombinant process, e coli is the host, the carrier of the gene of the Collagen per se. Since we need the host to multiply into colonies, it must eat. Hence, the food that we ought to feed the host must be Halal" (Food Science Officer, JAKIM).</p>
<p>5. Do you think bacteria-based Collagen is suitable to be produced in Malaysia?</p> <p>6. What do you think of the prospects of the bacteria-based Collagen in Malaysia?</p>	<p>The experts agreed that bacteria-based Collagen to be produced in Malaysia and it may be a massive prospect in the industry.</p> <p>"It (bacteria-based collagen) suitable to be produced as new technology, new knowledge and for food security as well." (Halal Expert, UNISZA)</p> <p>"The bacteria-based collagen is suitable to be produced in Malaysia. Its prospect is moving upwards because the collagen also used in cosmetics aside from food production and pharmaceuticals." (INHART Officer)</p>

4.3 The Viability of The Recombinant of Collagen-Like Protein (Bacteria-Based Collagen)

From the perspectives of the experts, producers, or manufacturers may have the interest to produce the Collagen-based on the bacteria because the technology is sustainable and cost-effective.

"from the manufacturers' perspective, they certainly thinking of the profit. Thus, if the bacteria-based Collagen can minimize the cost of production, they will perform the production besides, if the demand is high" (Food Science Officer, JAKIM).

"... the technology is proven and sustainable, cost-effective as well. People will use it. And good quality." (Food Technologist, UniKL)

Moreover, for the experts, they also expect that the bacteria-based Collagen may give profit to the manufacturers. It is because the cost involved in the bacteria-based collagen production is cheaper than animal-based Collagen.

"... because it (bacteria-based collagen) is cheap. It also generates more bacteria in one time instead of animal-based collagen during the production." (INHART Officer)

"... it (bacteria-based collagen business) is a profitable venture. Because for the animal-based, you have to find the sources particularly and for bacteria-based Collagen, everything can be controlled. For example, the cow may have a poor health condition, and we did not become aware of." (Food Technologist, UniKL)

Meanwhile, the JAKIM Officer explained that, if the bacteria-based Collagen can function similarly to the real Collagen, it can boost production and increase demand. However, there was also an expert felt hesitate to agree that manufacturers willing to produce the bacteria-based Collagen and that he was in doubt to say that the production is profitable.

"... they (manufacturers or producers) may say they agree to produce, but then, they will ask on who would bear the cost for this new technology? ... they may look at their return on investment (ROI). If their ROI took like five years, they would refuse this technology." (Halal Expert, UNISZA)

The halal expert also emphasized that, for the current situation, bacteria-based Collagen will not boost production and increase demand for a collagen-based product. In his opinion, the bacteria-based Collagen is good. Still, it is hard for the manufacturers to change their current based Collagen into bacteria-based due to high cost incurred unless with the government assistance or support to develop this new technology.

"... for this time being, my answer is no (no demand and did not boost the production). Except with the government assistance. The government willing to give incentive, the existence of consumer awareness on the halal ingredients and so on." (Halal Expert, UNISZA).

In contrast, other experts said otherwise.

"... we can control the system, where we are the one who would be controlling the bacteria and the media itself" (INHART Officer)

Moreover, if the manufacturers plan a wise strategy, they can stay longer in the economy. Aside from that, the company should also observe their target consumers.

"Company may stay longer in the industry if they can maintain their track record." (Halal Expert, UNISZA)

"This is about competitiveness, the pricing and the strategy." (Food Technologist, UniKL)

The halal status is always an issue concerned by Muslims. For the experts, halal certification is rather vital in Malaysia, but the firms are not required to issue the halal certificates. Some experts also stressed out that

the halal certification in Malaysia is essential to prove the raw material in the ingredients of the product. The experts also had a mutual agreement that the halal certification may guarantee the place in the industry.

"... Malaysia is one of the halal hubs. Then, we are promoting halal hub over the world. The halal certification may guarantee the place of a company because it has undergone the integrity process from the starting until the end." (INHART Officer)

"In Malaysia, it (halal certification) is imperative because most of the raw ingredients that we use in our food production. The raw materials ingredients are imported from other countries. This halal certification may guarantee the place of a company in the industry" (INHART Officer)

"Halal certificate is not mandatory, but it is rather voluntary. Even so, if you issued the certificate, it would be good. It may firm a company's place in the industry." (Halal Expert, UNISZA)

"... I would say the halal certificate is important because halal is not only meant for Muslims. Because halal is a benchmarking for quality and setting so when consumers want quality and setting, halal is a choice." (Food Technologist, UniKL)

Meanwhile, JAKIM Officer emphasized that halal certification is vital to the extent that a company will do anything to get the halal certification. Moreover, JAKIM has frequently audited the companies even after securing the certificate to ensure that a company still complies with shariah in their production. Moreover, the halal certification also guarantees the place of the company in the industry. On an important note, JAKIM is the only halal authority governed by the government, unlike other halal authorities in other countries which are more profit-based certification bodies in which the transparency of that halal authority is doubtful. JAKIM has gone to several countries to audit the halal certification bodies to ensure that the managements comply with Islamic laws.

The experts also know the collagen-like protein, but their explanations on this alternative source of Collagen differ. They are also aware that collagen-like protein is a new thing in collagen product.

"... gelatine is also from protein but, because of different composition of amino acid, we called it gelatine." (INHART Officer).

"There are a lot of proteins that behave close to collagen" (Food Technologist, UniKL).

"'Whey' protein is one of the examples of collagen-like protein)" (Halal Expert, UNISZA).

5. Discussions

Based on the results of the interviews, we summarized some crucial points in Table 4.

Table 4 Summary of the output

Themes	Summary
Information on the Collagen	<ul style="list-style-type: none"> • This theme is to acquire the definition collagen. Five from six experts gave similar answers on the definition of Collagen from their perspectives. • An expert in the pathology field answered differently from her perspective in the medical field. • All experts except for the pathologist mutually agreed that Collagen has benefits according to its features and physicochemical. • The sources of Collagen were known from animal and mostly from bovine or swine. Hence, they acknowledged the halal issues came up on the sources of Collagen.

<p>Information on the suitability of the recombinant of collagen-like protein (bacteria-based Collagen)</p>	<ul style="list-style-type: none"> • Experts came up with different ideas on the suitability of the bacteria-based Collagen. • The experts explained on the recombinant process of the bacteria-based Collagen of which the bacteria must be fed for it to grow and must carry similar physicochemical features as animal-based Collagen. • The experts had different opinions on how the bacteria-based Collagen should be produced, either in the lab or in mass production. • For the bacteria-based Collagen to be announced halal, the features and characteristics of bacteria-based Collagen must be safe, clean and fulfil the halal requirements. For instances, the food fed to the bacteria should also come from halal sources.
<p>The viability of the recombinant of collagen-like protein (bacteria-based Collagen)</p>	<ul style="list-style-type: none"> • This theme discussed on the viability of the products in the market if they are produced using bacteria-based Collagen. • The products shall hit higher sales if the bacteria-based Collagen fit the features and characteristics of natural Collagen. • The experts predicted high demand for products using bacterial Collagen, especially among consumers who are doubting animal-based Collagen. • According to experts, halal status is vital, especially in Malaysia. It was owing to the safety and cleanliness of a product that is always concerned by Muslim consumers.

From the in-depth interviews with six experts in halal food, food technology and the halal officers, we may acknowledge that those in different fields have different perspectives on the issue of alternative source of Collagen. In terms of the definition of Collagen, the view from the pathologist is much different from other experts who are mainly in food based. For the information on Collagen, most experts gave similar answers. The benefits of Collagen are mostly in foods and cosmetics as the functions of Collagen itself are reversible, elastic and can upgrade the products' quality. However, religious issues emerge on the sources of Collagen, particularly from animals. Though some say that Collagen could be obtained from plants, the experts said that the Collagen from plants has different physicochemical as compared to animal-based Collagen. Certain products are unable to adopt Collagen from the plant. However, various studies found that marine Collagen can be applied into various products including foods, pharmaceuticals, and even the materials in medical treatment (Abdul Jabar, 2011; Mahboob et al., 2014; Nagai et al., 2004; Nagai & Suzuki, 2000; Raman & Gopakumar, 2018; Yamada et al., 2014).

The second theme of the interview is about the suitability of bacteria-based Collagen. According to the experts who are from the research field, the bacteria-based Collagen is familiar to them. Still, JAKIM officer who involves in industries did not found any manufacturer that used bacteria-based Collagen in Malaysia. The question on the suitability of the bacteria-based Collagen to be produced in either lab or mass production has been answered differently. Scientific study has said that the recombinant bacterial Collagen can be quickly assembled in large quantity (Yu et al., 2014) similar to a statement by JAKIM officer except that she is still unable to discover any product used bacterial Collagen.

The INHART Officers and food technologist said that the bacteria-based Collagen is suitable to be produced in mass production. Meanwhile, a halal expert from UNISZA claimed that bacteria-based Collagen should be produced in the lab since it may incur a higher cost of production if it is produced in mass production. In contrast, the JAKIM Officer said that the process to produce bacteria-based Collagen could reduce the cost because it does not involve lots of animal slaughter because the bacteria can grow exponentially. Anyhow, JAKIM Officer was not sure to answer on which route of production is better because she did not find any company that uses bacteria-based Collagen in its product. However, if there

is, she added, the issue on the halal status may arise. Since the bacterial Collagen still in research, we find few studies discussed on halal bacterial Collagen. But, there was a study from Indonesia explained on the process of bacterial Collagen extracted from milky fish scale and it is indeed halal and healthy Collagen since it is from the fish scale (Susanti et al., 2019).

On the issue of safety, the interviewees gave various perspectives. From the view of food technologist who is also an expert in the halal industry, he clarified that the bacteria-based Collagen must be appropriately controlled and screened during the recombinant process. The view is similar to the JAKIM Officer, who stated that the bacteria in the recombinant process should be fed for it to multiply into colonies. Thus, the sources of nutrients fed to the bacteria must be from halal sources. With proper control, the bacteria-based Collagen will be considered safe and halal if the source of bacterial Collagen is from *halal* sources such as the experimental study conducted by Susanti et al. (2019) where the study reported that the most potential proteolytic bacteria as the source of protease for production halal and healthy Collagen were from the milky fish scale. All in all, the experts mutually agreed that the bacteria-based Collagen has a massive prospect in the Malaysian industries.

The final theme of the interview is regarding the viability of the bacteria-based Collagen. Indeed, for most manufacturers, profit is a priority. They must ensure that bacteria-based collagen products able to give them higher profit than that of animal-based product. However, the switch might not as easy as expected. An expert did suggest that a company should produce final products based on bacteria-based Collagen instead of animal-based Collagen because consumers are concern about the origin of the sources used in a particular product. Even so, a comparative experiment has performed between bacterial collagen hydrogel and commercial collagenase ointment on wound treatment. Even though the study was performed on rat dorsum, the outcome showed that the bacterial collagen hydrogel promoted better wound healing and it can be considered a potential wound dressing for skin regeneration (Moraes et al., 2016). Therefore, there is still a high possibility of great demand in recombinant of collagen-like protein-based products.

The halal status in Malaysia is vital to prove that the material used as an ingredient in a product is clean and safe. The experts had mutually agreed that halal certification might guarantee the place in the industry since the Malaysian herself is a Muslim country. Moreover, the halal authority of Malaysia, JAKIM has been known worldwide as accorded to JAKIM Officer. She added that JAKIM has been auditing the certification bodies from non-Muslim countries. Some Muslim countries only recognize JAKIM logo and have trust in it. Besides, halal products not only demanded in Malaysia with the majority of Muslim population but also gaining worldwide recognition since halal certification has become a new benchmark for safety and quality assurance (Halim et al., 2014). Bottom line, consumers prefer halal products if they crucially wanted a safe, hygienic and high-quality products to consume.

6. Conclusion

This current study aims to discuss the issue of halal Collagen and the experts' opinion on the new technology of the recombinant collagen-like protein to substitute non-halal and doubtful sources of Collagen. The study is carried out by holding an in-depth interview with the experts who are from various areas of expertise and different academic background. Most of the interviewees have similar definitions of Collagen. However, they had different opinions on the suitability of bacteria-based Collagen to be used in final production. The experts mutually agreed that the bacteria-based Collagen has a massive prospect in Malaysian industries and companies should produce final products that use bacteria-based Collagen as it may attract a lot of consumers who concern about the sources used in a particular product, particularly among Muslims. The experts also agree that halal certification on the recombinant collagen-like protein can boost confidence among consumers on the final products produced.

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