Effect of Double Roll Crusher Complete with Preheating on Bruising Level and Free Fatty (FFA) Acid Content of Oil Palm Fruit Bunches

Che Rahmat Che Mat*; Andrew Yap Kian Chung*; Rohaya Mohamad Halim*; Nu'man Abdul Hadi* and Ummi Kalsum Hasanah Mohd Nadzim*
*Malaysian Palm Oil Board,
6, Persiaran Institusi, Bandar Baru Bangi, 43000 Kajang, Selangor, Malaysia.
E-mail: rohaya@mpob.gov.my

OVERVIEW

In conventional milling process, fresh fruit bunches (FFB) is sterilised using pressurised batch steriliser utilises 40-45 PSI saturated. The heating condition is crucial to ensure adequate steam penetration into inner layers of the compact bunches in order to duly condition the fruitlets. The sterilisation process usually needs 90-120 min and prolonged heating induces adverse effect on the crude palm oil (CPO) quality. In order to enhance steam penetration, bunch crushing approach has been explored. Experimental results showed that bunch crushing increases the fruit bruising level significantly which promotes free fatty acids (FFA) formation due to lipase catalyst. However, empirical data demonstrated that 5 min of preheating after bunch crushing inhibits the FFA formation effectively and could last for 60 min. Thus, the new approach to crush open FFB during conventional horizontal sterilisation is feasible. The atmospheric saturated steam heating (1 bar) facilitates steam penetration into FFB and hence reduce oil losses due to high unstripped bunches and kernel losses from improper nut conditioning.

INTRODUCTION

Pressurised batch sterilisation at 40-45 psi saturated steam for 90-120 min is normally employed in palm oil mills to condition and pre-treat the FFB prior to oil extraction (Noerhidajat *et al.,* 2016). The heating condition is crucial to ensure adequate steam penetration into inner layers of the compact bunches in order to duly condition the fruitlets. However, prolonged heating induces adverse effect on the CPO quality such as elevating free fatty acid (FFA) content and oil oxidation (Hasimah *et al.,* 2016; Tan *et al.,* 2017).

Owing to this problem, a pilot sterilisation system was developed to study the sterilisation effect of FFB for 60 min at atmospheric pressure. However, atmospheric pressure steam would not be able to penetrate the inner layers of the bunch at atmospheric pressure due to its compact structure. Therefore, crushing of FFB using a double-roll bunch crusher was introduced to expose the inner layers of the bunch for steam penetration. The short sterilisation process using the atmospheric pressure produced higher quality palm oil compared to that of pressurised batch process.

However, the use of bunch crusher could incur the bruising of palm fruits and increases the FFA content. The FFA formation is due to the catalytic action of lipase enzyme in the mesocarp to hydrolyse the triglycerides into glycerol and FFA upon bruising of the oil palm fruitlets (Krisdiarto and Sutiarso, 2016). The objective of this study was to analyse the effect of bruising level towards FFA. The study was carried out involving more than 200 FFB with various sizes and maturity stages.

MATERIAL PREPARATION

Samples Preparation

Mature FFB were obtained from nearby oil palm plantations and receiving station in MPOB Palm Oil Mill Technology Centre (POMTEC) Negeri Sembilan, Malaysia.

TABLE 1. FFB CATEGORIES AND THEIR RESPECTIVE PROCESSING STEPS

Abbreviation	Processing steps
S1	FFB were collected from receiving ramp and were sterilised without crushing.
S2 (Control)	FFB were carefully selected and harvested from plantation, crushed and then sterilised.
S3	FFB were collected from receiving ramp, crushed and then sterilised.

Each mature FFB used in the experiments weigh 20-25 kg approximately, categorised into S1, S2 and S3, and under went different processing steps as summarised in *Table 1*.

EXPERIMENTAL PROCEDURES

Oil Palm Fruitlets Bruising Level Determination

The samples for this study were categorised into three group and labelled as S1, S2, and S3. S1 was the FFB sample taken from the mill receiving ramp without crushing to reflect the initial fruits bruising level upon reaching the mill.

Sample S2 served as a control where the FFB were harvested manually in the plantation and transported carefully to the mill and then crushed using a crusher. The FFB were considered as not exposed to any bruising during the handling prior to crushing process in the mill.

Sample S3 was FFB samples taken from the mill receiving ramp followed by crushing. The FFB unloading process was carried out quite harshly which could increase the fruits bruising level. The FFB then were loaded into steriliser cages using a loader or backhoe. Data obtained from this sample reflected the actual oil palm fruitlets bruising level in palm oil mill due to transportation and crushing process.

Matured FFB (S2 and S3) samples were crushed using a double-roll bunch crusher with 600 cm diameter and 1000 cm length, which can accommodate four bunches at one time. The distance between two rollers was 15 cm, and the rotational speed were set at 22 and 32 rpm *(Figure 2a).* A machete was used to cut the crushed bunches into spikelet as shown in *Figure 2b*. The bruising level was determined visually 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.

FFA content in palm oil from every sample was determined based on standard test method where known oil mass is dissolved in neutralised *iso*-propanol and FFA are neutralised with sodium hydroxide (MPOB, 2019).

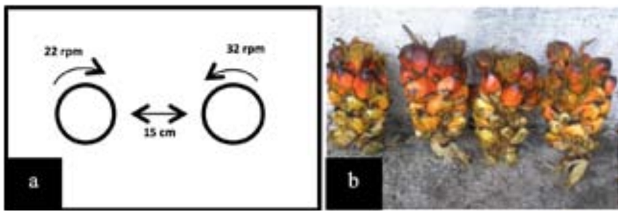


Figure 2. (a) An illustration of a gap and rotation of rollers in the bunch crusher and (b) spikelet of the oil palm bunch after crushed.

EXPERIMENTAL FINDING

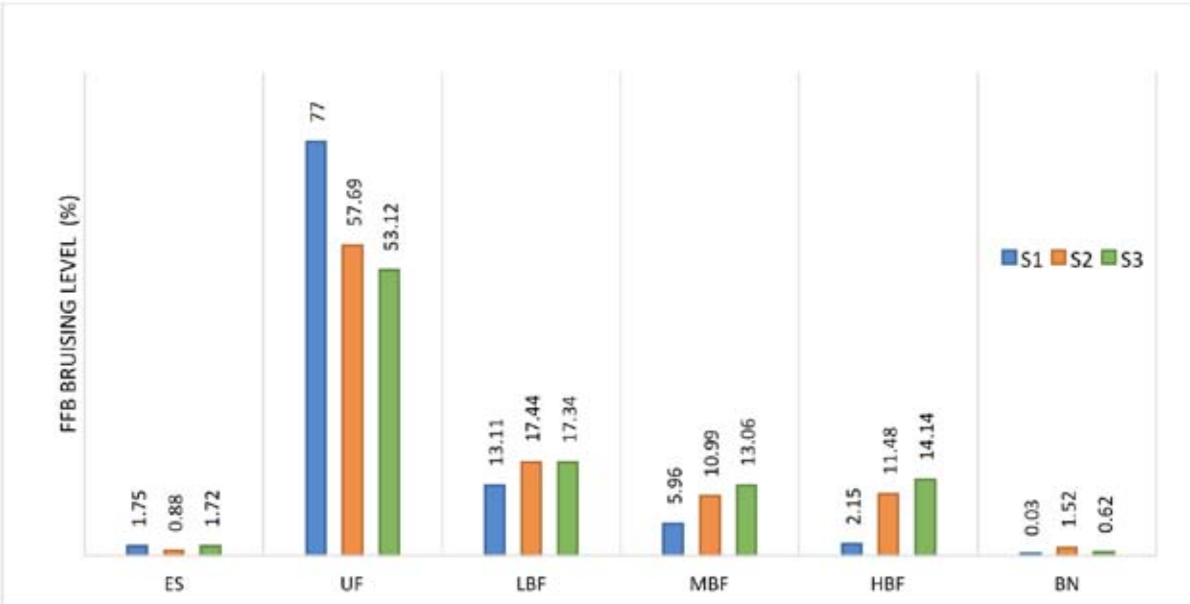
Effect of Crushing on Oil Palm Fruitlets Bruising Level

Observation results showed that the use of bunch crusher increased the oil palm fruitlets bruising level. *Figure 3* depicts the oil palm fruitlets condition before and after crushing.

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 *(Figure 4).*

Figure 3. Samples of matured FFB. (a) before sterilisation, (b) and (c) crushed FFB after sterilisation.

Figure 4. Different bruising levels of oil palm fruitlets.



Notes: S1: Bunches taken from loading ramp (no crushing);
S2: Bunches taken from plantation (crushing);
S3: Bunches taken from loading ramp (crushing);
ES: Empty Socket; UF: Unbruised fruitlets; LBF: Least-bruised fruitlets; MBF: Moderately-bruised fruitlets; HBF: Heavily-bruised fruitlets; BN: Broken nuts.

Figure 5. FFB bruising level.

Figure 5 shows the results of bruising level for S1, S2 and S3 FFB samples.

The percentages of the least-bruised, moderately-bruised and heavily-bruised oil palm fruitlets for the S1 FFB sample were 13.11%, 5.96% and 2.15%, respectively. *Figure 6* shows the bruising of oil palm fruitlets. FFB from the mill receiving ramp averaged at 0.03% broken nuts, and 77.0% unbruised fruitlets.

S1 contained in average 1.75% loose fruits, whereas the number of broken nuts was very low and, in most samples, no broken nuts were observed. This indicated that the current FFB transportation practice caused mild bruising effect to the oil palm fruits and insignificant damage to the palm nuts.

S2 contained in average 0.88% detached fruits, lower than S1 based on the number of empty sockets in each bunch. This signified that proper FFB transportation 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 sample were 17.44%, 10.99%, and 11.48%, respectively. The average percentage of broken nuts was

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

1.52%, while the percentage of unbruised fruitlets was 57.69%. These data showed that the bruising level was high, irrespective of the freshness of the crushed fruits. Nevertheless, the bruising level was higher in uncrushed and aged fruit bunches and could affect the quality of the CPO produced.

The average percentage of the detached fruits for S3 FFB bruising level (empty sockets) was 1.72%. This demonstrated that the use of bunch crusher did not increase the number of empty sockets in each bunch compared to S1 samples. Average percentage of detached fruits in S1 was about 1.75%.

The optimum design parameters of the bunch crusher, such as size of roller and gap between rollers, are crucial to ensure that the bunch can be opened up 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, fruits bruising is 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 for the S3 sample were 17.34%, 13.06% and 14.14%, respectively. The average percentage of the broken nuts was 0.62%, while the average percentage of unbruised fruitlets was 53.12%. 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.

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 bruising level comparison was carried out on samples collected at the loading ramp as it reflected the real condition of the fruit bunches for the CPO production in palm oil mill. *Table 2* shows the bruising level comparison 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 unbruised oil palm fruitlets decreased by 23.88%. This shows that the use of bunch crusher increase the heavily-bruised oil palm fruitlets of more than 10% compared to

TABLE 2. COMPARISON OF BRUISING LEVEL FOR SAMPLES S1 AND S3

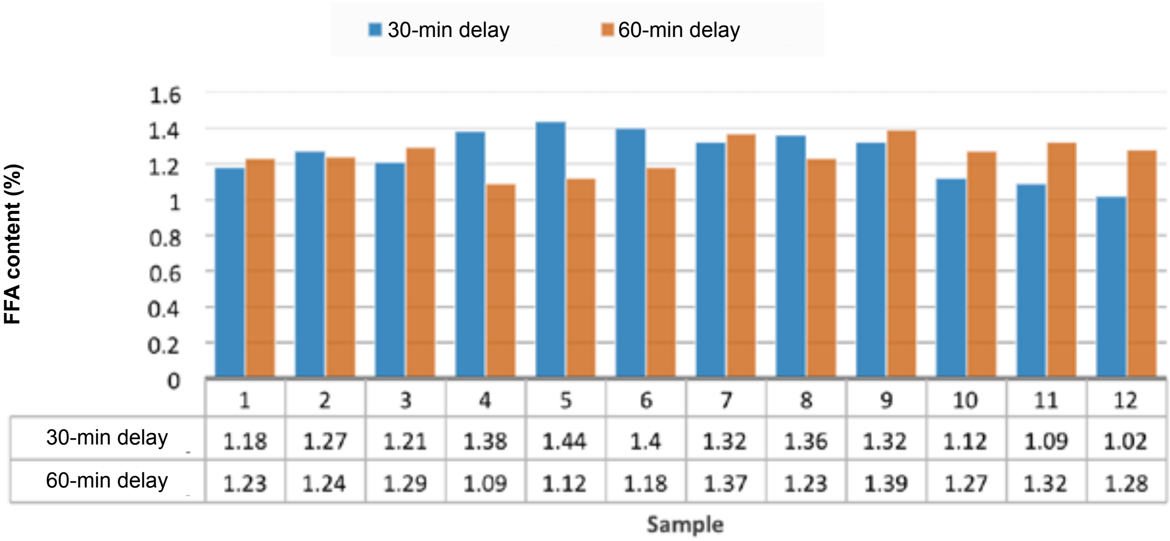
Category	Bruising Level (%)		
	S1 [a]	S3 [a]	Caused by crushing [b]
Unbruised fruitlets	77.00	53.12	(23.88)
Least-bruised	13.11	17.34	4.23
Moderately-bruised	5.96	13.06	7.10
Heavily-bruised	2.15	14.14	11.99

Note: S1: bunches taken from loading ramp (no crushing); S3: bunches taken from loading ramp (followed by crushing)
bS3 compared to S1; value in bracket ( ) means percentage reduction.

the least-bruised and moderately-bruised oil palm fruitlets. (Similar study by other researchers also reported that an increase by 30.74%, from 2.88% to 33.62% bruised level due to crushing).

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 affects the bruising of fruitlets mesocarp fibre, the compressing force affects the cracking of nuts.

Figure 7. Crushed bunches preheating in autoclave.



	1	2	3	4	5	6	7	8	9	10	11	12
30-min delay	1.18	1.27	1.21	1.38	1.44	1.4	1.32	1.36	1.32	1.12	1.09	1.02
60-min delay	1.23	1.24	1.29	1.09	1.12	1.18	1.37	1.23	1.39	1.27	1.32	1.28

Figure 8. Average FFA content in crushed bunches that underwent 5 min preheating, followed by 30 and 60 min delayed in sterilisation.

Preheating Effect in Minimising FFA Production

The crushed bunches were subjected to preheating for 5 min in autoclave as shown in *Figure 7* and delayed for 30-60 min before sterilisation. *Figure 8* shows the FFA content in the oil palm fruitlets that were preheated for 5 min after the oil palm fruit bunches were crushed and then left outside autoclave for 30 and 60 min. These bunches were subsequently sterilised for another 60 min at atmospheric pressure.

The average FFA content in the oil palm fruitlets that were sterilised after 30-min and 60-min 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 lipase activity deactivation. After preheating, the oil palm fruit bunches were sterilised for only over an hour after 60 min delay, but still yielded low FFA content of about 1.36%. The FFB sterilisation at lower pressure of 14 psi compared to 40 psi in conventional practice was possible when the bunch was crushed. The sterilisation duration (60 min) was also shorter compared to conventional practice (about 90 min) due to larger surface area of the crushed bunch.

CONCLUSION

The results of this study showed that the double-roll bunch crusher application was effective in allowing steam penetration into the FFB inner parts. The process of crushing also enables short FFB sterilisation at atmospheric pressure to achieve complete oil palm fruitlets detachment compared to conventional pressurised batch sterilisation process. However, the oil palm fruitlets bruising level increased significantly irrespective of the fruits initial condition.

FFA formation due to the increase in bruising level could be avoided by preheating the crushed bunches for 5 min at atmospheric pressure. This 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 min and 60 min after preheating. These findings suggest that the crushed bunches sterilisation could be delayed for over 60 min after preheating process without significant increase in FFA content.

REFERENCES

Hasimah, K; Azwan, M L and Awang, R (2016). Effect of heat treatments on the yield, quality and storage stability of oil extracted from palm fruits. *Malaysian J. Analytical Science*, *20(6)*: 1373-1381.

Krisdiarto, A W and Sutiarso, L (2016). Study on oil palm fresh fruit bunch bruise in harvesting and transportation to Quality. *Makara J. Technology*, *20(2)*: 67-72.

MPOB (2019). *Palm Oil Mill Laboratory Manual*. MPOB. Bangi.

Noerhidajat; Yunus, R; Zurina, Z A; Syafiie, S; Ramanaidu, V and Rashid, U (2016). Effect of high pressurized sterilization on oil palm fruit digestion operation. *International Food Res. J, 23(1)*: 129-134.

Tan, J C X; Chuah, C H and Cheng, S F (2017). A combined microwave pretreatment/solvent extraction process for the production of oil from palm fruit: optimisation, oil quality and effect of prolonged exposure. *J. Science of Food and Agriculture*, *97(6)*: 1784-1789.