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Palm oil as a versatile halal ingredient: A review of its sterilization process

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Abstract: Palm oil is one of many edible oil crops available for human consumption. It prevails as a necessary halal raw material because of its outstanding characteristics and versatility of applications; such as its high-pressure oxidation resistance, capability to dissolve insoluble chemicals and its high coating power; besides it does not cause any skin irritation if used in cosmetics. To reach acceptability, the oil palm fruit undergoes various steps, namely sterilization, thresher, digester, screw press and oil clarifier. The Sterilization process is key for the success of further steps and is very costly compared with other processes. Additionally, it is necessary to optimize the entire process until the final product is reached. The sterilization process still needs further research pertaining to efficiency issues regarding energy usage and minimum oil losses that are cost effective for small and big factories. In this article, the process, types and energy consumption of palm oil sterilization are briefly described. This would be beneficial for beginners who are interested in palm oil milling, especially the sterilization process.

Keywords: Palm oil sterilization; palm oil; sterilizer; FFB; energy

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Introduction

Palm oil, *Elaeis guineensis*, is widely planted in Indonesia, Malaysia and Thailand. 71% of palm oil is used for foods (margarine, processed foods, chocolate, *etc.*), 24 % for consumer products (cosmetics, detergents, candles, *etc.*) and 5% for energy use (electricity, heating fuels, *etc.*) (AGEB, 2010). There are three causes of the growth of palm oil production, such as its low production cost compared with other cash crops, existing health benefits in vegetable oils compared with other animal products and the versatility of its application in domestic uses, industry, medical and agricultural fields (Lim, 2010). The versatility of its application renders it to be an important halal raw and intermediate ingredient to fulfil the demand of Muslim market. Palm oil became raw material for cooking oil, margarine, soap and cosmetics. Palm oil can be used for many purposes because of its high-pressure oxidation resistance, capability to dissolve insoluble chemicals and its high coating power; also, it does not cause any irritation to the body if used in cosmetics. Palm oil structure consists of three layers which are: kernel, shell and mesocarp (Figure 1). There are three types of palm oil based on the thickness of the shell, which are: Dura, Tenera and Pisifera.

Palm oil fruit comprises of 22.1% of oil yield when fully mature (Table 1). The Maturity index of palm oil fruit can affect the oil yield and free fatty acid (FFA). Processing palm oil fruit without delay could produce 87% of oil extraction and a good quality FFA reaching 2.31% (Badmus, 1991). FFA intended for commercial purposes should not exceed 5% (Noraini & Siew, 1990). Therefore, it is important to process palm oil fruit immediately after harvesting (Khaik *et al.*, 1985; Hudzari *et al.*, 2011). Fatin *et al.*, (2014); Ali *et al.*, (2014); Zu *et al.*, 2012 and Rajanaidu and Tan (1983) stated that the FFA percentage could increase due to a long storage period which results in damaged fruit while Copeland and Belcher (2001) reported that a high FFA in vegetable oil generally indicates the poor process that causes the breakdown of triglyceride after refining.

FFA also indicates the degree of purity of oil; purer oils show a lower value of FFA. Table 2 shows a percentage of FFA not more than 3.5%. For impure palm oil, the percentage of FFA could possibly increase, as mentioned. Microbial contamination and oxidation might also occur during storage (Tagoe *et al.*, 2012; Tan *et al.*, 2009).

Table 1. Oil yield and FFA for each maturity level (Mangoensoekarjo & Semangun, 2003)

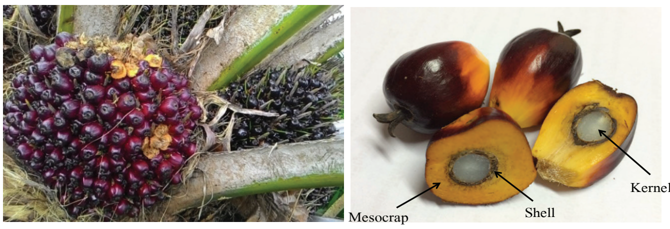
Fruit maturity	Oil yield (%)	FFA (%)
Immature fruit	16	1.6
Half-mature fruit	21.4	1.7
Mature fruit	22.1	1.8 – 2.1
Over-mature fruit	21.9	2.6 – 3.8

Table 2. Composition of CPO (Crude Palm Oil) (Morad *et al.*, 2006)

Composition	Unit	Value
Triglyceride	%	≥95
FFA	%	3.5
Diglycerides	%	2 – 6
Colour	-	Reddish brown
Moisture	%	0.25
Peroxide	Meq/kg O_2	1.0
DOBI	-	2 – 3.5
Phosphorus	Ppm	15
Iron	Ppm	5

Palm oil has to undergo a series of intricate procedures in order to reach the optimum process. A combination of triglycerides and water will produce glycerol and FFA. Hence, the process need to be controlled to achieve the values as indicated in Table 2; whereby Triglycerides must be more than 95% and FFA not more than 3.5%; respectively. Below is the chemical reaction of the palm oil process:

$$\underset{\text{Triglycerides}}{CH_3H_5\,(OOCR)_3} + \underset{\text{Water}}{3H_20} \rightarrow \underset{\text{Glycerol}}{C_3H_5(OH)_3} + \underset{\text{FFA}}{3RCOO} \quad (1)$$



(a) (b)

Figure 1. (a) Palm oil fruit in bunch and (b) Palm oil fruit in fruitlet.

Sterilization

Sterilization plays an important role in palm oil factory processing (Kamal, 2003; Jusoh *et al.*, 2013). This process is key for the success of the following steps such as thresher, digester, screw press and oil clarifier (Owolarafe & Faborode, 2008). The Sterilization process uses steam with pressure at 40 psi (140°C) for 75–90 minutes (Mahidin, 1998; Sivasothy., 2000). The purposes of sterilization include softening the fruit, facilitating the fruit release, enzyme inactivation, reducing the water content in the fruit and facilitating oil extraction (Matthaus, 2012; Let, 1995; Olie & Tjeng, 1974; Hadi *et al.*, 2009). Although palm oil fruit is well-sterilized, oil extraction has to be optimized. Furthermore, oil loss should be minimized to achieve optimum results.

Oil loss during the sterilization process gets a lot of attention in order to keep it under control during the process. Oil loss mostly occurs in condensation sterilizers (Wood *et al.*, 1985; Sundaresan *et al.*, 1990), empty fruit bunch (Wood *et al.*, 1985; Velayuthan, 1985), fruits still attached bunch (Wood *et al.*, 1985; Velayuthan, 1985), and kernel (Velayuthan, 1985). Oil that is obtained from a condensation sterilizer should be utilized in mechanical fields because of its higher iron content which could reduce oil stability when mixed with CPO (Wai-Lin, 2011).

The natural process of sterilization includes stopping the enzyme activity in palm oil fruit to avoid the increase of FFA when the process occurs (Tan, 2002). During the sterilization process, the moisture is influenced by steam which chemically breaks down resin and starch causing oil to foam during the frying process because of its solubility in water. Poor sterilization might be caused by secondary oxidation that leads to discoloration of palm kernel and deterioration of bleaching index (DOBI).

The Sterilization technology focuses on handling FFB during the sterilization process to eliminate the usage of a sterilization cage as a substitute batch for a continuous process. The new invention introduced continuous sterilization at atmospheric steaming pressure (Sivasothy, 2006), vertical sterilizer, tilting sterilizer (Loh, 2009), oblique and spherical sterilizer (Lim, 2007), modification of sterilization cages and steam distributor for an increased sterilization efficiency. The Sterilization process of microwave irradiation has a lot of advantages. It has a fast sterilization process to inactivate the enzyme (lipase) and it saves energy by using low temperatures (Chow & Ma., 2001; Tan., 1981). A Laboratory and small scale for sterilization of microwave were also tested (Nazarulhisham & Kaida, 2009). There are three generations of palm oil sterilization: conventional, second generation and third generation (Table 3).

Table 3. Palm oil sterilization process.

Generation phase	Sterilization process
Conventional	Horizontal batch sterilization
Second generation	Continuous sterilization Vertical / tilting / inclined / spherical sterilization
Third generation	Microwave sterilization Mobile sterilization

Types of Sterilization

At present, palm oil industries are much more developed which caused major changes for the sterilization processes in factories. The Sterilization process should be much more efficient to avoid oil losses at any stage of the process. There are three kinds of sterilizers, namely horizontal sterilizer (Figure 2), vertical sterilizer (Figure 3) and continuous sterilizer (Figure 4). Each kind of sterilization machine has its advantages and disadvantages, see Table 4. The horizontal sterilizer is the most commonly used, but it is also quite harmful for workers. For the vertical sterilizer, it is space saving due to its vertical position, but it has a high steam pressure and a longer process duration. On one hand, the continuous sterilizer possesses the advantage of having good productivity and a good maintenance process. While on the other hand, the continuous sterilizer has a high steam consumption during the process which is a major drawback.

Each type of sterilizer has been tested in different cases, see Table 5. They are conventional sterilizer, dry heating, hot compressed water, batch sterilizer, continuous sterilizer, microwave, batch sterilizer, mini sterilizer, ultrasound and radio frequency sterilizer. Faster processes of sterilization include dry heating, microwave, ultrasound and radio frequency heating. This technology has the potential to further develop sterilization techniques, but it still requires more efforts in making it more cost-effective and easier to adopt in factories.

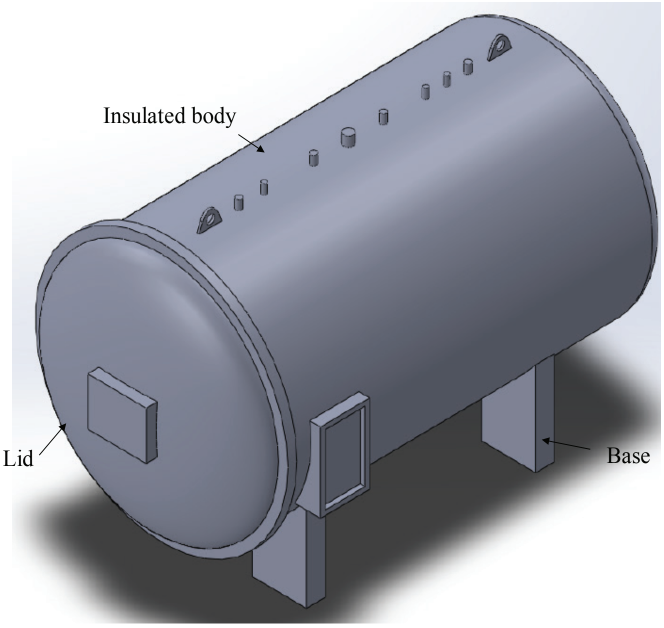


Figure 2. Horizontal sterilizer

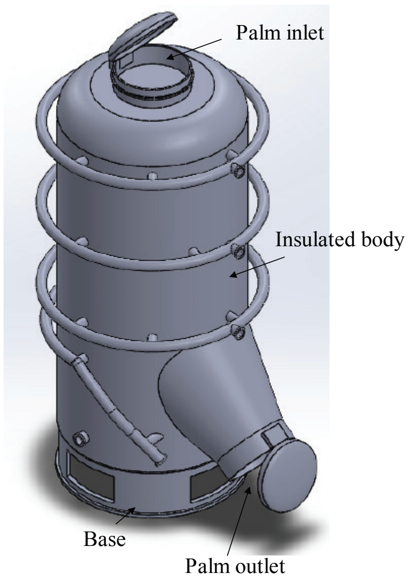


Figure 3. Vertical sterilizer

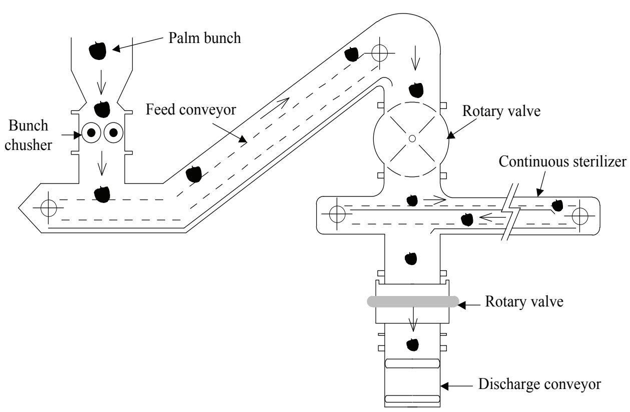


Figure 4. Continuous sterilizer

Table 4. Advantages and disadvantages of different types of sterilizers

Sterilization	Advantages	Disadvantages	References
Horizontal sterilizer	Most commonly used	Quite dangerous for workers	(Hadi *et al.*, 2012)
Vertical sterilizer	Space saving for factory	Needs a high steam pressure and has a longer process	(Hadi *et al.*, 2012
Compact Modular Continuous	Good productivity	-	(Eaton., 2012
Continuous sterilizer	Overall process has good maintenance	High steam consumption	(Hadi *et al.*, 2012; Reese, C.D., 2009; Sivasothy., *et al.*, 2006 Loh., 1994)

Type of sterilization	Pres-sure	Temp.	Time	Result	Referenc-es
Conventional sterilizer	10 MPa	80°C	60 min	Potential to inactivate Lipase Production Microbial in palm oil	(Umar *et al.*, 2017)
Dry heating	-	-	1 and 5 min	FFA is 1.02 – 2.19 %	(Hadi *et al.*, 2012)
HCW (hot compressed water)	30, 40 and 50 bar	120°C and 180°C	10 min	FFA is 0.807 that is good quality for SQ grade	(Sarip *et al.*, 2016)
Batch sterilization	-	-	-	FFA content is 2.68	(Sivasothy *et al.*, 2006)
Continuous sterilization	-	-	-	FFA content is 2.10	(Sivasothy *et al.*, 2006)
Microwave	-	-	3 min	FFA is 0.26% and quality of CPO with hexane extraction is superior	(Cheng *et al.*, 2011)
Batch sterilizer	4 MPa	121°C	20, 40 and 60 min	40 min duration showed a good quality of oil	(Akhmazillah & Sarmidi, 2011)
Microwave	-	-	-	Lower energy usage and can be processed in less than 17 minutes	(Sarah 2013)

Type of sterilization	Pres-sure	Temp.	Time	Result	References
Mini sterilization	2.6 bar	140°C	40, 50, 60 and 70 min	optimum heat transfers 248 kJ/kg in 60 min of sterilization	(Hadi *et al.*, 2012
Ultrasound	-	30–100°C	5-30 min	No changes in FFA quality	(Khalis *et al.*, 2015)
Radio frequency heating	-	-	3,6,9 and 12 min	A temperature of more than 320.5 K can reduce the FFA content	(Choto *et al.*, 2014)

Table 5. Sterilization process of palm oil fruit

Energy Utility of Sterilization Process

During the sterilization process, the energy was consumed to support steaming of fresh fruit bunches (FFB). Palm oil fruit will be detached from the bunches. The empty fruit bunch (EFB) was used as a raw material for fuel. Some palm oil factories started to burn press fiber and shell to generate steam and energy (Yusoff, 2006). Different biomass has different characteristics that could influence their ability to produce energy (Chua *et al.*, personal communication, 2009; Damodaran, 2005; Demirbas, 2004). The Average amounts of produced energy for various biomasses are shown in Table 6. Palm oil shell contains a great caloric value of 10.093 kJ/kg dry. Other potential biomasses are palm fiber, palm kernel cake and empty fruit bunch which also have the potential to be used as a source of fuel.

Table 6. Palm oil biomass energy potential

Biomass	Moisture (%)	Calorific value (kJ/kg)	Calorific value (kJ/kg (dry)
EFB	65	6.578	18.795
Palm fiber	45	10.480	19.055
Shell	10	18.084	20.093
Palm kernel cake	7	17.562	18.884

Sources: Wahid (2008)

The Palm oil industry requires a large amount of energy consumption during processing. The Sterilization process possesses the highest energy consumption. The necessity to reach optimum conditions is still in demand to increase profitability for the palm oil industry around the world. Energy efficiency and consumption rates are shown in Table 7. From Table 7, it can be noted that dual energy sources of charcoal and firewood could be alternative sources of energy with an efficiency of 56%. In addition, energy consumption from FFB exhibits an energy efficiency of 54.6% and gives a payback period of 1.51 years. The used sterilizer with a capacity of 2 tons and 150 grams shows an energy efficiency of 47.4% and 19.12%, respectively.

Table 7. Energy efficiency and usage for palm oil industry

Capacity of sterilizer	Energy consumption	Energy efficiency (%)	Result	References
0.42 ton	17 kWh / ton FFB	54.6	Increases thermal efficiency, giving additional income and a pay back of 1.51 years	(Sommart & Pipatmanomai, 2011)
150 gram	180kJ	19.12	Energy efficiency decreases while the process takes a longer time	(Choto *et al.*, 2014)
1 kg	5.4 kWh / kg FFB	56.0	Dual energy sources (charcoal and firewood) could be an alternative	(Bamgboye & Onwe, 2015)
2 ton	2.25 kW	47.4	Better than conventional counterparts, suitable for small and medium farmers	(Ologunagba *et al.*, 2010)

Conclusion and Recommendation

The sterilization process is a vital operation in the palm oil industry. The success or failure of this step is crucial for the outcome of the following stages. Therefore, minimizing oil losses is needed to save energy consumption during the sterilization process. Furthermore, the sterilization technology should be cost effective for smallholdings as well as large factories.

Conflict of Interest

The authors declare that there is no conflict of interest in this work.

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