
**UNIVERSITI PUTRA MALAYSIA**

# *FORMULATION AND CHARACTERIZATION OF HALAL PALM-BASED SHORTENING IN SIMULATING LARD PROPERTIES FOR FOOD INDUSTRY*

**NUR ILLIYIN BINTI MOHAMED ROSLAN**

**IPPH 2021 5**

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**Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Doctor of Philosophy**

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Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Doctor of Philosophy

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**Chairman : Associate Professor Siti Salwa Abd Gani, PhD**
**Faculty : Halal Products Research Institute**

Shortening is a commercially prepared edible fat that is primarily used in the cooking and baking of food. The function is to 'shorten' or tenderize food; especially baked goods. Shortening is formulated 100% from either animal fat and/or vegetable fat. Plant-based fats, such as palm oil and its fraction, can substitute the use of animal fat such as lard as the source of shortening. Lard which is traditionally used as shortening, however, has the limitation due to the teaching of Islam that prohibits the consumption of it and the derivatives. Besides that, there is a growing negative perception of animal fats and their implications on human health among the consumer as well. Many halal shortenings can be found easily in the market. Usually, the formulation involved vegetable oils such as palm oil, soybean, canola oil, and olive oil. However, the compatibility of those halal shortening to lard in terms of their quality is scarcely found. Besides, the study of the development of halal shortening tends to simulate lard properties is still limited. Thus, this present study covers the formulation of halal palm-based shortening by using mixture design as the tool of optimization in simulating lard properties. The formulation is comprising of a combination of palm oil (PO), palm olein (POO60), palm mid fraction (PMF), and soybean oil (SB). The selected formulations were further characterized in terms of physicochemical properties such as hardness, microstructure, thermal behaviour, fatty acid content (FAC), triacylglycerol (TAG), and polymorphism. The effect of the emulsifier on the physicochemical properties of the palm-based shortenings has also been investigated. The application of the palm-based shortenings was done in dough and cookies preparation to compare the performance between those made out from palm-based shortening and those of lard.

The optimization of palm-based shortening involved two responses which were slip melting point (SMP) and solid fat content (SFC). The analysis of variance expressed

the precision of the special cubic model for SMP, employing high F-value (27.73), low P-value (<0.0001), and R-squared (0.9541) with insignificant lack-of-fit. Meanwhile, the linear model for SFC indicated a high F-value (103.87), low P-value (<0.0001), and R-squared (0.9432) with insignificant lack-of-fit. The effect of the three combinations of variables was also investigated, in which the palm oil had contributed to give a positive effect to the blends in both responses (SMP and SFC). The formulated palm-based shortening was found similar in terms of the slip melting point and the solid fat content as lard in the portion of PMF: PO: SB: POO60 (10.00:35.18:34.82:20.00) (PO: SB: POO60). In the comparison to lard, the most similar shortening namely F14 (10.00: 35.18: 34.82: 20.00) was further characterized with another shortening namely F9 (10.00: 39.99: 30.01: 20.00) which contained the highest palm oil portion in the formulated blends. The characterization involved hardness, microstructure, thermal behaviour, fatty acid content, triacylglycerol, and polymorphism. The total amount of saturated fatty acid in the prepared shortening was comparable to lard; (F9 and F14; 39.44 % and 37.83 % respectively) and lard was 36.43 %. It was also found that the blend of F9 and F14 possessed the amount of oleic acid with 35.63 % and 34.95 % in which are close to the amount of lard (39.23 %). Similarly, the content of linoleic acid displayed the comparable content of fatty acid composition with lard (20.7 %) which was 22.84 % and 24.97 % for the blends of F9 and F14, respectively. The hardness of the prepared shortenings was found higher than lard. The microstructure of the palm-based shortening was found better-arranged and smaller as compared to lard. The TAG molecular groups of PLO and POO were found dominant in the prepared shortening as well in lard. Thermal behaviour of the prepared shortening was found similar to lard with melting range temperature at 0-1°C. Polymorphic form of the palm-based shortening was similar to lard which was in β'+β form.

The next chapter demonstrated the effect of emulsifier on the formulated palm-based shortening in simulating lard properties. F14 shortening remained to have the hardness closest to lard. From the microscopic view, the incorporation of emulsifier in the shortening exhibited a more arranged fat crystal and showed the dissimilarities to lard. There were no significant changes as the addition of emulsifier in the shortening on the fatty acid content and TAG distribution. the high melting peak of F903 shortening (C6:31.89 ºC) was found to have the closest to the high melting peak of lard which was at (A3: 29.62 ºC). The polymorphic crystal forms of all samples were similar to that of lard with a mixture of β' and β crystal form.

The formulations were applied in cookie making in the next chapter. The dough and cookies that were prepared from palm-based shortenings were compared to those prepared from lard. the dough prepared from F141 shortening was found similar to the dough which was prepared from lard in terms of hardness which was 16.16 N and 11.77 N respectively. The dough prepared from lard, F9, F14, and F141 showed insignificant elasticity behaviour. The tan δ values of F14, F9, F141 were very similar to lard, which are 0.56, 0.54, 0.56, respectively, as compared to lard (0.55). The thickness of the cookies made out of F903 (6.2 mm) showed a similar thickness as the cookies made out of lard (6.2 mm). Besides that, cookies containing dough F1403 (0.7 mm) and F141 (0.7 mm) were found to have a similar width to the cookies

containing lard (0.7 mm). Meanwhile, the spread ratio of the cookies prepared from F9 (9.6), F14 (9.4) and F141 (9.5) exhibited a similar value to those made from lard (9.6). The cookies that containing F14 shortening, showed the most similar value of a* and b* (6.47, 29.7) to the lard-based cookie (6.40, 26.47).

In this present study, the palm-based shortening is comparable to traditional shortening such as lard. Thus, this could be a useful finding in improving the formulation of halal shortening that tends to simulate lard properties.

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# FORMULASI DAN PENCIRIAN LELEMAK HALAL BERASASKAN MINYAK SAWIT DALAM MENSIMULASIKAN SIFAT-SIFAT LEMAK BABI UNTUK INDUSTRI MAKANAN

Oleh

**NUR ILLIYIN BINTI MOHAMED ROSLAN**

**November 2020**

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Lelemak merupakan lemak yang boleh dimakan, disediakan secara komersial yang mana kebanyakannya digunakan dalam masakan dan pembakaran makanan. Fungsinya adalah untuk 'memendekkan' atau melembutkan makanan; terutamanya yang berasaskan bakeri. Lelemak diformulasikan samada 100% daripada lemak haiwan dan/atau lemak sayuran. Lemak berasaskan tumbuhan seperti lemak sawit dan fraksinya mampu menggantikan penggunaan lemak haiwan seperti lemak babi sebagai sumber lelemak. Lemak babi yang secara tradisinya digunakan sebagai lelemak, bagaimanapun mempunyai limitasinya kerana ajaran Islam yang tidak membenarkan penggunaannya dan apa yang diterbitkan daripadanya. Selain daripada itu, terdapat juga persepsi negatif terhadap lemak haiwan dan implikasinya kepada kesihatan manusia di kalangan para pengguna. Banyak lelemak halal yang boleh didapati dengan secara mudah di pasaran. Kebiasaanya, formulasinya melibatkan minyak sayuran seperti minyak kelapa sawit,minyak soya, minyak canola dan minyak zaitun. Walaubagaimanapun, kualiti lelemak halal yang lebih kurang sama dengan lemak babi kurang dijumpai. Selain itu, kajian mengenai pembangunan lelemak halal yang cenderung kepada sifat-sifat lemak babi masih terhad.

Oleh itu, kajian ini adalah meliputi formulasi lelemak berasaskan minyak sawit dengan menggunakan *mixture design* sebagai alat bantu dalam optimatasi peniruan sifat-sifat lemak babi. Formulasi tersebut terdiri daripada kombinasi lemak minyak sawit (PO), olein sawit (POO60), stearin separa sawit (PMF) dan minyak soya (SB). Formulasi yan terpilih diteruskan dengan proses pencirian dari segi sifat kimia-fizikal seperti; kekerasan, mikrostruktur, sifat termal, komposisi lemak asid, komposisi triasilgliserol dan polimorfik.Kesan pengemulsi ke atas sifat kimia-fizikal lelemak berasaskan sawit juga turut diselidik. Aplikasi lelemak berasakan sawit telah

dijalankan ke atas adunan dan penyediaan biskut untuk membandingkan prestasi di antara yang diperbuat daripada lelemak berasaskan minyak sawit dan lemak babi.

Optimatasi lelemak berasaskan sawit melibatkan dua pemboleh ubah bertindakbalas iaitu titik lebur (SMP) dan kandungan lemak pepejal (SFC). Lelemak berasaskan minyak sawit yang telah diformulasikan ditemui menyerupai lemak babi dari segi titik lebur (SMP) dan kandungan lemak pepejal (SFC) pada nisbah PMF: PO: SB: POO60 (10.00:35.18:34.82:20.00). Untuk perbandingan dengan lemak babi, lelemak yang paling hampir menyerupai lemak babi yang dinamakan sebagai F14 (10.00: 35.18:34.82:20.00) telah dilakukan pencirian lanjut bersama lelemak lain iaitu F9 (10.00: 39.99: 30.01: 20.00) yang mana mengandungi nisbah lemak sawit yang paling tinggi di dalam campuran lemak-lemak tersebut. Pencirian tersebut melibatkan kekerasan, mikrostruktur, sifat termal, komposisi lemak asid, komposisi triasilgliserol dan polimorfik. Jumlah lemak tepu dalam lelemak yang disediakan adalah standing dengan lemak babi; (F9 dan F14; 39.44 % dan 37.83 % ) dan lemak babi adalah 36.43 %. Adunan F9 da F14 juga didapati mempunyai jumlam olik asid sebanyak 35.63 % dan 34.95 % yang mana hamper dengan jumlah lemak babi (39.23%). Begitu juga dengan kandungan linolik asid yang standing dengan komposisi lemak babi (20.7 %) yang mana masing-masing berjumlah 22.84 % dan 24.97 % bagi adunan F9 dan F14. Tekstur lelemak yang disediakan didapati lebih keras daripada lemak babi. Struktur mikro lelemak berasaskan kelapa sawit didapati lebih tersusun dan lebih kecil berbanding lemak babi. Kumpulan molekul triasilgliserida PLO dan POO telah ditemui sebagai pendominasi di dalam lelemak yang disediakan (F9 and F14),begitu juga di dalam lemak babi. Sifat termal lelemak yang disediakan didapati lebih kurang sama dengan lemak babi dengan suhu peleburan pada julat 0-1°C. Bentuk polimorfik lelemak berasaskan sawit sama dengan lemak babi iaitu dalam bentuk β'+β.

Bab seterusnya menunjukkan kesan pengemulsi ke atas lelemak berasaskan minyak kelapa sawit dalam mensimulasikan sifat-sifat lemak babi. Lelemak F14 masih mempunyai kekeresan yang paling hampir dengan lemak babi. Daripada pandangan mikroskopi, pengabungan pengemulsi dalam lelemak mempamerkan kristal lemak yang lebih tersusun dan menunjukkan ketidaksamaan dengan lemak babi. Tiada perubahan yang signifikan berlaku setelah penambahan pengemulsi di dalam komposisi asid lemak dan taburan trigliserid. Puncak lebur tinggi pemendekan F903 (C6: 31.89 ºC) didapati paling hampir dengan puncak lebur tinggi lemak babi yang berada di (A3: 29.62 ºC). Bentuk kristal polimorfik dari semua sampel adalah serupa dengan lemak babi dengan campuran bentuk kristal β 'dan β.

Prestasi lelemak telah dinilai dalam adunan dan penyediaan biskut dalam membandingkan prestasi dengan lemak babi. Doh yang disediakan dari lelemak F141 didapati serupa dengan doh yang disediakan daripada lemak babi dari segi kekerasan masing-masing ialah 16.16 N dan 11.77 N. Doh yang disediakan daripada lemak babi, F9, F14, dan F141 menunjukkan sifat elastik yang tidak signifikan. Nilai tan δ lelemak F14, F9 dan F141 sangat mirip dengan lemak babi, masing-masing 0,56, 0,54, 0,56, dibandingkan dengan lemak babi (0,55). Ketebalan biskut yang

dibuat daripada F903 (6.2 mm) menunjukkan ketebalan yang serupa dengan biskut yang dibuat dari lemak babi (6.2 mm).

Selain itu, biskut yang mengandungi lelemak F1403 (0.7 mm) dan F141 (0.7 mm) didapati mempunyai persamaan dengan biskut yang mengandungi lemak babi. Sementara itu, nisbah sebar biskut yang disediakan daripada lelemak F9 (9.6), F14 (9.4) dan F141 (9.5) menunjukkan nilai yang mirip dengan lemak babi (9.6). Biskut yang mengandungi lelemak F14 menunjukkan nilai a* dan b* (6.47, 29.7) yang paling mirip dengan biskut berasaskan lemak babi (6.40, 26.47). Didapati bahawa biskut yang mengandungi lelemak F141 mempunyai persamaan dari segi analisis profil tekstur adunan dan sifat reologinya. Begitu juga dalam penyediaan biskut di mana biskut yang disediakan daripada lelemak F14 turut menunjukkan ciri yang hampir dengan biskut yang disediakan daripada lemak babi dari segi lebar dan kekerasannya.

Lelemak berasaskan sawit setanding dengan lelemak tradisi seperti lemak babi,maka ia boleh dicadangkan sebagai alternatif kepada formulasi lelemak halal.

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This thesis was submitted to the Senate of the Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Doctor of Philosophy. The members of the Supervisory Committee were as follows:

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| | |
|---|---|
| AOCS | American Oil's Chemist Society |
| ANOVA | One-way analysis of variance |
| DSC | Differential Scanning Calorimetry |
| FAC | Fatty Acid Composition |
| GC | Gas chromatography |
| HPLC | High performance liquid chromatography |
| LD | Lard |
| MAG | Monoacylglycerol |
| MPOB | Malaysian Palm Oil Board |
| NMR | Nuclear magnetic resonance |
| PO | Palm Oil |
| POO60 | Palm Olein |
| PLM | Polarized light microscope |
| PMF | Palm Mid Fraction |
| PUFA | Polyunsaturated Fatty acid |
| $R^2$ | Coefficient of variation |
| Sat | Saturated Fatty acid |
| SB | Soybean oil |
| SFC | Solid fat content |
| SMP | Slip melting point |
| TAG | Triacylglycerol |
| TPA | Texture Profile Analysis |
| Unsat | Unsaturated Fatty Acid |
| WAXD | Wide Angle X-ray diffraction |
| XRD | X-ray diffraction |

# CHAPTER 1

# INTRODUCTION

## 1.1 Introduction

Shortening is an edible fat commercially used in food industries for frying and cooking, and is an important ingredient in the baking industry. It is a generally 100% fat product formulated with properly refined animal and/or vegetable oils for functionality and to eliminate undesired flavor and aroma (Metrozh, 2005).The word 'shortening' refers to the ability of fat to "shorten the structure of food component", thus generating suitable characteristics for food products (Ghotra et al., 2002). It provides a softer texture and desirable flavour for the final product because it prevents the cohesion of gluten strands during mixing. Shortening also assists in the entrapment of air during the creaming process which leads to the aeration and leavening essentials for product structure (Mert and Demirkesen, 2016).

Economically, the global demand for shortenings is expected to hit USD 4.57 billion by 2022, at a CAGR of 4.2 percent from 2017. The application of shortening may include sectors such as bakery, confectionery, and snacks and savoury. The market growth is due to the rise of demand for shortening application in various application as well as the increase of demand of bakery and confectionery products. The market is well known in Europe for items such as breads, cereals, cakes, biscuits, and pastries. In the Asia-Pacific region, bread and baked goods consumption per capita has increased as demand for bakery and confectionery products has risen. The major factor driving the demand for baked goods are affordability, convenience, and health benefits. The source of shortening can be vegetable oils or animal-based. As compared to animal-based shortening, vegetable-based shortening dominates the market. The increase in awareness of safe, fortified, non-hydrogenated, trans-free vegetable shortenings can be attributed to the high consumer demand for vegetable shortenings in the industry (Anon, 2017a). Figure 1.1 illustrated the projected shortening market by region in 2022.

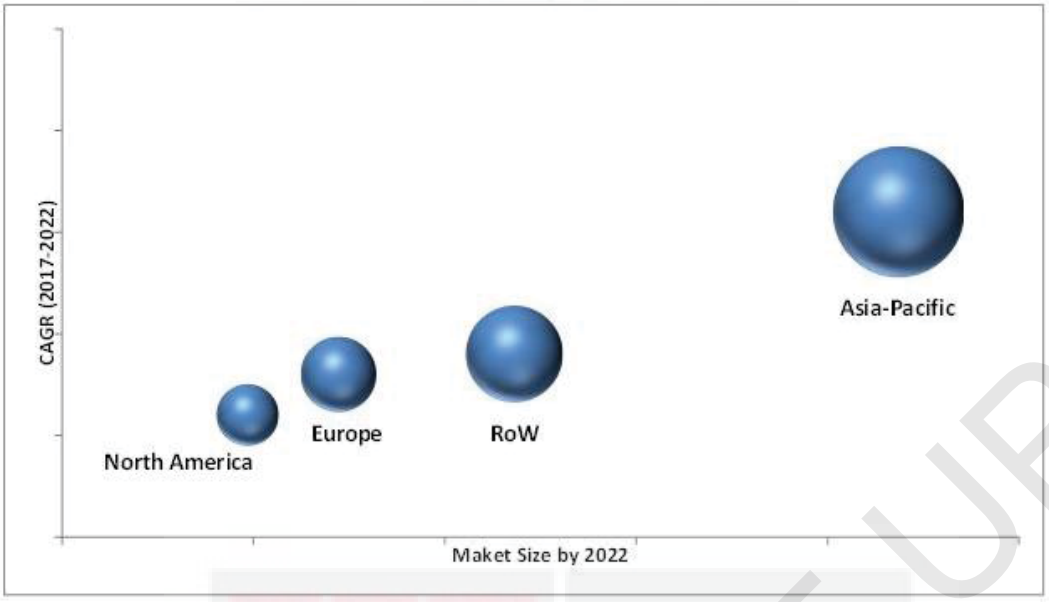


**Figure 1.1 : Shortenings Market by Region, 2022 (USD Billion)**
(Source: Anon,2017)

Lard or pork fat is normally used as shortening in food products such as cookies, cakes, pastries and bread because of to its abundance, inexpensive, and possesses good properties such as good plasticity and palatability to the bakery products (Yanty et al., 2012; Silva et al., 2011; Hugo and Roodt, 2007; Seriburi et al., 1998). However, there are certain laws for the Muslims and Jews that prohibited them from consuming any product containing or deriving from pig, including pork (Nur Illiyin et al., 2014; Regeinstein, 2003).

On another note, one study reveals that the consumption of animal fats including lard increases risk of heart diseases, obesity, hypertension, and colon cancer (Wang et al., 2013; Chicco et al., 2008; Sinkeldam et al., 1990; Rogers et al., 1986). Hence, it is important to find other alternative to replace the application of lard shortening especially for the Muslim community and to maintain good health in a long run.

Even though the halal shortening can be found easily in the market, the quality of the shortening as compared to lard is questionable. Lard is known as a traditional shortening that come from animal-based often be related to a good performance as ingredient especially in bakery products. It can be found in abundance as it is considered as waste in abattoir industry and can be obtained in cheaper price (Yanty et al., 2012). There is a need to study the compatibility of halal shortening to lard in producing better shortening with better performance or similar to that animal fat. Thus, the alternative of lard could be provided for certain targeted market and surely can be used for those who avoid to consume that animal fat.

However, research on producing alternatives for lard shortening are still limited. One of the study involves the application of plant-based materials as shortening such as using avocado, soybean, palm oil, cocoa butter, *Madhuca longifolia*, *Shorea Macrophylla*, Canola oil, palm stearin and pink guava seed oil (Noor Raihana et al., 2017; Yanty et al., 2017a; Yanty et al., 2017b ; Nur Illiyin et al., 2014; Nur Illiyin et al., 2013). Those studies used the conventional method to find the most similar formulation that can simulate lard properties. There are still in need to find the best alternative lard substitute with a better formulation and methodology that will produce better shortening with better chemical and physical properties. Thus, this present study would mainly cover the formulation of halal shortening that include palm-based as the major components using mixture design as the tool instead using the conventional method. The aim of this formulation is to find the best ratios of the blends that could have similar characteristics and properties to lard.

It is known that palm oil has become the second most consumed oil in the world since 1985, after soybean oil. Today, palm oil remains to stand among the most commonly used vegetable oil in the world with a competitive market price (Anon, 2018; Sue and Pantzaris, 2009). The balance fatty acid content of the palm oil is around 48 % saturated fatty acids (SFA) and 52 % unsaturated fatty acids (UFA). It's SFA content is higher than other oils like sunflower, olive or rapeseed which is considered healthy, and below coconut oil that possess high SFA of myristic and lauric (Gesteiro et al., 2019). Due to its abundance, a new formulation of shortening could be produced to optimise the use of palm oil and its derivatives. Palm oil and its fraction is the most suitable fat for shortening production because of its high nutritional value. Thus, this leads to increasing demand for cost effective palm-based shortening (Mba, 2015).

In the modification of fat, the things that should be considered are the reasonable cost, the availability of materials, and the environment friendly method. By blending various vegetable oils in a mixture, the melting point can be altered to achieve a desirable physical property. Moreover, the blending process is simple, free from chemicals and highly cost effective (Rios et al., 2014; Siddique et al., 2010). In order to generate a formulation, mixture design can be used for optimisation (Mohamad Zen, 2016). The objective of utilising this tool is to minimise the exertion, time, and resources included while obtaining a legitimate outcome (Kamairudin et al., 2014). D-optimal design was recommended as it is a sufficient and more effective method compared to other methods due to its ability to simultaneously combine many variables with a low number of runs (Eriksson, L., 2008).

The development of emulsifier is parallel with the development of shortening (Orthoefer, 2008). Generally, the function of emulsifier is to improve the texture and ensure there is no separation in mixture (Minoli et al., 2017). A number of studies done show the various effect of emulsifier in the end products of the shortening (Özhamamci et al., 2019; Fredrick et al., 2008; Miskandar et al., 2005; Manohar et al., 1999). The effectiveness of the emulsifier usually depends on the types of emulsifier used as well as the concentration that included in the shortening (Garzon et al., 2018; De Lyn, 2014; Stauffer,1996).

In this study, the formulation of shortening was applied in the cookie preparation in comparison to the preparation of the similar cookie with lard. Cookie is a small baked product with low moisture content that is convenient to the consumer (Misra and Tiwari, 2014). The physical properties of dough and cookie such as the hardness, rheological properties and color appearance were determined for the acceptance of the product in comparison to the reference.

## 1.2 Problem statement

Nowadays, shortenings can be found easily in the market with a variety of formulation. Consumer have more concerned in terms of health that make the vegetables oils always be preferred as the source of ingredients (Anon,2017). In terms of halal perspective, vegetable oil is a permissible source as long as the process and processing aid are not contaminated with non-halal derivatives. Vegetables oils such as palm oil is preferably used as the main component in shortening due to the reasonable price and the balance composition of its fatty acid (FAO, 2015). Some of the shortening products consist of the blend of vegetables oils such as such as palm oil, soybean oil, sunflower oil, canola oil, and olive oil (Lida et al.,2017). However, there is a lacking on the study of the quality of those shortening as compared to lard. Besides, the study of development of halal shortening that can simulate lard properties are scarcely found.

## 1.3 Hypothesis

It may be possible to formulate the palm-based shortening that simulate the lard properties.

## 1.4 Research Objective

The palm-based shortening is promising as a halal shortening since it is from plant-sources. Palm oil has a balanced fatty acid composition besides its fraction can be the hard stock without going through the hydrogenation process that is often related to trans-fatty acid content (Lida et al., 2017). The halal palm-based shortening could be formulated to be healthier shortening and may provide functionality as a fat ingredient in the food industry.

Hence, the main objective is to formulate shortening from palm-based sources in simulating the properties of lard as halal alternatives. The specific objectives of this research are: -

1. To optimize the formulation of palm-based shortening in simulating lard properties by using mixture design.
2. To determine the physicochemical properties of the selected palm-based shortening as compared to lard.

3. To investigate the effect of emulsifier on palm-based shortening as compared to lard.
4. To evaluate the performance of the palm-based shortening and lard in the cookie's preparation.

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