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EVALUATION OF DOUBLE-ROLL CRUSHER ON OIL PALM FRUIT BUNCHES AND EFFECT OF BRUISING LEVEL ON FREE FATTY ACIDS CONTENT

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Abstract

Sterilisation of oil palm fruit bunches at atmospheric pressure employed in palm oil mills hinders the penetration of steam into the inner layers of the bunch. Therefore, a double-roll bunch crusher was developed to increase the surface area of the bunch. However, this process will also contribute to bruised fruitlets, as well as exposing the oil to oxidation and increasing free fatty acids content. This study was carried out to evaluate the bruising level of the oil palm fruitlets after crushing, and the effect of preheating of the crushed fruit bunches on the increase of free fatty acids. The comparison was made to the bruising level of oil palm fruitlets at various points in the milling process and after crushing with the control sample of bunch collected from the plantation. It was found that the percentage of moderately-bruised fruitlets and heavily-bruised fruitlets after crushing increased from 5.96% to 13.06%, and 2.15% to 14.14%, respectively. Harsh handling during transportation of oil palm fruit bunches was found to increase the bruising level by 23%. The increment of free fatty acids was successfully halted through the preheating of the crushed bunches. Results also showed that the use of bunch crusher was effective in allowing penetration of steam into the inner parts of the oil palm fruit bunches. The crushing also shortened the sterilisation process of the oil palm fruit bunches at atmospheric pressure compared to that of the pressurised batch sterilisation process.

Keywords: Bruising level, Bunch crusher, Free fatty acid, Oil palm fresh fruit bunch, Palm oil mill.

1. Introduction

Crude Palm Oil (CPO) is produced from the sterilisation of oil palm Fresh Fruit Bunches (FFB) and followed by the separation of oil palm fruitlets from the bunch, squeezing of oil from the mesocarp fibre, and purification of pressed oil [1]. The pressurised batch sterilisation process of FFB is usually employed in palm oil mills due to its ability to condition and pre-treat the FFB prior to further processes [2].

Based on study by Idris et al. [3], the quality of the CPO is measured using a string of parameters, namely the Free Fatty Acid content (FFA), Deterioration of Bleachability Index (DOBI), and moisture content. In Malaysia, the acceptable commercial grades for the FFA and DOBI are below 5.0% and more than 2.3, respectively [4]. The quality of the CPO in terms of oxidation value can be determined through its Peroxide Value (PV), measured in milliequivalent per kilogram (meq/kg).

According to Noerhidajat et al. [5], the pressurised batch sterilisation of FFB currently practised in palm oil mills utilises a very high-pressure steam and a long heating duration of 40-45 psi and 90-120 minutes, respectively. This heating condition is crucial to ensure maximum penetration of steam into the inner layers of the compact FFB structure, which will condition the fruitlets attaching to the sockets and enable complete detachment of the fruitlets. However, prolong heating at high-pressure gives an adverse effect on the quality of the CPO, i.e., high FFA and oxidation level. As stated by Palm Oil Refiners Association of Malaysia [4] and Ai [6], the FFA obtained is approximately 4-6%, whereas the specification for the market requires FFA to be less than 5%. PV often exceeds 2 meq/kg, which reflects that the oil has been severely oxidised, high values of FFA and PV result in low colour deterioration during the refining process [7]. As a result, the amount of bleaching compound increases in order to change the colour of oil from reddish orange to bright yellow [8].

Owing to this problem, a continuous pilot scale of sterilisation system was developed to study the effect of sterilisation of FFB for 60 minutes at atmospheric pressure. However, steam was not able to penetrate the inner layers of the bunch at atmospheric pressure due to the compact structure of the bunch. Therefore, the FFB was initially crushed using a double-roll bunch crusher to expose the inner layers of the bunch for steam to penetrate. As stated by Kandiah et al. [9], the short sterilisation process at the atmospheric pressure produced higher quality palm oil compared to that of the pressurised batch process (3.91% FFA, 0.58 meq/kg PV, and 2.99 DOBI).

However, the use of bunch crusher could increase the bruising of palm fruits and thereby increase the FFA content. The formation of FFA is due to the catalytic action of lipase enzyme in the mesocarp to hydrolyse the triglycerides into glycerol and FFA upon the bruising of the oil palm fruitlets. For this reason, a comprehensive study on the bruising effect was carried out involving more than 200 fruit bunches with various sizes and maturity stages.

The application of low-pressure steam during the sterilisation process frequently leads to undercooked mesocarp, which reduces FFB detachment. It lowers the percentage of the crude palm Oil Extraction Rate (OER) compared to that of the pressurised batch process. A study reported by Kandiah et al. [10], shows that 24% of fibres could not be removed via continuous sterilisation compared to 2.13% via pressurised batch sterilisation. For this reason, the loose fruits must be further cooked to facilitate the removal of mesocarp, which will increase the palm oil extraction rate.

2. Materials and Methods

2.1. Preparation of samples

FFB were obtained from oil palm plantations and receiving station in MPOB Palm Oil Mill Technology Centre (POMTEC) Negeri Sembilan, Malaysia. The FFB sent to the mill were obtained from several nearby plantations. All the FFB used in this study were matured fruits as the palm oil mill only accepts fruits of more than 95% maturity. All the chemicals used for analysis were of analytical grade purchased from Merck (Hesse, Germany).

Matured FFB bunch was used in each experiment with an approximate weight of 20-25 kg each. The category of FFB and its processing steps is summarised in Table 1.

Table 1. Categories of FFB and their respective processing steps.

Abbreviation	Sample type	Processing steps
S1	Sample	1. FFB loaded from lorry to mill's receiving ramp 2. FFB was collected from receiving ramp 3. FFB was sterilised (no crushing incurred)
S2	Control	1. FFB carefully selected and harvested from plantation 2. FFB was crushed then sterilised
S3	Sample	1. FFB loaded from lorry to mill's receiving ramp 2. FFB was collected from the receiving ramp 3. FFB was crushed then sterilised

2.2. Experimental design

2.2.1. Determination of bruising level of oil palm fruitlets

The bruising level of the oil palm fruitlets after crushing was determined using matured FFB labelled as S1, S2, and S3 as shown in Fig. 1. S1 was the FFB sample taken from the mill-receiving ramp prior to crushing. It reflected the initial bruising level of the fruits upon reaching the mill. The FFB loading process was carried out quite harshly, which could increase the bruising level of the fruits, Fig. 1(b). The FFB was then loaded to the steriliser cage using a loader or backhoe.

Sample S2 consisted of the manually harvested FFB in the plantation and crushed using a crusher in the mill. Sample S2 was categorised as control sample where the FFB was carefully transported by the researcher from the plantation to the mill, Fig. 1(a). The FFB experienced no additional bruising during the transportation process prior to the crushing process in the mill.

Sample S3 consisted of the FFB samples taken from the mill-receiving ramp followed by crushing, Figs. 1(c) and (d). Data obtained from this sample reflected the actual bruising level of the oil palm fruitlets in palm oil mill due to transportation and crushing of FFB.

Samples of matured FFB (S2 and S3) were crushed using a double-roll bunch crusher with a diameter of 600 cm and length of 1,000 cm, which can accommodate four bunches at one time. The distance between the two rollers was 15 cm, and the rotational speeds were set at 22 and 32 rpm, Fig. 2(a). Furthermore, a machete was used to cut the crushed bunches into spikelets as shown in Fig. 2(b). As reported by Hadi et al. [11], the bruising level was determined by analysing individual fruitlets on each spikelet and then the oil palm fruitlets were categorised as least-bruised, moderately-bruised and heavily-bruised. The percentages of the sound fruitlets, broken nuts and loose fruits after crushing were also quantified.

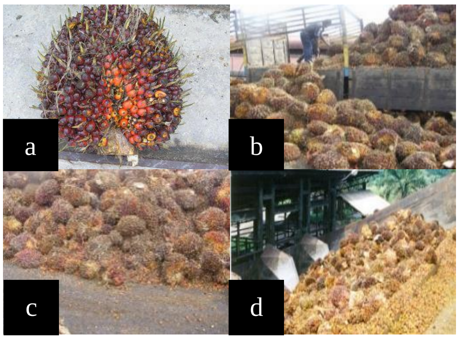

Fig. 1(a) FFB taken from oil palm plantation (control), (b) FFB taken during unloading of FFB from a lorry at receiving station, and (c) and (d) crushed fruit bunches reflecting the actual bruising level.

Fig. 2(a) An illustration of a gap and rotation of rollers in the bunch crusher and (b) spikelets of the oil palm bunch after crushed.

2.2.2. Preheating of crushed FFB

In this study, the samples of matured FFB (S3) weighing about 20 kg were collected from the ramp and then crushed. The crushed FFB were immediately sterilised for 5 minutes in an autoclave at atmospheric pressure and 120 °C temperature. The sterilised FFB were then removed from the autoclave and left outside autoclave for 30 and 60 minutes prior to resterilised for another 60 minutes. Different sterilisation durations were employed to determine the duration needed for maximum FFA production to be halted.

After 60 minutes of sterilisation, all fruits detached of the crushed FFB by manual threshing. The mesocarp was removed from the oil palm nut by hand pressing. Approximately 500 g of mesocarp was used to obtain the crude palm oil by pressing the mesocarp using a handheld mechanical presser. The oil was separated from the solid particles using a centrifuge (Sorvac RC-50) at 3,000 rpm for 5 minutes. The oil was analysed for the FFA content. Figure 3 shows the flow chart for samples preparation and analysis methods used in this study.

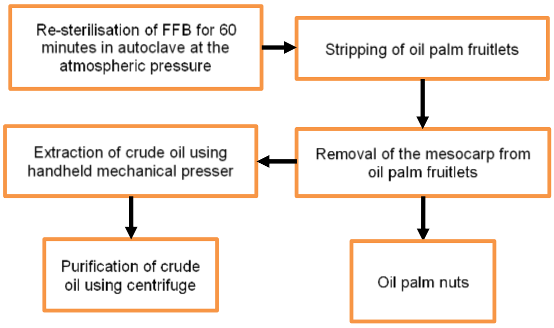

Fig. 3. Flowchart for sample preparations to study effect of preheating in the production of FFA in crushed FFB extraction of oil and analysis of FFA.

2.2.3. Oil palm FFA analysis

According to Idris et al. [3], the determination of FFA content was carried out in accordance with MPOB Test Methods. The acid value is defined as the amount of sodium hydroxide needed (in mg) to neutralise 1 g of FFA (as palmitic acid). Approximately 5 g of the preheated palm oil (60-70 °C) was mixed with 50 mL of isopropanol. The mixture was titrated against potassium or sodium hydroxide with 3-4 drops of 1% of phenolphthalein solution as an indicator. The phenolphthalein solution was prepared by dissolving 1 g of phenolphthalein in 10 mL of isopropanol. A persistent pink colour appearance for 30 s denotes the end of the titration process. The amount of sodium hydroxide used to neutralise FFA in the oil sample is used to calculate the FFA content using Eq. (1):

$$\text{FFA content (\%, as palmitic acid)} = \frac{25.6 \times N \times V}{W} \quad (1)$$

where, N is normality of sodium hydroxide solution, V is volume of sodium hydroxide solution used for titration in milliliters, and W is weight of the oil sample in grams.

3. Results and Discussion

3.1. Effects of crushing on bruising level of oil palm fruitlets

Through observation, it was found that the use of bunch crusher increased the bruising level of the oil palm fruitlets. Figure 4 depicts the condition of oil palm fruitlets before and after crushing.

Fig. 4(a) Samples of matured FFB before sterilisation, and (b) and (c) Samples of matured FFB after sterilisation.

The bruising levels were determined by differentiating and calculating the amount of bruised fruits in each spikelet based on the least-bruised, moderately-bruised and heavily-bruised oil palm fruitlets, and broken nuts against the total number of fruitlets in the bunch (Fig. 5).

Table 2 shows the results of bruising level of the uncrushed FFB collected at the loading ramp (S1). The percentages of the least-bruised, moderately-bruised and heavily-bruised oil palm fruitlets were 13.11%, 5.96%, and 2.15%, respectively. Figure 6 shows the different bruising levels of the oil palm fruitlets. The average percentage of broken nuts for the FFB from the mill receiving ramp was 0.03%, and the percentage of sound fruitlets was 77.00%.

This indicated that the transportation of FFB caused the least bruising effect to the oil palm fruit and insignificant damage to the palm nuts. The percentage of loose fruits was 1.75%, while the number of broken nuts was very low and in most samples, no broken nut was observed. It proved that the current transportation practice gives minimum impact to the bruising level of the oil palm fruitlets**.**

Table 2. Bruising level of uncrushed FFB from loading ramp.

Bunch code	Fruit counts	Oil palm fruits bruising level (%)											
		ES	%	SF	%	LBF	%	MBF	%	HBF	%	BN	%
S1*a*	1840	42	2.28	1496	81.30	209	11.36	78	4.24	15	0.82	0	0.00
S1b	1814	21	1.16	1366	75.30	268	14.77	138	7.61	21	1.16	0	0.00
S1*c*	1739	16	0.92	1400	80.51	235	13.51	72	4.14	15	0.86	1	0.06
S1*d*	1641	67	4.08	1286	78.37	211	12.86	69	4.20	8	0.49	0	0.00
S1*e*	1374	23	1.67	1068	77.73	188	13.68	62	4.51	31	2.26	2	0.15
S1*f*	1688	18	1.06	1424	84.40	147	8.70	62	3.67	37	2.19	0	0.00
S1*g*	1261	21	1.67	910	72.16	155	12.29	112	8.88	63	5.00	0	0.00
S1*h*	1438	17	1.18	952	66.20	255	17.73	150	10.43	64	4.45	0	0.00
Average		**1.75**		**77.00**		**13.11**		**5.96**		**2.15**		**0.03**	

Note: S1: Bunches taken from loading ramp (no crushing); ES: Empty Socket; SF: Sound fruitlets; LBF: Least-bruised fruitlets; MBF: Moderately-bruised fruitlets; HBF: Heavily-bruised fruitlets; BN: Broken nuts.

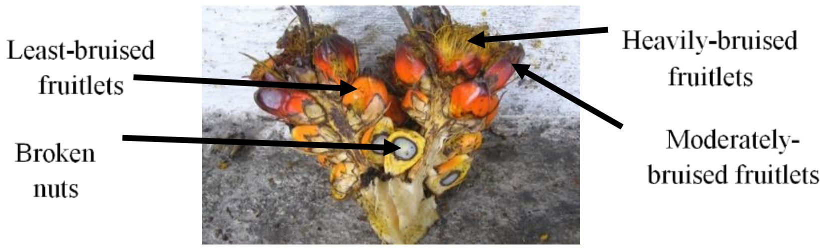

Fig. 5. Different bruising levels of oil palm fruitlets.

Fig. 6(a) Least-bruised fruitlets, (b) moderately-bruised fruitlets and (c) heavily-bruised fruitlets.

Table 3 shows the bruising level of S2 FFB sample (bunches manually harvested from the plantation, followed by crushing). The average percentage of the detached fruits was 0.87%, lower than the samples obtained from the loading ramp (S1) based on the number of empty sockets in each bunch. This signified that proper transportation of FFB can minimise the amount of detached or bruised fruits prior to processing. However, the use of bunch crusher increased the bruising level significantly.

The average percentages of the least-bruised, moderately-bruised and heavily-bruised oil palm fruitlets for the S2 FFB sample were 17.44%, 10.99%, and 11.48%, respectively. The average percentage of broken nuts was 1.52%, while the percentage of sound fruitlets was 57.69%. These data reflected that the bruising level was high irrespective to the freshness of the crushed fruits. Nevertheless, the bruising level was higher in uncrushed and aged fruit bunches, which could affect the quality of the CPO produced.

Moreover, Table 4 shows the bruising level of FFB collected from the mill receiving ramp after crushing (S3), where the average percentage of the detached fruits (empty sockets) was 1.72%. This demonstrated that the use of bunch crusher has not increased the number of empty sockets in each bunch if compared to samples from the loading ramp (S1). The average percentage of detached fruits in S1 FFB was about 1.75% (Table 2).

Table 3. Bruising level of crushed FFB from plantation.

Bunch code	Fruit counts	Oil palm fruits bruising level (%)											
		ES	**%**	**SF**	**%**	**LBF**	**%**	**MBF**	**%**	**HBF**	**%**	**BN**	**%**
S2*a*	1562	27	1.73	995	63.70	198	12.68	208	13.32	118	7.55	16	1.02
S2*b*	1247	5	0.40	895	71.77	172	13.79	54	4.33	99	7.94	22	1.76
S2*c*	1508	5	0.33	872	57.82	313	20.76	42	2.79	245	16.25	31	2.06
S2*d*	1673	38	2.27	700	41.84	379	22.65	258	15.42	274	16.38	24	1.43
S2*e*	1661	3	0.18	1124	67.67	237	14.27	163	9.81	126	7.59	8	0.48
S2*f*	1903	6	0.32	825	43.35	390	20.49	386	20.28	251	13.19	45	2.36
Average		**0.87**		**57.69**		**17.44**		**10.99**		**11.48**		**1.52**	

Note: S1: Bunches taken from loading ramp (no crushing); ES: Empty Socket; SF: Sound fruitlets; LBF: Least-bruised fruitlets; MBF: Moderately-bruised fruitlets; HBF: Heavily-bruised fruitlets; BN: Broken nuts.

Table 4. Bruising level of crushed FFB from loading ramp.

Bunch code	Fruit counts	Oil palm fruits bruising level (%)											
		ES	**%**	**SF**	**%**	**LBF**	**%**	**MBF**	**%**	**HBF**	**%**	**BN**	**%**
S3a	1796	38	2.12	974	54.23	392	21.83	272	16.71	108	6.94	12	0.67
S3b	1375	40	2.91	691	50.25	196	14.25	193	14.04	245	17.82	10	0.73
S3c	1684	37	2.20	939	55.76	255	15.14	181	10.75	268	17.51	4	0.24
S3d	1584	24	1.52	943	59.53	277	17.49	176	11.11	152	9.60	12	0.76
S3e	1698	25	1.47	843	49.65	311	18.32	250	14.72	259	16.80	10	0.59
S3*f*	1540	19	1.23	921	59.81	229	14.87	202	13.12	150	9.74	19	1.23
S3*g*	1730	17	0.98	703	40.64	421	24.34	254	14.68	326	18.84	9	0.52
S3*h*	1524	21	1.38	977	64.11	190	12.47	142	9.32	212	15.87	3	0.20
Average			**1.72**		**54.25**		**17.34**		**13.06**		**14.14**		**0.62**

Note: S1: Bunches taken from loading ramp (no crushing); ES: Empty Socket; SF: Sound fruitlets; LBF: Least-bruised fruitlets; MBF: Moderately-bruised fruitlets; HBF: Heavily-bruised fruitlets; BN: Broken nuts.

The optimum design of the bunch crusher, such as size of roller and gap between rollers is crucial to ensure that the bunch is opened by cutting only the inner part of the bunch without incurring too much damage to the fruits. It serves the purpose of enabling atmospheric steam to reach the inner layer of fruits while also maintaining the bunch in bulk form. Nevertheless, bruising to fruits was inevitable where the percentage of bruising level increased significantly after the fruit bunches passed through the bunch crusher.

The average percentages of the least-bruised, moderately-bruised and heavily-bruised oil palm fruitlets were 17.34%, 13.06%, and 14.14%, respectively. The average percentage of the broken nuts was 0.62%, while the average percentage of sound fruitlets was 54.25%. These data verified that the fruit bunches that were immediately transported from the plantation or collected at the loading ramp would be moderately-bruised and/or heavily-bruised after crushing.

However, the average bruising level was lower in fruit bunches that were immediately transported from the plantation (S2) compared to those collected at the loading ramp (S3). The moderately-bruised and heavily-bruised oil palm fruitlets in S3 were higher than S2 by 2.07% and 2.66%, respectively. Meanwhile, there was not much difference in the average of least-bruised oil palm fruitlets between both samples (17.44% in S2 and 17.34% in S3).

The comparison of bruising level was carried out on samples collected at the loading ramp as it reflected the real condition of the fruit bunches for the production of CPO in palm oil mill. Table 5 shows the comparison of the bruising level for S1 and S3 samples. The use of bunch crusher increased the percentage of moderately-bruised and heavily-bruised oil palm fruitlets by 7.10% and 11.99%, respectively. The percentage of the least-bruised oil palm fruitlets increased by 4.23%, and the percentage of sound oil palm fruitlets decreased by 22.75%. It showed that the use of bunch crusher increased the heavily-bruised oil palm fruitlets of more than 10% compared to least-bruised and moderately-bruised oil palm fruitlets. Similar study by other researchers reported by Kandiah et al. [10] shows a significant bruised level due to crushing was increased by 30.74%, from 2.88% to 33.62%.

FFB samples collected from the loading ramp (S1) and plantation (S2) had their nuts broken after subjected to the crusher. This indicated that the crusher gave both tearing and compressing effects. While the tearing force affected the bruising of fruitlets mesocarp fibre, the compressing force affected the cracking of nuts.

Table 5. Comparison of bruising level for samples S1 and S3.

Category	Bruising level (%)		
	S1[a]	**S3[a]**	**Due to crushing[b]**
Sound fruitlets	77.00	54.25	(22.75)
Least-bruised	13.11	17.34	4.23
Moderately-bruised	5.96	13.06	7.10
Heavily-bruised	2.15	14.14	11.99

Note: S1: bunches taken from loading ramp (no crushing);
S3: bunches taken from loading ramp (followed by crushing)
[b]S3 compared to S1; value in bracket ( ) means percentage reduction

3.2. Effect of preheating in minimising production of FFA

Due to the significant increase in the bruising level, the lipase activity has also increased rapidly. This will lead to the increase of FFA content if the oil palm fruitlets are not sterilised in due time. This study was performed to determine whether the preheating process could deactivate or slow down the production of FFA.

CPO mainly consists of triglycerides that are formed via the reaction of glycerol and fatty acids. Several researchers have reported the presence of lipase enzyme (triacylglycerol acylhydrolase) in the mesocarp of rotten oil palm fruitlets [12, 13]. According to Sambanthamurthi et al. [14], lipase catalyses the hydrolysis activity of triglycerides into monoglyceride and diglyceride before a complete degradation into glycerol and FFA. Lipase activity starts when the fruits start to bruise [15], and the activity occurs very rapidly with the increasing amount of bruised oil palm fruitlets. However, the sterilisation process at over 60 °C deactivates the lipase activity in the oil palm mesocarp [16].

Besides deactivating the lipase activity in the oil palm mesocarp, sterilisation also facilitates in loosening the fruits of FFB for maximum fruit recovery during the stripping process [17, 18]. Sterilisation is the first stage of the milling process that ensures the success of other subsequent stages. During the sterilisation process, high oxidation and over sterilisation could be possibly lead to high FFA content and low bleachability of the CPO. Another report from other researchers also found that heating parameters of the sterilisation process significantly influenced the CPO quality [19].

Table 6 shows the FFA content in the oil palm fruitlets that were preheated for 5 minutes after the oil palm fruit bunches were crushed and then left outside autoclave for 30 and 60 minutes. These bunches were subsequently sterilised for another 60 minutes at atmospheric pressure. The average FFA content in the oil palm fruitlets that were sterilised after 30 and 60 minutes delay were 1.26% and 1.36%, respectively, with a slight increase of 7%. This showed that the preheating process prior to sterilisation was sufficient to provide partial deactivation of the lipase activity. After preheating, the oil palm fruit bunches were sterilised for only over an hour after 60 minutes delay, but still yielded a low FFA content of about 1.36%. The sterilisation of FFB at a lower pressure of 14 psi compared to 40 psi in conventional practice was possible when the bunch was crushed. The sterilisation duration (60 minutes) was also shorter compared to the conventional practice (about 90 minutes) due to the larger surface area of the crushed bunch.

Table 6. Average FFA content in crushed bunches that underwent 5 minutes preheating, followed by 30 and 60 minutes delayed in sterilisation.

Sample	Average FFA content (%)	
	30-minutes delay	60-minutes delay
1	1.18	1.23
2	1.27	1.24
3	1.21	1.29
4	1.38	1.09
5	1.44	1.12
6	1.40	1.18
7	1.32	1.37
8	1.36	1.23
9	1.32	1.39
10	1.12	1.27
11	1.09	1.32
12	1.02	1.28
Average	1.26 ± 0.13	1.36 ± 0.09

Normally, the FFA content was maintained below 5.0% prior to refining process. As reported by Corley and Tinker [20], at least 0.3% FFA present in the oil processed from matured oil palm fresh fruitlets. However, the FFA content could increase by 60% within an hour if the fruits start to bruise due to sterilisation. It means that bruising of fruits due to transportation and handling gives greater risk to FFA increment resulting from the FFB, which are often left at the FFB receiving ramp for long duration prior to sterilisation. The crusher however, was placed in line next to the steriliser, therefore, a short delay between both processes was expected.

4. Conclusions

The results of this study showed that the application of a double-roll bunch crusher was effective in allowing penetration of steam into the inner parts of the oil palm fruit bunches. The crushing also enabled short sterilisation of FFB at atmospheric pressure to achieve complete detachment of oil palm fruitlets compared to that of the conventional pressurised batch sterilisation process.

This study also revealed that the use of double-roll bunch crusher increased the bruising level of the oil palm fruitlets significantly. The average percentage of the moderately-bruised fruits increased by 7.10% after the crushing process (from 5.96% in S1 to 13.06% in S3). Similarly, the average percentage of heavily-bruised fruits increased by 11.99% (from 2.15% in S1 to 14.14% in S3). The bruising level of fruits in FFB is normally around 23% due to harsh handling process during transportation to the palm oil mill or at loading ramp, while the remaining fruits are in sound condition.

The FFB that were left for 8-24 hours before sterilisation made the oil palm fruit bunches aged. Thus, the bruising level would increase significantly when the FFB were crushed in the bunch crusher. The FFB collected from the plantation (S2) and subjected to the crusher also showed high bruising levels of 10.99% and 11.48% for the moderately-bruised and heavily-bruised oil palm fruitlets, respectively. It can be concluded that the bunch crusher increased the bruising level irrespective to the initial condition of the fruits. Additionally, the bruising level was higher in the aged fruit bunches compared to fresh fruit bunches.

The production of FFA due to the increase of bruising level could be avoided by preheating the crushed bunches. Preheating for 5 minutes at atmospheric pressure could reduce the lipase activity in the production of FFA. The study also showed that the increase in FFA content was only 7% (from 1.26% to 1.36%), although the sterilisation process was delayed for 30 and 60 minutes after preheating. These findings suggest that the sterilisation of the crushed bunches could be delayed for over 60 minutes after preheating process without a significant increase in FFA content.

Nomenclatures

N	Normality of sodium hydroxide solution
V	Volume of sodium hydroxide solution used for titration in millilitres
W	Weight of oil sample in grams

Abbreviations

CPO	Crude Palm Oil
DOBI	Deterioration of Bleachability Index
FFA	Free Fatty Acid
FFB	Fresh Fruit Bunches
MPOB	Malaysian Palm Oil Board
OER	Oil Extraction Rate
POMTEC	Palm Oil Mill Technology Centre
PV	Peroxide Value

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