Solid State Science and Technology, Vol. 25, No 2 (2017) 118-127
ISSN 0128-7389 | *http://journal.masshp.net*

OIL LOSS IN PALM BIOMASS USING CONTINUOUS STERILIZERS, CONVENTIONAL, AND COMPACT MODULAR CONCEPT: A CASE STUDY FOR FELDA PALM OIL MILLS

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ABSTRACT

The effect of three types of sterilizer [continuous (CS), conventional (CV), and compact modular concept (CMC)] on the oil loss in oil palm biomass was studied. The statistical test was conducted on the oil loss data retrieved from 15 FELDA palm oil mills from 2009 to 2013. The results showed the test was significant where F (p-value 0.007<.05) indicating oil loss in the palm biomass has significant difference, according to its sterilizer system. It can be concluded that the different sterilizer system affected the oil loss in palm biomass. As for the oil loss content in the oil palm biomass, the CS system indicated the lowest oil loss content, followed by the CV system and CMC system.

Keywords: oil loss (OL); conventional (CS); continuous (CS); compact modular concept (CMC)

INTRODUCTION

Palm oil production is one of the main national gross domestic products (GDP) and high potential for food and biofuel markets [1]. Despite the increment up to 17 million tonnes of crude palm oil (CPO) which shows positive impact on the economy, the rapid plantation of oil palm results in high production of palm biomass [2]. The palm biomass produced from the milling processes are empty fruit bunches (EFB), palm oil mill effluent (POME), oil palm mesocarp fibre (OPMF), palm shell, palm kernel, and oil palm decanter cake (OPDC) (Figure 1) [3]. Sterilization is a crucial and the first process through by the fresh fruit bunches (FFB) after the grading process [4].

This process initiated the inhibition of free-fatty acid (FFA) enzyme development which disrupt the oil quality and enhanced the strippability of fruitless detachment from FFB spikelets [5,6].

FELDA palm oil mills adapted three types of sterilizer system which are continuous (CS), conventional (CV) and compact modular concept (CMC). According to Table 1, it shows the distinct features of each sterilizer system. These various features will affect the system's efficiency and effectiveness, and hence, observed in terms of the oil extraction rate (OER) and oil loss (OL). Normally, OER as a performance tool by the palm oil mill for assessing the mill effectiveness in palm oil production [7]. However, the rising concern for the environment which effected by the palm oil mill wastage, the recovery in the oil loss from the palm biomass is the main priority.

Table 1: The features of sterilization system [8,9]

Description	CS	CV	CMC
System	Continuous	Batch	Batch
Cage size [tonne/cage]	No cage	2.50	15
Temperature [°C]	140	140	140
Pressure [psi]	12	40	>40
Steaming [mins]	30 – 40	70 – 90	>90

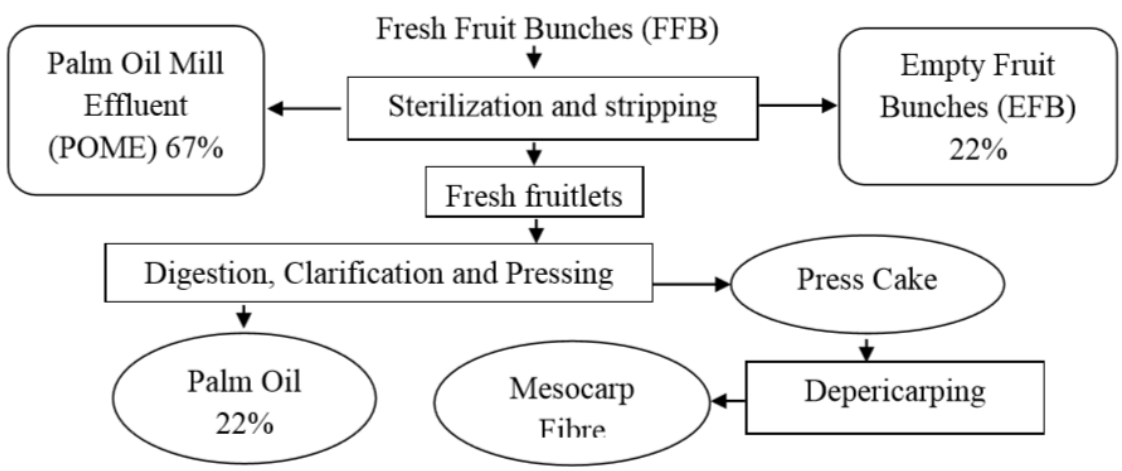

Figure 1: Simplified flow diagram of palm oil mill wastes (re-drawn) [10]

The objective of this study was to compare the oil loss in different types of sterilizer system according to different palm biomass, which are empty fruit bunches (EFB), palm oil mill effluent (POME) and oil palm mesocarp fibre (OPMF).

EXPERIMENTAL

Materials and methods Data Collection
All the data collected from FELDA palm oil mills across Peninsular Malaysia. The data selection is based on the percentage of internal crop processed at the range of 65% to 90% FELDA planting material to avoid biased data selection and types of sterilizer system. The oil loss data on palm biomass collected from year 2009 to 2013. In each sterilizer system, five mills were selected and undisclosed for the confidential purposes. Thus, 15 mills were selected for this study.

Data Analysis
The data statistically analyzed using the Social Package for Social Sciences (SPSS) version 19. Analysis of variance test (ANOVA), One-way ANOVA test and Post-Hoc test were performed for the means treatment comparison.

RESULTS AND DISCUSSIONS

Correlation of Oil Loss and Sterilizer Systems
The plot of total oil loss mean shown in Figure 2. It indicates CS system recorded the lowest oil loss, followed by CV system and CV system for the high oil loss. The difference of oil loss among the palm biomass for each sterilizer system was further elaborated in Figure 3. From the Figure 3, it shows differences across sterilizer systems with the OPMF records the highest oil loss, second by EFB and lastly, POME.

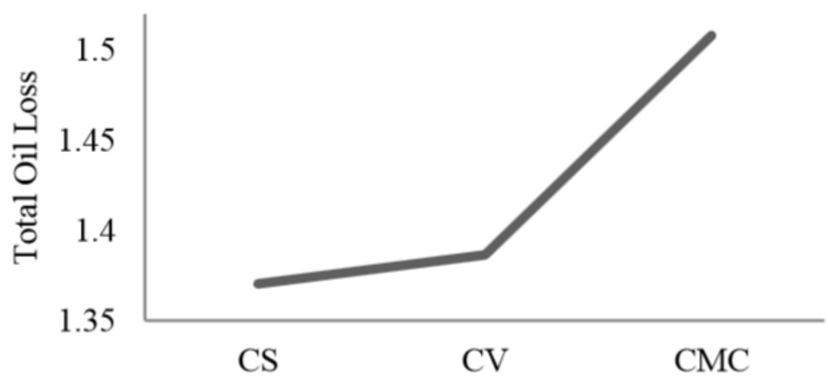

Figure 2: Total means plots of oil loss against the sterilizer system

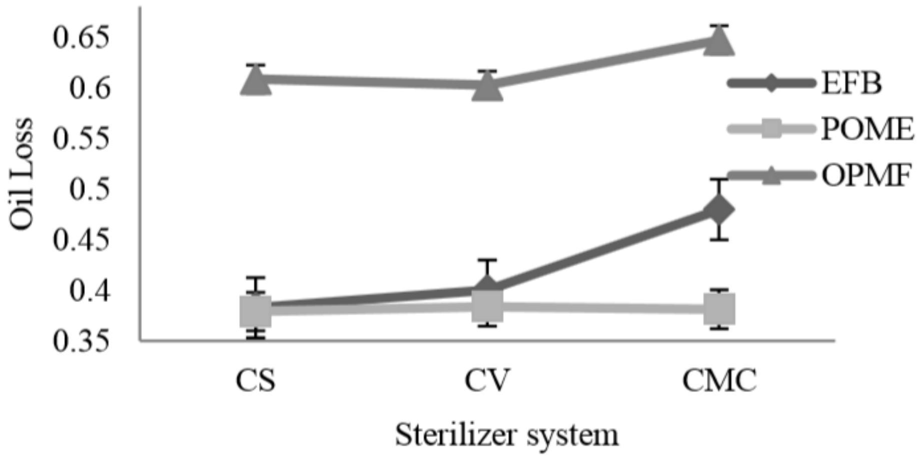

Figure 3: Comparison of oil loss from biomass against sterilizer system

The ANOVA test proves the types of sterilizer system affect the oil loss in palm biomass. In the Table 2 results indicate the value of F (df = 2, 72, $p < .05$) = 5.379 is significant and the null hypothesis is rejected. Hence, there is a significant difference in oil loss between type sterilizer systems. Further test of the Tukey's HSD Post-Hoc multiple comparisons were conducted to identify the significant difference between system. It was to determine which sterilizer system has the highest significant difference onto the oil loss in palm biomass. The mean difference (I-J) tabulated in Table 3 indicates the mean oil loss between each system where the negative result shows the lowest rank of results. The CS system records the lowest oil loss due to the improvement of low steaming pressure [11], secondly the CV system and third, the CMC system.

Table 2: ANOVA results for the oil loss mean sample among sterilizer system

Oil Loss	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.283	2	.142	5.379	.007
Within Groups	1.895	72	.026		
Total	2.178	74			

Table 3: Multiple mean comparisons between sterilizer system

Tukey HSD						
(I) Mill_Type	(J) Mill_Type	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
CS	CV	-.01600	.04588	.935	-.1258	.0938
	CMC	-.13760*	.04588	.010	-.2474	-.0278
CV	CS	.01600	.04588	.935	-.0938	.1258
	CMC	-.12160*	.04588	.026	-.2314	-.0118
CMC	CS	.13760*	.04588	.010	.0278	.2474
	CV	.12160*	.04588	.026	.0118	.2314

*. The mean difference is significant at the 0.05 level.

Oil Loss in Empty Fruit Bunches (EFB) between Sterilizer Systems
The empty fruit bunches (EFB) records 25% to 28.50% produced after each cycle of oil palm processing [3,5,12].

Table 4: ANOVA test results for the oil loss in EFB among three sterilizer

EFB_OL	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.133	2	.067	2.735	.072
Within Groups	1.755	72	.024		
Total	1.888	74			

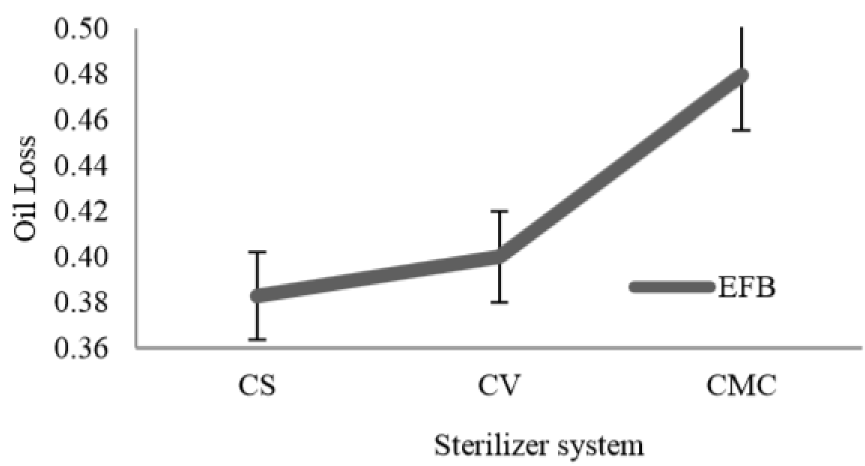

Figure 4: The oil loss percentage in EFB against types of sterilizer system

Figure 4 shows the oil loss in EFB among the sterilizer system. The CS system records the lowest oil loss in EFB, followed by CV system and lastly CMC system. Though there are differences of oil loss shown in the Figure 4, the statistical analysis shows there is no significant difference of oil loss in EFB among the different sterilizer system adapted in the mills. Table 4 shows the analysis of variance (ANOVA) test for oil loss in EFB among the types of sterilizer system in the mills. The results indicate the value of F ($df = 2, 72, p > .05$) = 2.735 is no significant and thus, null hypothesis is accepted. The EFB produced after the striping process (Figure 1) which undergoes the same process, despite the differences in sterilizer systems adapted.

Oil Loss in Palm Oil Mill Effluent (POME) between Sterilizer Systems
POME produced after the milling process (Figure 1) was discharged and pumped to the settling pond before its final storage in the composting area [5]. POME was settled in the pond at the retention time about 24h to 48h [13]. In each one tonne of crude palm oil (CPO) produced, about 3.50 tonnes of POME were produced as palm biomass [14]. The range of oil loss recovered from POME usually around 0.6% to 0.7% [15,16]. This low oil loss percentage has regarded the potential of oil recovery in POME and conventionally discharged in open pond systems. The drawback in the open pond system caused environmental issues related to the methane gases released [3,17].

Table 5: ANOVA test results for the oil loss in POME among three sterilizer

POME_OL					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.000	2	.000	.023	.978
Within Groups	.461	72	.006		
Total	.462	74			

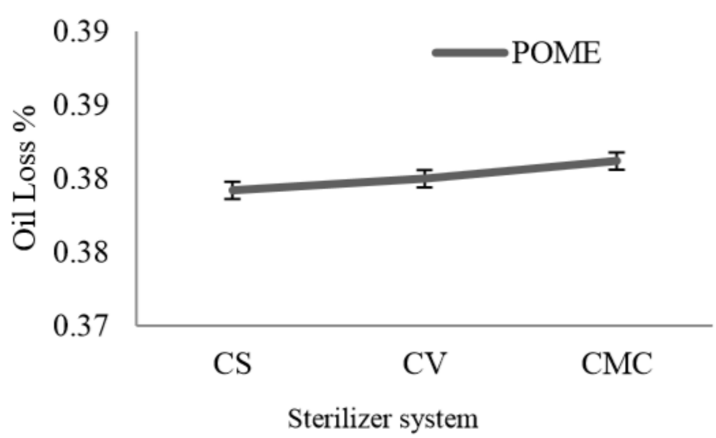

Figure 5: The oil loss percentage in POME against types of sterilizer system

The comparison of oil loss among three sterilizer system further explains in Figure 5 which shows the CS system records the lowest oil loss followed by CV system and lastly, CMC system. According to the Figure 5, it shows there are no differences in oil loss percentage among the sterilizer system and further prove with the statistical analysis shown in Table 5.

In Table 5, the ANOVA test for oil loss in POME among the types of sterilizer system in milling processes indicate the value of F ($df = 2, 72, p > .05$) = 0.023 is no significant and thus, null hypothesis is accepted. Therefore, the result shows there is no significant difference of oil loss in POME among the type sterilizer system adapted in the mills. Despite the different adaptation of sterilizer system in the mills, the rest of the flow process in milling processes has remained the same.

Oil Loss in Oil Palm Mesocarp Fibre (OPMF) between Sterilizer Systems
About 5% to 11% of oil residue content in the OPMF [6]. The oil loss in OPMF shows slightly different results from the previous palm biomass. For OPMF, the CV system records as the lowest oil loss, followed by CS system and lastly, the CMC system (Figure 6). OPMF is one of the lignocellulasic materials which stated as the high oil loss in palm biomass across the three sterilizer system (Figure 3) [16].

Table 6: ANOVA test results for the oil loss in OPMF among three sterilizer

OPMF_OL	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.030	2	.015	3.349	.041
Within Groups	.318	72	.004		
Total	.347	74			

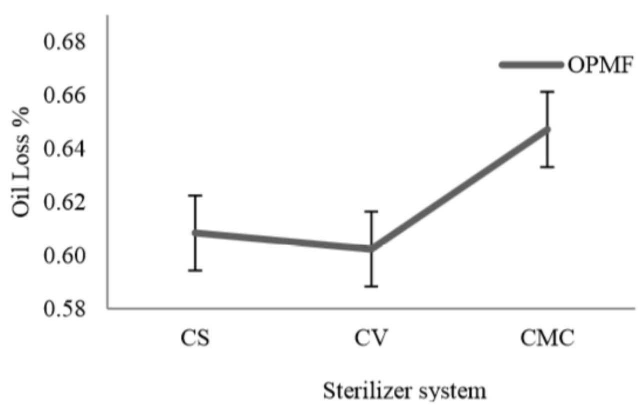

Figure 6: The oil loss percentage in OPMF against types of sterilizer system

Analysis of variance (ANOVA) test in Table 6 for oil loss in OPMF among three sterilizer system indicates the value of F (DF = 2, 72, $p > .05$) = 3.349 is significant and thus, the null hypothesis is rejected. Therefore, the result shows there is a significant difference of oil loss in OPMF among the type sterilizer system adapted in the mill.

During the mill processing, the fruitlets were exposed to several harsh mechanical processes such as bunch stripping and pressing [19]. These processes ruptured the OPMF surface area and increased its pore volume. Those mechanical processes crushed the mesocarp structures which then create the solid residues that attract oil droplets [20]. The CS system involved cutting the FFB in half in order to increase the fruitlets strippability. As the FFB moves along the continuous steaming feeder, the exposed OPMF easily absorbed the oil droplets with the supplies of water emulsion. It is reported that the moisture and oil content in CS system is slightly higher than the CV system. Thus, this place the oil loss in CS system is slightly higher than the CV system [21].

The CMC system produced a high volume of waste water after the sterilization process due to high pressure of steam is applied. As this system requires more steaming time, the water stagnant will form at the bottom of the cage. During the sterilization process, the mesocarp will be softened and the weight pressure of FFB will increase and thus, rupture the mesocarp outer layer. The oil will be compressed and wash down into the water stagnates. This will ease the oil absorption by the micofibrils of OPMF [22]. These fibrils are hydrophilic nature where it enables the oil droplets in water emulsion absorb by these microfibrils [23,24].

CONCLUSIONS

Overall, the CS system shows the lowest oil loss among the types of sterilizer system followed by the CV system and lastly, the CMC system. For the oil loss in palm biomass, the OPMF records the highest oil loss followed by EFB and POME respectively. In the comparison of oil loss, according to the palm biomass, the CMC system shows the highest oil loss in all selected biomass. The CS system shows the lowest oil loss in EFB and POME, however, shows the second highest oil loss in OPMF. As for the CV system, it shows the average oil loss for both EFB and POME, however shows the lowest oil loss in OPMF. Indeed, the different types of the sterilizer system adapted in the palm oil mills do have a significance difference in the oil loss.

ACKNOWLEDGEMENT

Authors are grateful for the financial support by the Ministry of Higher Education (MOHE) Malaysia, Long-term Research Grant Scheme (600-RMI/LRGS 5/3 1/2012) and Universiti Teknologi MARA, Shah Alam Campus as well as the FELDA Industries Sdn. Bhd for the technical support in this study.

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