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MINI REVIEW

The potential of hydrocolloid-modified fish gelatine in substituting non-halal gelatine for halal dessert cuisine

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Abstract

Gelatine is one of the essential ingredients in dessert making that enhances product development. As porcine and bovine gelatines are exquisite ingredients in many food products, especially in desserts, religious and cultural restrictions need to be considered. The limits in religions on porcine and bovine gelatine consumption contribute to mammal gelatine substitutes such as fish gelatines. However, the fish gelatine has lower thermal and rheological properties compared to mammalian gelatines. The lower rheological properties decrease the mechanical strength, gelling mechanism, and capability to stabilize in dessert products. Hydrocolloid-modified fish gelatines can overcome such drawbacks by improving their gel properties. This study reviewed the physical and chemical properties of different hydrocolloids used to modify fish gelatines which are agar with locust bean gum, carrageenan with locust bean gum, and gellan with calcium chloride, and their potential to emulate the texture and sensory properties of non-halal gelatine in dessert products. The study of modified fish gelatine with hydrocolloids can be a learning paradigm among food service establishments to intensify the need to explore the components used in food manufacturers and food industries. The new research that introduces hydrocolloid-modified gelatine will give various selections in creating new products without the intervention of non-halal or forbidden substances, especially in the gelatine-based dessert.

1. Introduction

The demand for gelatine is rising globally as its multifunctional properties contributed to many sectors, including the food industry. The utilization of gelatine in the food industry resulted in the increase of stabilization, texturization, and mouthfeel properties of the products (Karim and Bhat, 2009). In the dessert-making industries, gelatine has long been used as a gelling and foaming agent for the production of sweets, confectionaries, ice cream, and jellied-coated meat products (Wu *et al.,* 2015). However, it had been reported in 2016 that Europe has commercially produced gelatine approximately 80% from pigskin, 15% from cattle hide splits, and 5% from pig and cattle bones, and fish (Gelatine Manufacturers of Europe, 2018). As porcine and other mammals were reported to contribute major sources of gelatine production, religious and cultural restrictions need to be considered (Karim and Bhat, 2008; Kamal Uddin *et al*., 2021).

In the food industry, gelatine has been a debatable issue among Muslim Jurists, and each of the Muslim countries has a different perspective based on Islamic scholars and fatwa (Zin *et al*., 2021). Predominantly, most Islamic scholars acknowledge permitted animals that have gone through the slaughtering process according to *Shariá* rules to produce gelatine are halal to consume (Jamaludin, Ramli and Rahman, 2011; Benzertiha *et al*., 2018). However, gelatine obtained from pork and carrion has caused disagreement among Muslim jurists and is not permitted to be consumed (Shah and Yusof, 2014; Batu *et al.,* 2015; Rakhmanova *et al.*, 2018).

In Malaysia, any food products that contain non-

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halal gelatine are prohibited from being consumed as the Department of Islamic Development Malaysia (JAKIM) is obligated based on the *Syafi'i* and *Hanbali* Islamic Scholar groups. Even though the majority population in Malaysia practices Islam as indicated by 61.3%, Malaysia is not able to keep up with the market demand as a halal gelatine supplier (United States Department of State, 2018). The argumentative on non-halal mammalian gelatine has expanded fish gelatine utilization among Muslims, Jews and vegans. Even though fish gelatine can potentially be substituted with mammalian gelatine, fish gelatine has minimal thermal and rheological properties compared to mammalian gelatine (Sow, Tan and Yang, 2019; Derkach *et al*., 2020). Fish gelatine modification can overcome the problems by mixing fish gelatine with various hydrocolloids (Huang *et al*., 2019). The incorporation of hydrocolloids with fish gelatine, including agar, κ-carrageenan, pectin, and gellan, has been reputed to enhance the textural properties of fish gelatine (Petcharat and Benjakul, 2017). Therefore, this review focuses on the physical and chemical properties of different hydrocolloids used to modify fish gelatines which are agar with locust bean gum, carrageenan with locust bean gum, and gellan with calcium chloride, and their potential to emulate the texture and sensory properties of non-halal gelatine in dessert products.

2. The application of gelatine from the Islamic law perspective

In Arabic terms, Halal can be defined as "permitted, allowed and lawful" for human consumption, in which any food or drink is permissible to consume by Muslims (Batu and Regenstein, 2014; Marmaya *et al*., 2019). According to the Quran and hadith by Prophet Muhammad, lawful food and drink must follow and be endorsed by Islamic law (Lubis *et al.,* 2016). As reported by Shah and Yusof (2014), two commodities need to be emphasised when discussing halal products from the Islamic perspective; the food must not only be permissible according to Islamic Law, but it has to be of excellent quality and safe (*tayyib*) (Shah and Yusof, 2014; Aliff *et al*., 2015).

Gelatine obtained from pork and carrion has disagreement among Muslim jurists (Shah and Yusof, 2014; Batu *et al.,* 2015; Rakhmanova *et al.,* 2018;). One group of Muslim scholars concurred that gelatine obtained from pork and carrion sources is prohibited (*haram*). In contrast, several other criticisms have been put forward concerning gelatine extracted from prohibited (haram) sources being permissible (halal) because the *Istihalah* process has taken place (Nazih, 2004). In terms of terminology, *Istihalah* is the process that changes the nature of the source that occurs naturally or chemically, and the new substance will no longer belong to the original name (Kashim *et al.,* 2015). An obvious example is mentioned by Marei (2001), which is any part of a pig (impure) turning into soap (pure), as well as the reason that applies to the gelatine process. Although the terminology seems ambiguous among Muslim jurists and raises debates and dialogues in forums, *Istihalah* needs to include a scientific fact in terms of molecular techniques in regulating the status of halal and haram in one product (Aris *et al.,* 2015).

In the transformation of gelatine, the argument in *Istihalah* occurred when the whole aspect of change remains debatable. Jamaludin and Radzi (2009) acknowledged the statement from Syafi'i and Hanbali by stating the transformation of gelatine involves three stages: firstly, the transformation of physical attributes, secondly, the transformation of chemical bonding, and thirdly the transformation of both physical and chemical modifications. Along the transformation process, Jamaludin *et al.* (2018) strengthen the allegation by proving that gelatine's chemical composition has remained uninterrupted.

The finding suggested that even though gelatine extraction involves extreme conditions, the chemical transformation does not alter the amino acid content and remains intact (Jamaludin *et al.,* 2011). Moreover, harsh treatment such as excessive heating will degrade the gelatine quality; meanwhile, lower heat conditions will affect the lengthening and unfolding of gelatine strands (Hoque *et al.,* 2010). Thus, excessive treatment cannot be performed to sustain the quality of the gelatine grade and the chemical transformation does not occur. Hence the *Istihalah* concept becomes unacceptable according to Syafi'i and Hanbali.

The Islamic legislation towards non-permitted gelatine's acceptability depends on the fatwa regulated by the Islamic authorities in one country. In Malaysia, a fatwa on food gelatine issued by the National Fatwa Committee of Malaysia held in July 1999 mentioned that any food and drink that has endured biotechnology using porcine DNA was contradictory with Syariah laws and haram to consume (Izhar *et al.,* 2017). This is due to Malaysia's Department of Islamic Development under the Prime Minister's Department (JAKIM). The authorized body to issue and consult the halal certification in Malaysia, Khalek (2014) has narrowed the concept of *Istihalah* according to Syafi'i and Hanbali madhab. JAKIM disapproved and unaccepted any gelatine derived from *haram* sources for consumption.

3. Fish gelatine as an alternative to mammalian

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gelatine

There are two types of animals that could produce gelatine, the first habitat that lives under the water, and the second category of animals that live predominantly on land. According to Al-Qaradhawi and Daud (2016), those marine animals that by nature depend on and require water for survival are halal to consume with no regard for the situation. Allah S.W.T. with full mercy benefited the halal marine catches without slaughtering for human consumption regardless of the sources supplied from any races and religions.

All seafood animals have no restriction to consumption among Muslims as Allah S.W.T. enlightened in Al-Quran about the permissibility including the fish carrion. Said the Prophet, upon whom be peace, "Its (the sea) water is pure and its dead (animals) are lawful (i.e., they can be eaten without any prescribed slaughtering)". Thus, the doubt about fish and fish derivatives should not become an issue among Muslims as what mammalian animals have reported.

As reported by Karim and Bhat (2009), warm-water fish gelatine has been identified to have comparable characteristics to porcine gelatine and therefore should be used as a replacement for mammalian gelatine in food products. In addition, Choi and Regenstein (2000) investigated the physicochemical differences between porcine and fish gelatine and concluded that fish gelatine possesses very similar properties to porcine gelatine. Gel strength, viscosity, gelling and melting points are the most important gelatine properties for food product development.

3.1 Properties of fish gelatine

Conceptually, the physical properties of gelatine are essential to determine the suitability application in specific food systems. Several studies examining the effect of viscosity, bloom strength, and melting point in gelatine have been reported. Commercially, gelatine with a high viscosity and high gel strength is preferred (Mahmoodani *et al*., 2014). Gelatine with high viscosity is required for food stabilizers, medicines and photography functions (Schrieber and Garies, 2007). Fish gelatine that categorized under both warm-water and cold-water fish, hence the level of viscosity is contradicted by the way high viscosity gelatine appears in a short and brittle gel. In contrast, low-viscosity gelatine produced persistent and extensible gels (Zhou *et al.,* 2006). Karayannakidis and Zotos (2016) found that in order to stabilize the confectionary products, commercial gelatine must have a viscosity range of 2 to 7 cP or up to 13 cP for products like gelatine gums, chewable sweets, marshmallows, and nougat.

Gel strength, also known as bloom strength, acts as a useful property of gelatine, which can achieve the gelling function (Martins *et al*., 2018). Hanani (2015) studied the importance of gel strength to measure the firmness of the gelatine, with the average molecular weight between 30 and 300 bloom (<150 is a low bloom, 150–220 a medium bloom, and 220–300 a high bloom). According to Gómez-Guillén *et al*. (2011) and Karim and Bhat (2009), age, tissue, water species, fish species, pretreatment and extraction, and acid and alkali concentration affect the chemical composition of weight dissemination and amino acid structure.

Gelatine melts at a temperature that is higher than its melting point but lower than the human body (Nikoo *et al*., 2013). Nonetheless, fish gelatine has a lower gelling and melting temperature than mammalian gelatine. Karim and Bhat (2009) indicated the application of fish gelatine in many commercial industries is limited since the melting temperature of fish gelatine (11–28°C) is lower than that of mammalian gelatine (28–31°C). Although fish gelatine has a low melting point, it ruptures rapidly in the mouth without leaving a chewy mouth taste (Batu *et al*., 2015). It can be used in other applications that do not require higher gel strength. Rustad *et al.* (2011) supported the fact that low melting temperature, particularly for cold-water fish, could be useful in non-high bloom, such as frozen or refrigerated food products. As a result, Lv *et al.* (2019) also suggested that fish gelatine is beneficial for hypertensive people's dietary intake.

Gelling properties such as viscosity, gel strength, and melting point are undeniably decisive in indicating the quality of gelatine preparation in dessert products. Most importantly, the range of hydroxyproline and proline content in fish gelatine indicates the limits of viscosity, gel strength, and melting point. The properties are used to ensure the dessert items meet the requirements and characteristics of the product's development. To achieve these objectives, the food service facility or food industry must recognize the type of fish species (warm water or cold water fish), extraction process (pH, temperature), and duration of the extraction to well replace the non-halal gelatine. It is also necessary to well diverse the use of fish gelatine, as it will provide opportunities for new food products, create new market value among Muslims, and conserve the environment from fish waste.

3.2 Proline and hydroxyproline contents in fish gelatines

Gelatine is mostly extracted from mammalian (bovine and porcine) and aquatic species (warm-water and cold-water fish). In terms of initial characteristics,

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the rheological properties in mammalian gelatine are mostly recognized compared to warm water and cold water fish gelatine. The importance of rheological properties will determine the mechanical strength, gelling mechanism, and capability to stabilize under different temperatures, frequency, and shear stress, particularly in dessert products (Sow, Tan and Yang, 2019). Cold-water fish gelatines have been reported to have a lower content of amino acids (proline and hydroxyproline), which exhibit lower rheological properties (Alfaro *et al*., 2014; Da Trindade Alfaro *et al*., 2014). As a result, Chuaynukul *et al.* (2018) concluded that the heat stability of cold-water fish gelatines is less stable than mammalian gelatines, which contrasts with warm-water fish gelatines.

There are contradictory facts about proline and hydroxyproline contents in fish gelatines (warm water and freshwater) and mammalian gelatines. Phawaphuthanon *et al.* (2019) reported that fish gelatines have 17-25% higher amino acids than mammalian gelatines, which contributed to 30% of total amino acids. In comparison, the proportion of proline and hydroxyproline is typically 24% for mammalians and 16%-18% for fish species (Ahmed, 2017), while Alfaro *et al.* (2014) reported that the content of proline and hydroxyproline in mammalians gelatines contains about 30% of amino acids. Meanwhile, the contents in fish gelatines extracted from warm-water and cold-water fish reported are about 22% - 25% and 17%, respectively. The percentage is generally associated with the number of collagens found in different species of habitat among marine animals. However, Lin *et al.* (2017) indicated whether seasonal conditions influenced all collagens found in similar levels of proline and hydroxyproline within a species or not, the question has not been precisely answered but limited research suggested seasonal variation.

Overall, the proline and hydroxyproline content in fish gelatine is paramount in determining physicochemical and rheological properties. Fish gelatine that encompasses lower proline and hydroxyproline content will provide a low gel modulus and low gelling and melting temperatures (Karim and Bhat, 2009). Therefore, the lower range of proline and hydroxyproline will not contribute to a unique texture, excellent stabilizer, finest gelling properties, melt-in-mouth texture, and exclusive mouthtaste properties in dessert products compared to pudding confectionaries and milk ices (Hanani, 2015). Those principles are vital to ensure that sensory properties are acknowledged among the chefs and food service establishments. By far, mammalian gelatine will always be the premium selection to produce dessert products.

Apart from mammalian gelatine which has higher and better proline and hydroxyproline content, many researchers have commercially produced fish gelatine similar to mammalian gelatine properties. Warm-water fish and cold-water fish have been progressively examined to meet the market for halal purposes. Warm water fish such as tilapia, catfish, grass carp, silver carp, bighead carp, Catla, seabass, and rainbow trout have been found to produce gelatine with higher gel strength (Lin *et al.*, 2017), while Zhou *et al.* (2006) mentioned that even though cold-water fish, *Alaska pollock* gelatine has a lower gelling ability, by mixing cold water fish gelatine with warm water fish gelatine could enhance the gel properties. Choi and Regenstein (2000) further noted that even though fish gelatine has low gelling properties, especially cold-water fish species, fish gelatine offers a more desirable taste, flavour, and aroma in gelatine dessert gel products. Indeed, the intention to expand the fish gelatine application in dessert production to replace the non-halal gelatine is acceptable.

4. Fish gelatine modified with hydrocolloids

Hydrocolloid is categorized as safe food additives that belong to E-numbers (400-499), which physically act as food conditioners (stabilizers, thickeners, and emulsifiers). Essentially, food additives are not considered a new substance in the food service industry. In fact, food additives have been widely applied to preserve meats, fish, and other raw materials since a few centuries ago, and become food spoilage in a short period of time. Those spices and herbs are functional to improve the taste, sugars are used to preserve fruits, and vinegar preserves the pickles. The rapid advancement in food technology has brought food additives into a controversy which sparks the attention of Muslim consumers nowadays. Unlike the ancient conventional methods, some of the current food additives have added *syubhah* substances that are prohibited in Islam.

By definition, food additives are additional substances added to food products as sweeteners, colourants, and preservatives. Food additives are classified into two segments; natural or synthetic additivities, whereby those substances will be finally added to food products. The substances are broadly used during production, processing, treatment, transportation, packaging, and food storage (Al-Teinaz, 2020). In the food industry, most of the hydrocolloids are extracted from plants, mainly found in their seeds, fruits, tubers, and tree sap (Pegg, 2012). Since hydrocolloids are plant-based, many research studies have been performed to develop some exquisite textural properties as an alternative to non-halal mammalian gelatine. In Malaysia, it is reported that the potential of the

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upbringing of “veggie gelatine” into the wide market is under development and the International Islamic University Malaysia (IIUM) has carried out research on yam plants as gelatine replacer (Lestari *et al.,* 2019). However, as much as hydrocolloids could amend the rheology of the food system, the downside of this food additive is the “melt-in-mouth” property is lower than the mammalian gelatine.

Fish gelatine is notoriously known for poor gelling properties and perceives limited utilization as opposed to mammalian gelatine. To conquer the drawback, such an enhancement of gelling property could strengthen the fish gelatine gels. The incorporation of hydrocolloids with fish gelatine, including agar, κ-carrageenan, pectin, and gellan, has been reputed to enhance the textural properties of fish gelatine (Petcharat and Benjakul, 2017). Rafe (2019) has mentioned the role of hydrocolloids in food is inevitable as they can alter the rheology of the food system. He also mentioned the alteration of the properties would involve the viscosity and texture. Fish gelatine consideration needs an enhancement of polysaccharides. Brenntag (2017) reported that hydrocolloids have distinctive functions in the food system to thicken the gels, generate mouth-taste properties, form film, stabilize bake products, stabilize freeze-thaw, prevent crystal growth, stabilize emulsions and enhance encapsulation in food.

Ramírez *et al.* (2011) claimed food hydrocolloid acts as textural and functional components to restructure food while giving the stability of a few processed foods. Tan *et al.* (2018) successfully proved that the cooperation of xanthan, carrageenan, or locust bean gum will enhance the water-holding content of the dough, and improve the overall standard of zero-salt noodles. Yemenicioğlu *et al.* (2019) also believed that the use of hydrocolloids would expand progressively as they expected many studies to be conducted in the future. Gao *et al.* (2017) supported a recent trend that has emerged to incorporate hydrocolloids with food ingredients to resolve innovative utilization, of structural and textural components in the food systems. Overall, due to the growing trend, the use of hydrocolloids should not be limited to processed foods and other food productions, such as fish gelatine-based desserts.

As mentioned earlier, hydrocolloids have become an excellent synergy to fish gelatine. Many hydrocolloids were studied to find the compatibility to restructure the lower gelling properties in fish gelatine (Table 1) (Otoni *et al*., 2012). Based on the previous studies, the most commonly used hydrocolloids are agar, gellan, carrageenan, and alginate, while only a few studies focused on locust bean gum, gum arabic, xanthan gum, guar gum, and gum tragacanth. Therefore, the modification of mixed gels between different types of hydrocolloids and fish gelatine is essential to explore and comprehend. By understanding sol-gel-sol behaviour, hydrocolloids can be beneficial for halal food production (Somboon *et al*., 2014).

Although many studies on fish gelatine mixed with alginate have been reported, none of them matches the non-halal mammalian gelatine properties. Sow *et al.* (2019) reported that at low or high concentrations of sodium alginate, the formation of complex phase separation and similar mismatch properties to porcine gelatine matched the mean spherical aggregate size or the aggregate distribution. They also mentioned that the modification of fish gelatine with other hydrocolloids such as low acyl gellan matches the textural profile properties of porcine gelatine. Panouillé and Larreta-Garde (2009) agreed, that a complex formation behaviour of alginate and gelatine mixtures occurred and collapsed in some cases of high calcium concentrations and high strength, within the range temperature of 35°C to 45°C. Thus, they suggested additional confocal microscopy or scattering experiments could be conducted to enhance a better understanding of alginate gel coacervate.

4.1 Agar with locust bean gum

Agar is made of red (*Rhodophyceae*) seaweed from *Gelidiaceae* and *Gracilariaceae* species. This polysaccharide consists of linear polymers based on a disaccharide repeat structure of 3-linked β-D-galactopyranosyl and 4-linked 3,6-anhydro-a-L-galactopyranosyl units (Somboon *et al*., 2014). Agar has a unique structure composition compared to other hydrocolloids due to its high hysteresis, and significant difference in melting and setting temperatures, which normally melt at 85°C and set at 38°C (Pegg, 2012). Wüstenberg (2014) mentioned that agar is a thermoreversible gel and insoluble in cold water, which completely dissolves at a temperature above 80°C. By definition, thermoreversible is a property of certain substances (solution or gel). When the substance is cooled, it forms a gel and returns to a liquid when heated (Otoni *et al*., 2012). In other words, thermoreversible can be performed frequently without any permanent changes; given the right temperature, the substance can convert into a gel or reverse into the liquid form.

In the last few centuries, agar has been employed in Japan before being spread to other Asian countries, and then by the Western for Chinese cuisine and microbiological uses (Pegg, 2012). The power of hydrogelling agent in agar produced many Japanese desserts and confections such as Yokan, a stiff jelly with

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Table 1. Textural and sensory properties of hydrocolloid-modified fish gelatine in desserts.

Gelatine source	Hydrocolloid source	Water gel dessert ingredient	Result of mixed gels property	Result of sensory property	Reference
Tilapia	Gellan	None	Gel strength, gelling, melting temperature, and hardness increased when gellan increased. Springiness and cohesiveness decreased when gellan increased. A low level of gellan improved texture.	Higher levels of gellan reduced the likeness, and low levels of gellan (5%), had no effect on sensory.	Petcharat *et al*. (2017)
Tilapia	Gellan + $CaCl_2$	None	$CaCl_2$ increased the gel strength of mixed gels. When gellan and $CaCl_2$ increased, hardness increased, but springiness and cohesiveness decreased.	Higher levels of gellan and $CaCl_2$ decreased likeness. The increased brittleness and lower melting reduced the mouthfeel likeness. The low amount of gellan (2.5%) + up to 6 mM of $CaCl_2$ gives no negative impact on sensory.	Petcharat and Benjakul (2017)
Tilapia	Gellan k-carrageenan	None	Gellan increased the melting point of fish gelatine. Gellan more effective in cross-linking action with gelatine. k-carrageenan and gellan improved the mechanical and barrier properties of the film.	None	Pranoto *et al*. (2007)
Tilapia	Gellan + salts k-carrageenan + salts	None	The level used of agar increased the hardness (failure stress) and decreased the springiness (failure strain)	None	Sow *et al*. (2018)
Tilapia	Agar	None		Springiness and firmness decreased the likeness when agar increased. Appearance and colour decreased the likeness due to less transparency of agar in the gel matrix.	Sinthusamran *et al*. (2016)
Rohu Common carp Grass carp	None	Orange flavour instant drink mix	Grass carp skin gelatine showed high gel strength, viscosity, and melting point. Grass carp had comparable physical and mechanical properties to mammalian gelatine.	The fishy odour was not prominent and better aroma. Fish gelatine was highly rated in organoleptic evaluation.	Ninan *et a*l. (2011)
Alaska pollock Tilapia Porcine	None	Flavoured orange drink	The mix gelatines between Alaska pollock and tilapia in higher concentration has similar properties to high-bloom pork skin gelatine.	The authors did not perform the sensory evaluation test, but they suggested human senses could determine the impact on the variation of gelatines.	Zhou and Regenstein (2007)
Red tilapia	None	Lychee juice	High-pressure processing (HPP)-treated red tilapia gelatine showed a higher result of hardness, adhesiveness, gumminess, and chewiness than commercial tilapia gelatine of the jelly gel. Springiness and cohesiveness showed equal results for both jellies.	None	Yusof *et al*. (2018)
Seabass skin Seabass swim bladder	Agar k-carrageenan	None	Agar increased hardness, gumminess, chewiness, syneresis, gelling, and melting temperature but decreased cohesiveness.	The optimum level of hydrocolloids in gelatine gel will improve the melt-in-mouth property. 10% of agar in gelatine improved sensory properties for seabass skin and swim bladder.	Sinthusamran *et al*. (2018)

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a chewy mouthfeel mixed with green tea (Mouritsen *et al*., 2018), and some other food applications including meat, fish and poultry products, dairy products, and ice cream (Saha and Bhattacharya, 2010). Youssef (2013) mentioned that agar gels were a remarkable signature touch in molecular gastronomy because of their innovative application in cooking.

Even though agar has been used for ages and the application has broadened the scope in molecular gastronomy, Sinthusamran *et al.* (2016) reported that there are limited studies on the modification of fish gelatine with agar. For instance, in Western-style kitchens, gelatine used to be gelling properties in cooking. Nowadays, chefs have diverse utilization of new gelling agents such as methylcellulose, xanthan gum, agar, and gellan to maintain food products' texture (Brenner and Sörensen, 2015). Nevertheless, they only mentioned the new diversion of gelling agents in culinary, but the exploration of fish gelatine modified with agar in molecular gastronomy needs in-depth investigation to replace the non-halal gelatine in food. Somboon *et al*. (2014) declared that agar had been selected because of its ability to turn into gel at very low concentrations, which is accessible and compatible with mimicking the mammalian gelatines due to the halal issue.

Fish gelatine is widely known to have a weaker gelling property that contains lower gel strength and requires a higher amount of concentration to a gel. In contrast, agar has strong gel, low elasticity, and high syneresis (Haug *et al*., 2004). Thus, Somboon *et al.* (2014) reported that it could be useful to provide an alternative gelling agent to replace the non-halal mammalian gelatine when the two components are mixed. Since agar is commercially found in many dessert cuisines in Asia, agar is very compatible in hot climate countries, particularly in Southeast Asia. According to Pegg (2012), agar has a high melting point that makes food products resistant in hot countries, which can be a viable alternative to gelatine. The study also mentioned that the high melting point property in agar is also beneficial for baking, fillings, piping gels, glazes and icings.

Despite the fact that fish gelatine mixed with agar can imitate the mammalian gelling properties, Sinthusamran *et al*. (2016) reported that the incorporation of the two components decreased the springiness of fish gelatine/agar mixed gels. On the other hand, they narrated with a larger amount of agar; and the panelists demonstrated unpleasant sensory characteristics. This is because gelatine melts at the body temperature (35°C), allowing the flavour to release immediately and enhance the melt-in-mouth behaviour to bring out the taste (Sanchez, 2016), whereas agar has a negative mouthfeel sensational due to the brittleness and lower melting property, which is above the human body temperature. Based on the study from Sinthusamran *et al.* (2018), in regard to the incorporation of agar with seabass, they found that the addition of agar into fish gelatine (seabass) increased the chewiness of mixed gels, while the springiness of gelatine gels decreased when more than 10% of agar is used. They also reported that agar was an efficient gelling agent to increase the hardness of the mixed gels.

Based on the previous studies, the proper amount of agar in fish gelatine will improve and imitate gelatine gels' textural properties, although exhibit unfavourable sensory characteristics. Due to the agar brittleness and crunchy texture, it may cause lower springiness of mixed gels (Mao *et al*., 2001), thus Mortensen *et al.* (2017) suggested that adding locust bean gum into other hydrocolloids such as xanthan gum, agar or carrageenan, will increase the viscosity or gel strength. These two incorporations are normally applied in the molecular gastronomy kitchen, but adding fish gelatine into two mixed gels needs further investigation. Pegg (2012) also mentioned that locust bean gum could not perform into a gel, but by adding gelling hydrocolloids such as kappa-carrageenan or agar, the mixed gels will increase the gel strength, reduce syneresis, more elastic and less brittle. Furthermore, agar does not acquire a milky texture as carrageenan, thus mixing with locust bean gum could give a smooth texture and better stability for sensory characteristics (Stanley, 2006).

4.2 Carrageenan with locust bean gum

Carrageenan is extracted from red seaweeds a sulfated polymer of galactose and anhydrogalactose that plays three functions: iota-, kappa- and lambda-carrageenans (ι, k, and λ) (Candogan and Kolsarici, 2003). Unlike gelatine, KC does not melt in the mouth because k-KC will start to gel at 35°C and melt above 50°C, while i-KC will start to gel at 60°C (Blakemore, 2016). Both iota and kappa are thermoreversible. Iota forms a transparent elastic gel, and upon stirring, the gel is easy to destroy and can rebuild when the mechanical action stops. In contrast, kappa requires potassium ions to form a sturdy and brittle gel, and it is an excellent synergy with locust bean gum (Brenntag, 2017). Lambda -carrageenan does not act as a gelling agent, but it is most likely used as a thickener (Nazir *et al*., 2017). Due to its non-gelling ability, lambda has its function to promote mouth-feel texturization and creamy sensation to dairy products such as milk, yoghurt and butter.

K-carrageenan has a sturdy gel texture, Rafe (2019)

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reported that carrageenan could increase the firmness, viscosity, syneresis, and unfavourable mouth-feel sensation in skim yoghurt. The application of k-carrageenan has no limitation; it is notoriously well applied in culinary applications to turn into gels and foams when heated (Lersch, 2014). Goldfarb (2012) mentioned that carrageenan has the purpose in modernist cuisine to construct gelified sauces and jellies by the chefs and restaurateurs. The utilization of k-carrageenan has not only been used in modernist cuisine. Chen *et al.* (2020) have reported that the addition of k-carrageenan at an appropriate amount could beneficially increase the gel properties and potentially improve surimi texturization.

From the perspective of meat products, Imeson (2009) mentioned that carrageenan has the purpose of enhancing juiciness, mouth-feel sensation, slicing characteristics, cooking yields, and moisture-retaining. Despite the potential of carrageenan application in meat products, Demirci *et al*. (2014) have reported that a high amount of xanthan, guar, and carrageenan gum in meatballs decreased hardness, colour, taste, and general acceptance. They also mentioned that the addition of 1% of locust bean gum scores the highest in flavour and taste intensity.

As previously discussed, the application of k-carrageenan has no limitation in dessert application; k-carrageenan is synergistic with agar-agar, locust bean gum, and xanthan gum to provide a smooth and elastic texture. In modernist cooking, the concoction is prevalent, but awareness and familiarity are still in the early stages (Faat and Zainal, 2016). Some countries developed more scientific and advanced molecular gastronomy approaches to incorporate past cooking techniques (Kothalawala and Sivakumaran, 2018). According to Migoya (2012), a head chef who owns Modernist Cuisine uses k-carrageenan with locust bean gum for gel encapsulation dessert. In contrast, Myhrvold *et al.* (2011) mentioned that k-carrageenan is applied in hot cooking and desserts for gelling, pudding, and spherification. In addition, according to Youssef (2013), carrageenan and alginate are known in food manufacturing and have caught the attention of creative chefs such as Ferran Adrià, a Michelin-star level who purified the arts of spherification.

Therefore, with a proper amount of usage, k-carrageenan has proven will improve the texture and sensory quality of food products. The consumption of k-carrageenan leverages the textural properties of fish gelatine to imitate the mouthfeel sensation and rheological properties of mammalian gelatine. In contrast, Sow *et al.* (2018) documented that the higher concentration of k-carrageenan increased gel strength, hardness, and chewiness of fish gelatine. Still, gel cohesiveness and springiness were reduced when the concentration increased. As specified by Mao *et al.* (2001), this is due to k-carrageenan containing double helices, which are more rigid and stiff than triple helices of gelatine.

As a result, limiting the amount of k-carrageenan in mixed gel could maintain the acceptance of gelatine derivatives in food products. Pranoto *et al.* (2007) mentioned that the addition of k-carrageenan will increase the melting point of fish gelatine gels due to the lower amino acid structure, and molecular weight compared to mammalian's gelatine. This is also due to the transition in mixed gels microstructure and electrostatic between the two interactions (Derkach *et al*., 2015).

4.2 Gellan with calcium chloride

Gellan is categorized as a microbial polysaccharide extracted from the microorganism *Sphingomonas elodea,* formerly known as *Pseudomonas nelodea*. In the food industry, gellan is commonly used to increase food texturization (Petcharat and Benjakul, 2017), while for new culinary techniques and cooking methods, gellan works as thickeners, gelling agents, and stabilizers in high and intermediate restaurants (Ruiz *et al.,* 2013). The authors mentioned that some of the well-known and reputable restaurants, including Texturas el Bulli in Spain, CuisineInnovation in France, and Le Sanctuarie in the United States, applied sodium alginate, xanthan gum, gellan gum, carrageen, or methylcellulose in cooking for stabilizing and texturizing in culinary. Since gellan gum is found in two forms, the utilization is varied depending on the chemical composition. Low-acyl gellan performs as firm, non-elastic, brittle gels. Meanwhile, high-acyl gellan acts as soft and very elastic gels (Brenntag, 2017). As mentioned by Nazir *et al.* (2017), gelation occurs when the ions present in gellan with the association of double helices and gellan gum can form gels when hot solutions are reduced to chilled temperature at low concentrations with the presence of cations (Sworn, 2009).

In food production, gellan is added to jam for gelling and stabilizing. High-acyl gellan results in a soft, spreadable, and superior glazy texture, whereas the addition of low-acyl gellan provides a firmer composition and stable jam (Sworn, 2009). Due to its high melting and low yield stress, Heston Blumenthal invented his notorious dish, hot and cold tea, to allow the consumer to experience different angles of the tongue (Brenner and Sörensen, 2015). Blumenthal (2009) determined that the two identical teas are divided into

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two halves in a glass; the right and left sides are served in hot and cold, respectively. The consumer could taste two distinctive teas due to gellan strengthening each of the gel components, but the tea breaks up immediately upon pouring. As much as agar, k-carrageenan, and locust bean gum benefited many applications in the food industry and modernist cooking. Gellan is the preferred hydrocolloid because the gelled liquids deliver an excellent flavour and are as clear as water (Migoya, 2012). Furthermore, since low acyl gellan can be set at 40°C above than room temperature for a longer period, the thermoreversible gel property of gellan is best suited to increase the gel texture of fish gelatine.

According to Petcharat *et al.* (2017), gel properties of fish gelatine with a 5% of gellan improve textural properties and increase the gelling temperature to set the fish gelatine solutions at room temperature. The study also found that with an increasing level of gellan, the likeness in sensory properties in terms of appearance, colour, firmness, springiness, and desired mouth taste will decrease. According to Petcharat and Benjakul (2017), the increasing level of gellan with calcium chloride, gel strength, hardness, gelling, and melting temperature will also increase the sensory properties. In contrast, mixed gels above 5% with any amount of calcium chloride reduced the likeness on sensory scoring, while a 2.5% level of gellan with 6mm calcium chloride gave a positive likeness on sensory properties. Therefore, a low level of gellan in mixed gels could ameliorate the fish gelatine gelling property and positive acceptance of the sensory evaluation test.

In contrast to carrageenan, agar, and locust bean gum, food-grade gellan requires nutrient salts such as sodium, potassium, magnesium, and calcium cations (Morris *et al*., 2012). This is because the lower levels of divalent cations (Ca^{2+} and Mg^{2+}) are required to produce a better gel strength than monovalent cations (Na^+ and K^+); besides, the amount of cation will also affect the temperature of the gelation (Lau *et al.*, 2001). As proposed by Sow *et al.* (2017), the mixed solutions between gellan gum and calcium chloride ($CaCl_2$) could change the nanostructure forces in the gelatine-gellan system, and the formation of both solutions aggregated while the nebulous structure balanced the interaction between mixed gels. They also concluded that adding $CaCl_2$ and gellan into fish gelatine could modify the structure and be applicable as a replacement for mammalian gelatine. Lau *et al*. (2001) found that adding a small amount of calcium can improve the gelation temperature between gellan and fish gelatine compared to mixed solutions without calcium addition. Thus, as a result of calcium content, gelatine exists as a discontinuous phase, while exists as a continuous gel matrix; these mixtures can withstand high temperatures if the two polymers are mixed with the appropriate ratio.

Among all the studies of fish gelatine modification with gellan, Sow *et al*. (2018) reported the mimetic formulation of 180 Bloom FG + 0.025% (w/v) gellan + 3 mM $CaCl_2$ successfully matched the gel strength and melting temperature of 240 Bloom Porcine Gelatine. They concluded that the interaction of Ca^{2+} developed the fish gelatine-gellan (FG-GE) structure into a segregative FG-FG/GE-GE system, which ultimately brought it to a bi-continuous chain. Despite the formulation matching the physicochemical properties of porcine gelatine, the study did not include human interaction on sensory characteristics. As a result, the study needs to investigate further mouth-feel properties and overall acceptability among the food industry and culinary practitioners. The value of consumers' senses is critical in the food industry. It is also a huge challenge in food development because machines cannot replace the five human senses, particularly humans as test subjects (Choi, 2014).

5. Conclusion

Conclusively, Islamic scholars' contradictory perspectives regarding the usage of porcine and non-slaughtered bovine gelatine have brought the expansion of fish gelatine utilization in many food applications, including food manufacturing, food service establishments, and modernist cuisine. Fish gelatine has a paramount property to imitate the texture and physiochemical of non-halal gelatine even though it requires a synergistic combination with hydrocolloids such as agar, carrageenan, gellan, and locust bean gum. Among those combinations (locust bean gum, carrageenan with locust bean gum, and gellan with calcium chloride), carrageenan with locust bean gum showed promising results when combined with fish gelatines and other food products. The new research that introduces hydrocolloids modified gelatine will give various selections in creating new products without the intervention of non-halal or forbidden substances, especially in the gelatine-based dessert

Conflict of interest

The authors declare no conflict of interest.

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