Fats, oils, and emulsifiers

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12.1 Introduction

Fats and oils have been perceived as essential nutrients of human diet as well as concentrated sources of energy. They act as carriers of fat-soluble vitamins in the human diet (Raihana et al., 2015). Besides these, they also play an important role in the transport of substances that determine the growth and development of body muscles as well as the brain (FAO, 1994). In nature, oils and fats occur in a variety of sources; in plant seeds, fruits, and body parts of animals such as cow, goat, swine, etc. (Marikkar et al., 2017). Lard (LD) and tallow are examples of animal fats that are commercially exploited for applications in food, greases, biodiesel, etc. (William et al., 2002). Pig has a high proportion of adipose tissues, which is meant to reserve lot of fat. Rendering is one of the processes employed to recover LD from pig. The rendering of fatty tissues is achieved by application of heat, which denatures the proteins of the fat cell walls and renders them permeable to fat and water contained in them. Application of heat can be done either by a wet process or via a dry process. Wet rendering, in which substantial amounts of water are added into the chopped fatty tissues at minimal temperatures, results in the production of blandest fats. The process is, however, time-consuming and most rendered fats are obtained by autoclaving in live steam at temperatures of up to 150°C. In the dry process, fats are rendered in closed vessels under partial vacuum at temperatures up to 110°C. If the latter process produces an off-flavor, it has to be removed by deodorization (Swiftz, 1952). LD sold mostly in supermarkets is rendered from a mixture of high- and low-quality fat sources. While wet-rendered LD is pale white, dry-rendered LD is somewhat more brown in color (Khalid et al., 1996). Hence, it needs to be treated with bleaching and deodorizing agents to improve organoleptic characteristics that are important for marketing. At times, LD is hydrogenated or added with antioxidants to improve its stability and shelf-life.

Shortening is solid fat that is frequently used in baking applications to prevent cohesion of the flour gluten during mixing. In the past, LD was preferred over tallow as a shortening for baking applications. According to Nur Illiyin et al. (2013), LD and its hydrogenated forms were employed as base material for production of shortenings. Kamel (1992) stated that the unique liquid-to-solid content ratio of LD was the reason for its inclusion in the bread-making industry. It gained much preference in the preparation of pastry because of the “flakiness” it brought to products. LD was also used in producing compound shortening, which was a mixture of animal fat and vegetable oil.

Preparation and Processing of Religious and Cultural Foods. https://doi.org/10.1016/B978-0-08-101892-7.00012-2
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Edible oil/fat products like butter and ghee were examples of product that were blended with LD. According to Che Man et al. (2005), blends of vegetable fat and LD were preferred in some countries to produce shortenings of different types. Use of LD in frying was another important concern and was practiced mainly due to flavor-enhancing characteristic. In some food cultures, vegetable oils used for frying purpose were often blended with small amounts of LD in order to impart certain characteristic flavors in fried food (Marikkar et al., 2003). Hence, there is great deal of interest among some researchers to do research on LD characteristics, its detection in products, and lard alternative formulation.

12.2 Replacement of lard in meat products

Meat and meat products are essential components of daily diets in Western countries, where these are important sources of proteins, vitamins, and minerals. Traditional meat products contain up to 30% fat to provide good sensory attributes, especially those related with taste and texture (Gandemer, 2002). According to some reports, fat is essential for meat product processing because it stabilizes meat emulsions, reduces cooking losses, and improves water holding capacity (Muguerza et al., 2002). In addition, it also provides flavor, juiciness, and desirable mouth feel as well as other rheological properties (Jime'nez-Colmenero, 1996; Lindley, 1993). According to Nishioka and Irie (2005), LD has got some special stickiness behavior, which helped to achieve a good binding property in minced meat. The stickiness property of LD has been preferred in countries like Japan where it is one of the important factors contributing to eating quality (Nishioka and Irie, 2005). Ospina-E et al. (2010) stated that pork back-fat is the most commonly used fat due to its functional characteristics when compared to either beef or poultry fat. According to Maw et al. (2003), the high saturated fatty acid content of pork back-fat has led to it being used in cooked meat products. This could be probably due to its effect on the taste and texture of the final product. Nishioka and Irie (2005) also commented that the physical characteristics of animal fats including pork back-fat were very much influenced by their triglyceride composition having relatively higher proportion of palmitic fatty acid (about 25%). However, in recent times, animal fats were perceived to be unhealthy because of high cholesterol content and low proportion of polyunsaturated fatty acids. Owing to this reason, many studies were carried out to replace pork back-fat partially in meat products to fulfill the requirement to reach healthier formulations. However, this was a formidable task since there were uncertainties whether this move would affect the quality attributes of finished meat products (Ayo et al., 2008).

12.2.1 Fermented sausages

Fermented sausages are meat products containing pork back-fat and are characterized by high contents of fat, saturated fatty acids, and cholesterol. Bloukas et al. (1997) investigated the effect of partial replacement of pork back-fat with olive oil on the quality characteristics of fermented sausages. This study showed that up to 20% of pork back-fat could be substituted with olive oil in the form of pre-emulsified fat, if soy protein isolate were included as part of the ingredients. Muguerza et al. (2002) also studied fermented sausages with different fat levels (30, 20 and 10%) along with partial replacement (0 and 20%) of pork back-fat with olive oil. The sausages became lighter and more yellowish in color when a replacement of 20% pork back-fat by olive oil was tested. In another study, Spanish kind of sausages, known as Chorizo de Pamplona, was investigated for partial replacement of pork back-fat with pre-emulsified soybean oil (Muguerza et al., 2003). In this case, modifications of the formulation did not result in changes in hardness and springiness, but a slight increase in cohesiveness, gumminess, and chewiness in products was noticed with 20% of substitution. Additionally, authors mentioned that there was hardly any significant difference between the formulated product and control in terms of color. As the final products of these studies contained some amount of pork back-fat, they were still considered to be non-halal for Muslim consumers (Riaz and Chaudary, 2004).

12.2.2 Salami and pâtés

Salami is a type of cured sausage formulated with fermented-air-dried meat, typically beef or pork (Campell-Plat and Cook, 1995). Partial substitution of pork back-fat with extra-virgin olive oil did not significantly affect the chemical, physical, and sensorial characteristics of products, but water activity and texture were affected, which lead to the decrease of firmness (Severini et al., 2003). Pâtés is another product that is formulated with animal fats. Delgado-Pado et al. (2011) evaluated a reformulation process for pâtés to produce better lipid compositions by reducing the fat content while replacing pork back-fat with a healthier lipid combination and konjac gel in different proportions. Combination of lipids, namely olive oil, linseed oil, and fish oil-in-water emulsion, was employed for this purpose. Pâtés with partial replacement of pork back-fat had lowered the levels of saturated (SFA) (27.4% and 21.3%) and monounsaturated fatty acids (MUFA) (49.8% and 42.5%), while increasing the levels of polyunsaturated fatty acids (PUFA) (22.4% and 35.6%) compared with control pâtés. Rodriguez-Carpena et al. (2011) investigated partial replacement of pork back-fat with avocado oil, sunflower oil, and olive oils on the oxidative stability, color, and texture of porcine burger pâtés subjected to cooking and a subsequent chilled storage. In this case, use of avocado oil and olive oils enhanced oxidative stability of burger pâtés during storage. Although the addition of vegetable oils caused a significant reduction of saturated fatty acids with a concomitant enrichment in unsaturated fatty acids, the final products are still considered to be non-halal for Muslim consumers due to the presence of little amount of pork back-fat (Riaz and Chaudary, 2004).

12.2.3 Kung-wans and frankfurters

Kung-wan is a popular meat product among Taiwanese and Chinese communities. Although it is an emulsified meatball, their quality characteristics may have some differences from other emulsified meat products. Unlike sausage products which are tender and juicer, Kung Wan is preferred to be harder and more elastic by consumers (Hsu and Chung, 1998). There were several investigations on Kung Wan due to high fat content of animal origin that might lead to diseases such as coronary heart diseases, obesity, and cardiovascular disease (Ozvural and Vural, 2008; Vural and Javidipour, 2002). In an attempt to develop low-fat Kung-wan, Hsu and Yu (2002) studied 11 different plant oils as replacement for pork back-fat. Three controls (positive controls with 25% and 10% of pork back-fat and a negative control with 10% of water) and eight plant oils (coconut, sunflower, palm, corn, peanut, soy bean, tea seed, and olive) and three hydrogenated oils (coconut, palm, and soybean) were employed in this study. According to results, there were no changes on its textural properties, even 25% of pork back-fat was replaced. However, the decreasing fat and water contents decreased Kung-wan's red color to yellow color as well as thiobarbituric acid (TBA) value. Frankfurters are other examples of popular traditional meat products formulated with pork and pork back-fat by mixing with other ingredients. As fat in meat products plays a major role in forming important quality and sensor attributes, frankfurters might contain animal fat up to 30% of the formulation. Choi et al. (2010) investigated the effect of substituting pork back-fat with vegetable oils, namely, olive, grape seed, corn, canola, and soybean oil on the chemical composition, cooking characteristics, and sensory properties of frankfurters. Although this effort produced low-fat Frankfurters with reduced-fat content, the final product was reported to contain 10% pork back-fat.

12.2.4 Food emulsifiers

Halal-related controversies are also surrounded with emulsifiers, namely, monoacyl (MAG) and diacyl (DAG) glycerols. MAG and DAG are partial acylglycerols with either one or two of the hydroxyl groups esterified with different fatty acids. According to European Communities coding system, these are food ingredients bearing the number E471. Owing to the presence of hydroxyl groups in the structure, partial acylglycerols display remarkable surface activity, which enables them to reduce surface tension at the oil-water interface (Nina Naqiyah et al., 2016). Since MAG and DAG may have been derived from lipids from either vegetable or animal sources, the halal status of E471 emulsifiers is sometimes questionable. Previously, Nasyrah et al. (2014) cited a report, which said that some of the commercially available MAG and DAG could have been derived from hydrogenated lard. This was reaffirmed subsequently by Cheong et al. (2010), who evaluated lard as a potentially valuable raw material for production of MAG and DGA. The issue has grown in importance in light of many recent news highlights connected with the halal status of E471 emulsifiers in food products. Recently, some rumors spread that E471 in chocolate as well as some commercial brands of coffee and mayonnaise could have been derived from animals. The main reason for these rumors going viral in social media was due to the fact that some manufacturers failed to declare the origin of the E471 emulsifiers used in their formulation. Although utilization of animal fat in industrial products could be beneficial for animal carcass industry to handle the waste effectively, use of animal-derived ingredients in food might not be desirable due to food taboos based on religious restrictions (Nina Naqiyah et al., 2016).

12.3 Plant substitutes for LD

In recent times, considerable amount of work has been dedicated towards novel halal shortenings using plant oils and fats as replacement for LD in cookies. The main impetus for this initiative was a recent study, which showed the presence of LD in some commercial biscuit formulations (Yanty et al., 2014a). A screening of a series of plant fats, namely avocado butter, cocoa butter, palm oil, and mee fat, showed that use of single fat as replacement for LD may not be feasible (Yanty et al., 2012). It was due to the fact that their physicochemical and thermal properties were considerably different when compared to those of LD. It has been suggested that fat mixtures formulated using lipids such as palm oil (PO), palm stearin (PS), cocoa butter (CB), soybean oil (SBO), and mee fat could be an alternative option. MF being a semisolid fat is an ideal raw material for preparing shortening and other fat derivatives (Marikkar et al., 2017). Yanty et al. (2014a,b) noticed that SFC profile of MF as measured by NMR was quite similar to those of LD at certain temperatures, with some deviations at certain other temperatures (Fig. 12.1). The observed deviations in SFC profile of MF could be minimized possibly through blending with a suitable fat. Yanty et al. (2014a,b) evaluated binary mixture formulations composed of MF and PS at different ratios as a substitute for LD. Of the three binary mixtures formulated, MF:PS (99:1) showed closest compatibility to LD despite differences in their FA and TAG compositions. In terms of the SFC profile, MF:PS (99:1) showed the least difference to LD throughout the temperature range of 0–40°C (Fig. 12.2). There were also similar studies by other researchers using exotic plant fats such as engkabang fat, which is derived from the seeds of *Shorea macrophyilla*. Nur Illiyin et al. (2013) evaluated binary

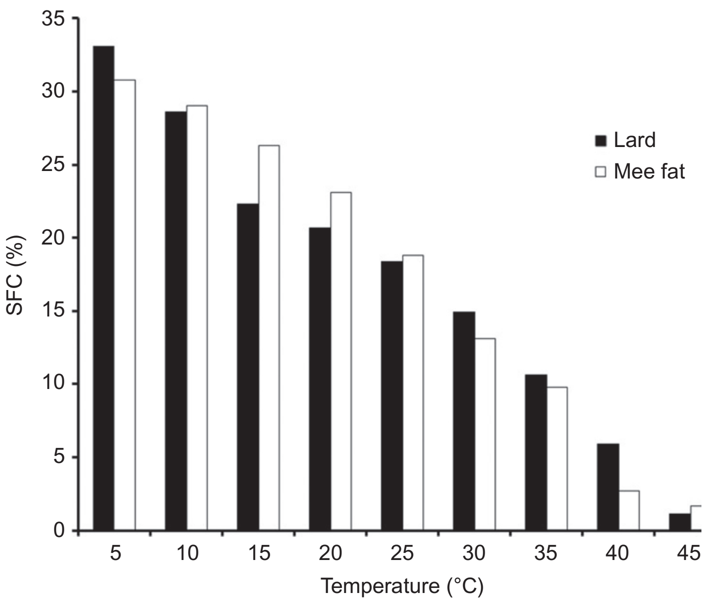

Fig. 12.1 SFC profile of lard and Mee fat. *SFC*, solid fat content.

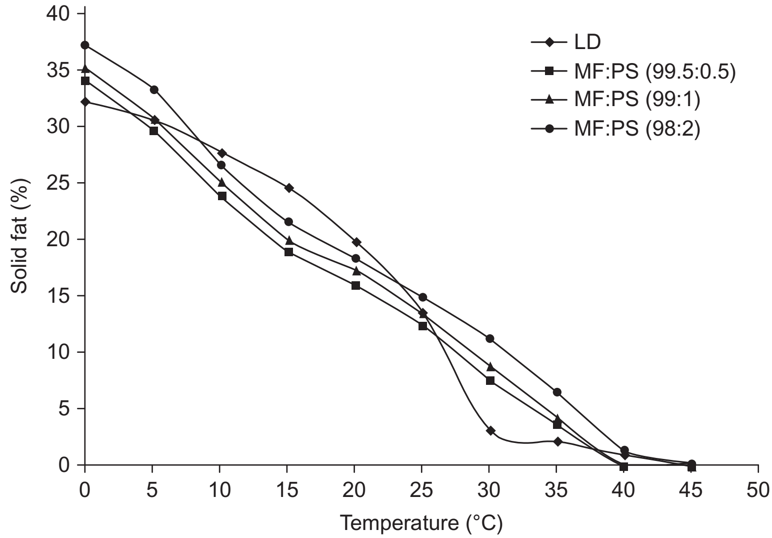

Fig. 12.2 SFC profiles of LD and binary mixtures of plant fats. *LD*, lard; *MF*, mee fat; *PS*, palm stearin; *SFC*, solid fat content.

mixtures formulated by mixing engkabang fat and canola oil at different ratios as replacement for LD. The results of SFC and melting point data, as well as polymorphic form and hardness analyses showed that the blending of EF with CaO within the range of 30%–35% would help produce a fat blend that has closer compatibility to LD.

Blending of Avo, PS, and CB in different ratios to produce ternary mixtures was another initiative of producing a fat mixture to mimic the thermal properties of LD. A previous report showed that Avo displayed SFC values that were always lower than those of LD throughout the temperature range (Yanty et al., 2011). It was hypothesized that incorporation of hard fat components like PS and CB into Avo could enhance the SFC to a level comparable to the SFC values of LD. After evaluating three different ternary mixtures of these fats, Yanty et al. (2017a) found that Avo:PS:CB (84:7:9) was the closest in similarity to LD in terms of some physical properties. The SFC of this mixture and LD showed the least differences throughout the temperatures that include 0, 5, 20, 25, 35, and 40°C (Fig. 12.3). In a separate study, the possibility of producing a fat mixture to LD was attempted using three different quaternary blends composed of PO, PS, SBO, and CB. Out of the three quaternary mixtures formulated, PO:PS:SBO:CB (38:5:52:5) was found to display the closest similarity to LD in terms of some compositional parameters and SFC behavior. The SFC of this fat mixture and LD showed the least differences throughout the tested temperatures that include 0, 5, and 25°C (Fig. 12.4).

As mentioned earlier, binary mixture of MP:PS (99:1), ternary mixture of Avo:PS: CB (84:7:9), and quaternary mixture of PO:PS:SBO:CB (38:5:52:5) were emerged as potential candidates to formulate a replacement for LD based on their chemical composition and SFC profiles. These three plant-based fat mixtures were processed into shortening and subsequently evaluated their functional properties in terms of

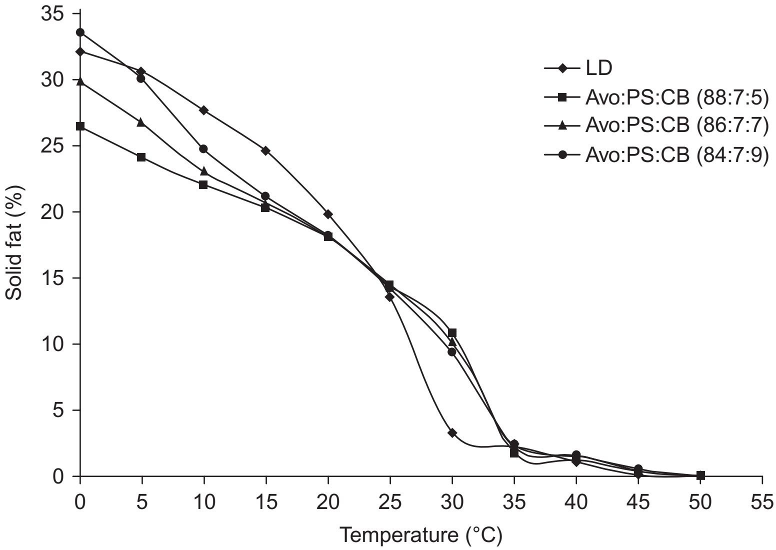

Fig. 12.3 SFC profiles of LD and ternary mixtures of plant fats. *LD*, lard; *Avo*, avocado fat; *PS*, palm stearin; *CB*, cocoa butter; *SFC*, solid fat content.

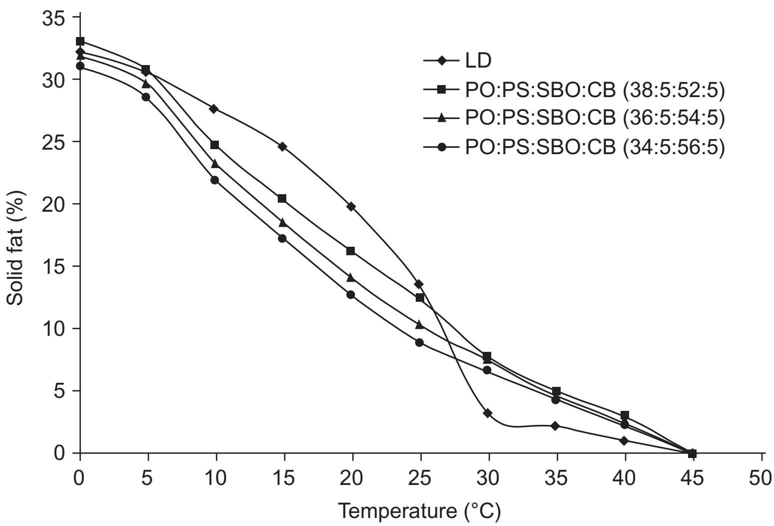

Fig. 12.4 SFC profiles of LD and quaternary mixtures of plant fats. *LD*, lard; *PO*, palm oil; *PS*, palm stearin; *SBO*, soybean oil; *CB*, cocoa butter.

hardness, consistency, microstructure, and polymorphism. According to Yanty et al. (2017b), hardness and consistency values of the three plant-based shortenings were comparably similar to those of LD shortening. This could probably be due to the solid content of these fats that are almost similar at 25°C (working temperature). The

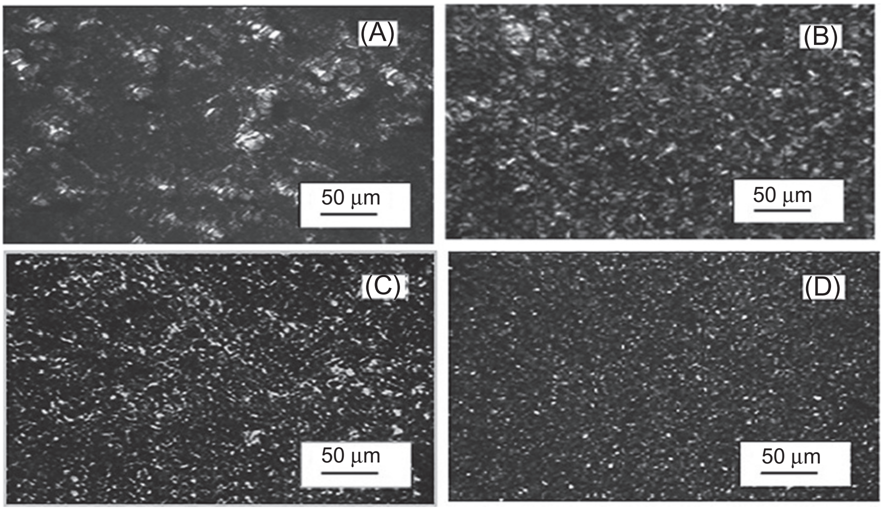

Fig. 12.5 Crystal distributions of (A) lard, (B) binary mixture, (C) ternary mixture, and (D) quaternary mixture shortenings at magnification of 10×10.

consistencies of formulated plant-based shortenings and LD shortenings were categorized as plastic fats and spreadable; hence, they were suitable to use in the production of cookies. Despite this, the microscopic analysis showed that the number and size of crystals in the formulated plant-based shortenings were dissimilar to those of LD shortening (Fig. 12.5). These differences in crystals behavior could be due to the different chemical composition of LD shortening and formulated plant-based shortenings. However, the differences in crystals behavior would not affect the polymorphism of shortenings. All the formulated plant-based shortenings and LD shortening displayed a mixture of β' and β-form polymorphs, of which the β' form was the predominant polymorph (Fig. 12.6). These results showed that formulated plant-based shortenings could be suitable as a LD substitute. Good shortenings with β' crystals are desired for a better product with a smooth mouthfeel and a better entrapment of liquid oil because of the spherulitic nature formed (deMan et al., 1989; Borwanker et al., 1992).

12.4 Concluding remarks

Fat derived from swine is prohibitive under halal and kosher food regulations. There is sufficient evidence to show that lard and pork back-fat were employed as shortening in the manufacture of several meat-based products. Efforts have been taken in recent times to develop *halal*-based shortenings to be used as ingredients in food product formulations. Plant-based fats such as mee fat, avocado oil, palm oil, and cocoa butter could not be used directly as lard substitute because their physicochemical and thermal properties were different when compared to those of lard. However, binary,

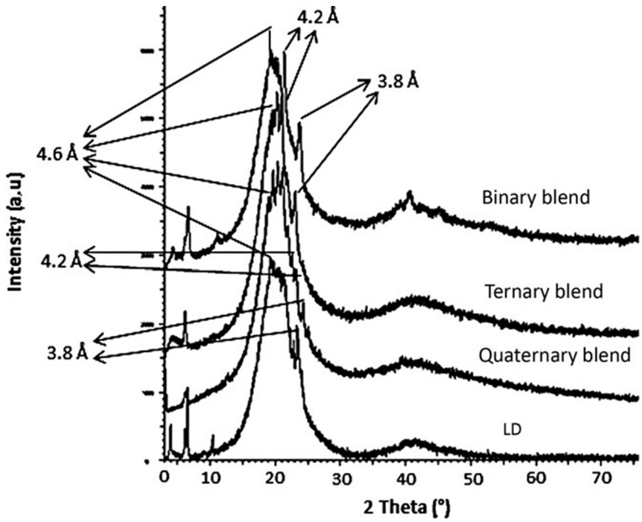

Fig. 12.6 Diffractogram of lard (LD) and three formulated plant-based shortenings.

ternary, and quaternary mixtures of these fats could serve the purpose by mixing at different ratios in order to mimic the composition and thermal properties of lard. For compatibility assessment, physical properties such as melting point, solid fat content profile, microstructure, polymorphic forms, and texture were considered to determine the most suitable mixture. It is also recommended to apply the formulated plant-based fat mixtures in real food such as formulated meat products, bakery, and confectionary products. This kind of quality and assessment could help to evaluate the actual performance of these plant-based mixtures in comparison to lard.

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