Production of High Quality Crude Palm Oil (CPO) and Low 3-MCPD Esters RBD Palm Oil

Rahmat N*; Syed Mohd Hadi S H*; Norliza S*; Syahril Anuar M R*; Yosri M S*; Mohammed Faisal MY*; Ahmadilfitri M N* and Ahmad Jaril A*

*Processing Technology, Sime Darby Research Sdn. Bhd.
Lot 2664, Jalan Pulau Carey,
42960 Carey Island, Kuala Langat, Selangor.

INTRODUCTION

In general, palm oil milling process starts with sterilisation of the fresh fruit bunches (FFB), continued with the separation of the palm fruits from the bunch, and followed by mashing and mechanical pressing for the extraction of crude palm oil (CPO). The CPO will go through clarification and purification to complete the palm oil milling process. Conventional palm oil milling process requires dilution of crude oil to increase its fluidity and later enhances the separation of oil from its by-product at the clarification stage. Though good milling practices recommend using hot water for crude oil dilution, many palm oil millers are using the steriliser condensate and empty fruit bunch (EFB) liquor as dilution to recover some oil that would be lost in both streams, thus increase the mill's oil recovery.

Re-streaming the steriliser condensate and EFB liquor for dilution may improve the oil extraction rate (OER). However, the oil recovered from these streams is found to affect the quality of CPO and contribute to chlorine contamination. Previous studies have shown that chlorine in the form of chloride ions is known as the precursor that contributes to 3-monochloropropane-1,2-diol (3-MCPD) esters formation during the refining process (Nagy *et al*., 2011; Matthaus *et al*., 2011; Craft *et al.,* 2012; Tiong *et al*., 2017).

3-MCPD esters is becoming a major concern in the palm oil industry, as it is classified as food processing contaminant and probably carcinogenic to human under Group 2B by Classification of International Agency for Research on Cancer. Presence of 3-MCPD esters contaminant is clearly known in soy a sauce and acid-hydrolysed vegetable proteins (HVP) since the past few years; however, the attention is now diverted to 3-MCPD esters that has been recently detected in oils and fats, especially in palm oil. Extensive efforts have been placed for the reduction of 3-MCPD esters in palm oils and fats.

3-MCPD esters are formed from the reaction of acylglycerol with chloride and converted to HCl under high temperature through two established and proven mechanisms namely, free radical addition of chlorine radical (Pudel *et al*., 2011) and nucleophilic S_N2 substitution of chloride ion. There were speculations that chlorine is precursor for 3-MCPD esters formation and a study by Norliza *et al.* (2016) confirmed this claim. The study stated a positive correlation between the content of total chloride in CPO with 3-MCPD esters concentration in refined bleached deodorised palm oil (RBDPO) with R^2 = 0.9.

As such, one of the strategies to minimise its formation in RBDPO is to focus on where these precursors are found inside the palm oil mill. Thus, this work is conducted to study the effect of re-streaming steriliser condensate and EFB Liquor towards CPO quality and 3-MCPD esters formation as well as to propose separate oil recovery processing for clean CPO production.

Effect of Re-streaming Steriliser Condensate and EFB Liquor to 3-MCPD Esters Formation

Trials were conducted by Sime Darby Research Sdn. Bhd. (SDRSB) to study the effect of re-streaming steriliser condensate and EFB liquor to the concentration of total chlorine (TC) in CPO sourced from two different dilution solutions – hot water and combination of steriliser condensate and EFB liquor. The CPO was later refined to study the effect of both dilution solutions towards 3-MCPD esters concentration in RBD palm oil. Several trials were performed by mixing the pressed undiluted crude oil

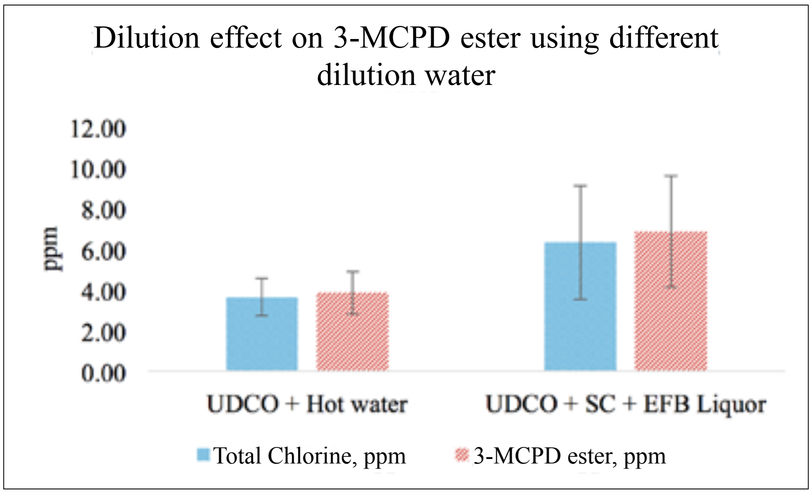

Figure 1. Effect of dilution using different dilution solution in UDCO towards 3-MCPD formation (lab scale).

(UDCO) with 30% hot water, and mixture of 26% steriliser condensate and 4% EFB liquor.

As shown in *Figure 1*, clean CPO and RBDPO sourced from hot water dilution had level of TC and 3-MCPD esters averaged at 3.64 ppm and 3.33 ppm respectively, while steriliser condensate and EFB liquor diluted CPO (unclean CPO) had higher level of TC and 3-MCPD esters, averaged at 6.31 ppm and 6.06 ppm respectively. This data tallies with an earlier study by Syed Mohd Hadi *et. al.* (2016) who noted the same trend using a similar feed from the same mill. Detection of chloride was done in total unit (total chlorine) regardless of its organic or inorganic form.

SEPARATE PROCESSING FOR CLEAN CPO PRODUCTION

In response to this finding, millers are urged to use hot water instead of re-streaming steriliser condensate and/ or EFB liquor for dilution. Through hot water dilution, the CPO produced is known as clean CPO with benefits elaborated below.

To recover the oil from these streams, separate processing route is suggested. By implementing separate processing route, the mill will be able to produce clean CPO with low chloride content which subsequently will produce RBDPO with lower 3-MCPD esters.

Figure 2 shows the separate processing route for oil recovery from steriliser condensate and EFB liquor.

In the separate processing route, high speed sludge separator is the main component for oil recovery. This is due to its capability to produce recovered oil with high purity of over 90%. The recovered oil transferred into pure oil tank will undergo purification and drying process at the end of milling for production of crude oil with moisture and dirt content below 0.25%.

CHARACTERISATION OF CLEAN CPO AND UNCLEAN CPO

To further validate the application of separate processing route, SDRSB has carried out investigation in commercial scale to confirm the findings on 3-MCPD esters level in RBDPO and to determine other advantages of clean CPO compared to unclean CPO.

Over 500 t of unclean and clean CPO was delivered respectively from the SDP mill to the refinery. The unclean and clean CPO were refined through conventional physical refining process with temperature of 255°C-260°C.

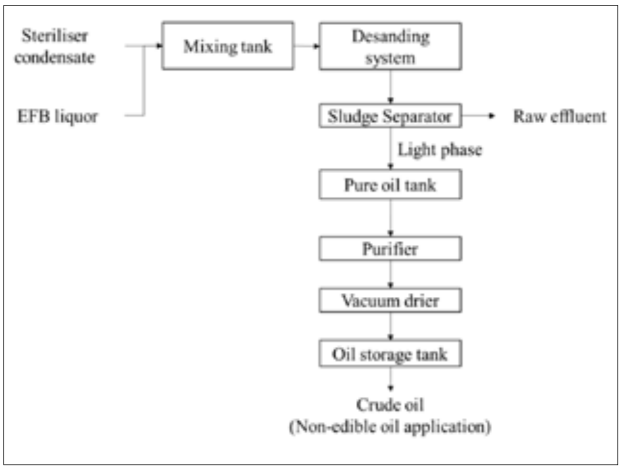

Figure 2. Separate processing route for oil recovery from steriliser condensate and EFB liquor.

3-MCPD Esters Level in RBDPO

TABLE 1. LEVEL OF TC AND 3-MCPD ESTERS IN CLEAN AND UNCLEAN CPO

Source of RBDPO/ analysis	FFA (%)	TC (ppm)	3-MCPD esters (ppm)
Unclean CPO	4.08±0.02	2.01±0.17	1.64±0.05
Clean CPO	3.80±0.01	1.38±0.21	1.15±0.14
% improvement	-	31.3	29.8

As shown in *Table 1*, it was observed that clean CPO produced lower 3-MCPD esters RBDPO as compared to the unclean CPO. By simply using hot water for dilution and separating the recovery of crude oil in steriliser condensate and EFB liquor from the main production line, approximately 30% reduction of TC and 3-MCPD esters can be achieved.

OTHER QUALITY ADVANTAGES OF CLEAN CPO

CPO Quality

Table 2 tabulates the quality of clean and unclean CPO samples. It was observed that the FFA in clean CPO is lower than unclean CPO. In terms of oxidation measured by peroxide value (primary), anisidine value (secondary) and total oxidation measured by UV, clean CPO showed better quality than unclean CPO. Furthermore, DOBI value of clean CPO was higher at 2.59 compared to 2.37 in unclean CPO.

In addition to better hydrolytic and oxidative quality, clean CPO also showed lower iron and copper concentration due to usage of hot water as dilution (*Table 3*). Throughout the milling process, metals tend to accumulate either from the crop or carried over throughout the mill process supply chain which dilution source might be one of possible causes. We also observed that phosphorus in clean CPO was extremely lower compared to unclean CPO.

As shown in *Tables 2* and *3*, clean CPO consistently recorded better quality and lower pro-oxidant level of iron and copper as compared to unclean CPO, which contributed to more stable oil and better refined oil quality afterwards.

RBDPO Quality

In relation to good CPO quality obtained from hot water dilution, the same trend was observed in RBDPO sample. *Table 4* shows the comparison of RBDPO quality sourced from unclean CPO and clean CPO.

As shown in *Table 4*, by having better CPO quality through separation of waste oils, better quality RBDPO quality with low oxidation level and better stability can be produced as well.

TABLE 2. CPO QUALITY IN UNCLEAN CPO AND CLEAN CPO

Source of CPO/ analysis	FFA, %	Peroxide value (2.0 max)	Carotene, ppm	Anisidine value (5.0 max)	Total oxidation by UV	DOBI (2.3 min)
Unclean CPO	4.08	2.10	607	4.11	2.421	2.37
Clean CPO	3.80	1.68	629	3.99	2.237	2.59

TABLE 3. METAL AND PHOSPHORUS CONTENT IN UNCLEAN CPO AND CLEAN CPO

Source of CPO/ analysis	Fe (ppm)	Phosphorus (ppm)	Cu (ppm)
Unclean CPO	5.0	12.5	0.03
Clean CPO	4.2	8.8	0.02

TABLE 4. RBDPO QUALITY IN UNCLEAN CPO AND CLEAN CPO

Source of RDBPO/ analysis	FFA (%)	Colour (Red)	Anisidine value	Induction period (Hour)
Unclean CPO	0.07	2.0	2.03	13.42
Clean CPO	0.06	2.4	1.81	13.58

Frying Performance

Both samples were subjected to 60 frying cycles for frying performance evaluation. Results showed that unclean CPO was prone to faster oxidation as compared to clean CPO as illustrated in *Figure 3*, especially after 30 cycles of frying. Moreover, the oil darkening effect was faster in unclean RBDPO than clean RBDPO.

RECOVERED OIL FROM STERILISER CONDENSATE AND EMPTY FRUIT BUNCH LIQUOR AS BIODIESEL FEEDSTOCK

As these oils are separated, the next question would be 'What can we use the oils for?'. Interestingly, the oil produced from these sources can be used for non-edible oil applications such as biodiesel production. Quality evaluation of the recovered oil from steriliser condensate and EFB liquor was conducted on a separate trial to determine its suitability as biodiesel feedstock.

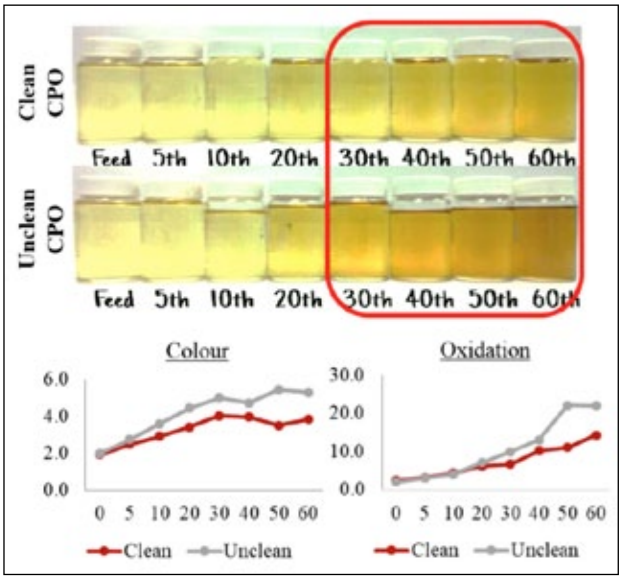

Figure 3. Frying performance result of clean RBDPO and unclean RBDPO.

Recovered Oil Quality

As shown in *Table 5*, sampling was done at different crop freshness to facilitate evaluation of results at all possible qualities of recovered oil. It was recorded that the recovered oils contained high FFA at the range of 7%–18% with very low DOBI and very high phosphorus content as compared to unclean CPO and clean CPO.

TABLE 5. QUALITY OF RECOVERED OIL FROM STERILISER CONDENSATE AND EFB LIQUOR

Sample/ analysis	FFA (%)	DOBI	Phosphorus (ppm)
A	7.67	2.01	*n.a
B	12.65	1.44	31.5
C	17.81	1.06	34.2
Unclean CPO	4.18	2.66	12.5
Clean CPO	3.92	2.98	8.8

**n/a – not available*

Recovered Oil Quality after Refining

Sample A, B and C as shown in *Table 5* were refined to determine its quality in order to compare it with biodiesel feedstock specifications. Results of refining is shown in *Table 6*.

TABLE 6. REFINED OIL QUALITY THAT SOURCED FROM STERILISER CONDENSATE AND EFB LIQUOR

Sample/ analysis	FFA (%)	Colour (lovibond red)	Moisture (%)	Insoluble impurities (%)
Biodiesel feedstock specification	0.2 max	15R max	0.1 max	
A	0.03	4.1	0.08	0.04
B	0.12	13	0.1	
C	0.19	15	0.1	

The quality of recovered oil after refining met the biodiesel feedstock specifications. It was noted that high colour in the refined oil may not impact the final biodiesel product thus was not included as one of the most important specifications.

CONCLUSION

Preventing the usage of steriliser condensate and EFB liquor as dilution in palm oil milling process would significantly contribute to production of better CPO quality with lower hydrolytic and oxidation level as well as lower chloride content. Additionally, by having lower concentration of TC in CPO, formation of 3-MCPD esters formation in RBDPO can be reduced. The oil recovered from these streams can be used for non-edible applications such as biodiesel production.

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