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A NEW SYSTEM FOR CONTINUOUS STERILIZATION OF OIL PALM FRESH FRUIT BUNCHES

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ABSTRACT

A system is proposed for continuous sterilization of oil palm fresh fruit bunches based on crushing bunches to facilitate steam penetration into bunches and subsequently heating the bunches using live steam at atmospheric pressure to an extent sufficient to facilitate stripping of the fruits. An attempt is made to evaluate this system using a pilot-scale set-up.

Keywords: bunch crushing, sterilization, continuous sterilization, continuous processing, mill automation.

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INTRODUCTION

In the conventional milling process, fresh fruit bunches are loaded in cages and pushed into sterilizers where they are cooked for about 70 to 90 min using steam at 40 psig. The process arrests oil quality deterioration due to enzymatic activity. It also facilitates the stripping of fruits from the bunches and the extraction of oil and kernel (Mongana Report, 1955). Operations related to the batch sterilization process absorb much of the process labour in a typical mill. Continuous sterilization has eluded the palm oil industry despite the many attempts made over the past five decades. The need to use steam at high pressure with intermittent pressure releases to achieve good sterilization complicates the problem of achieving continuous processing.

Exploratory studies (Sivasothy and Rohaya, 2000; Sivasothy *et al.*, 2000) on continuous sterilization of oil palm fresh fruit bunches, carried out using a double-roll bunch crusher and a laboratory-scale batch steam autoclave, showed that the extent of nut breakage by the crusher was small and that there was no significant deterioration in the oil quality due to bruising of the fruit mesocarp if the bunches are heated immediately after crushing. The sterilization time and steam pressure required to achieve complete stripping of fruits from the crushed bunches (*Figure 1*) were significantly lower than those normally used for uncrushed bunches.

The main aim of this study was to examine a new concept for continuous sterilization. The study allowed us to gauge the extent to which the results achieved by heating bunches using steam at atmospheric pressure in a laboratory-scale batch autoclave during exploratory studies were reproducible in a pilot plant based on the proposed concept. Since the concept is new, it was essential to demonstrate that it works on a pilot-scale before scaling up to a commercial system.

The pilot plant study also provided insight into the problems associated with integrating the new sterilization process with the rest of the milling process.

PROPOSED SYSTEM

The ability to sterilize bunches using steam at low pressure and without the use of multiple-peak cycles, facilitates the development of a continuous sterilization process. The problem of continuously transferring bunches to and from the sterilizer can now be more easily surmounted. Many different methods were explored, both for transferring bunches to and from the sterilizer, as well as for conveying the bunches through the sterilizer.

Ideally, the method used for conveying should ensure continuous and uninterrupted flow of the product and ensure consistent product retention time with little or no short-circuiting. There should also be little probability of product accumulating inside the sterilizer as this is detrimental to the oil and

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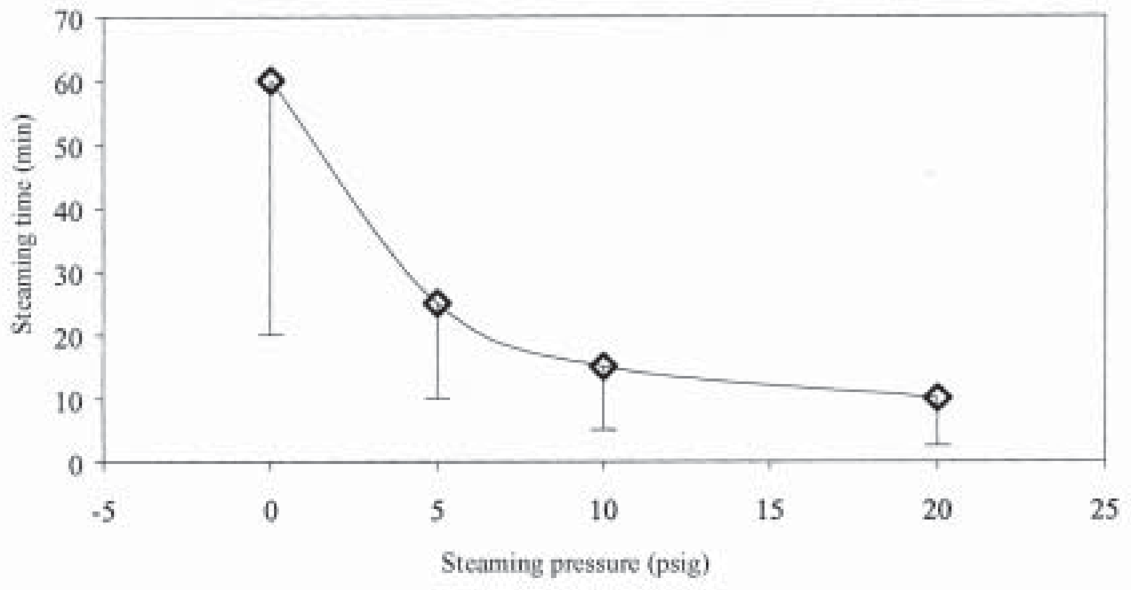

Figure 1. Relationship between steaming pressure and streaming time to achieve complete stripping of bunches.

kernel quality. The bunches should also be conveyed without being subjected to very high forces as the cooking progresses as the application of pressure may lead to oil being easily released from the cooked (softened) fruits and lost with the condensate and empty bunch stalks.

The system should also be designed to minimize steam loss from the feed and discharge openings. This requires both openings to be made as small as possible while allowing continuous and uninterrupted flow of the product through the system.

The system should preferably also be able to cope with fluctuating flow rates and permit changes in the retention time to cope with varying bunch ripeness.

Preferably, the system (both the valve and the continuous sterilizer) should be designed to enable heating the bunches using steam at, or slightly above, atmospheric pressure.

Figure 2 illustrates a proposal for a continuous sterilization system that sufficiently addresses the above considerations.

As in the preliminary studies, disruption of the closed-knit arrangement of the spikelets in the fresh fruit bunches is achieved using a double-roll crusher. This crusher provides many advantages, including minimal nut breakage, simple and compact design, low investment cost, low power consumption, low maintenance and operating cost, and ability to handle all types of bunches. A single crusher should be able to handle a typical palm oil mill's entire throughput.

As shown in *Figure 2*, the bulk of the heating is achieved inside an enclosed vessel called the continuous sterilization chamber. The bunches are heated for about 60 min inside this vessel using live steam while they are conveyed using a double-deck scraper conveyor or some other type of conveyor. By making use of both the forward and return paths of the scraper conveyor for conveying the bunches as shown in *Figure 2*, it is possible to reduce the overall length of the chamber.

The bunches are pre-heated using steam that bleeds from the continuous sterilization chamber. This facilitates heating the bunches immediately after they are crushed to above 60ºC to deactivate the lipolytic enzymes responsible for the formation of free fatty acids. Pre-heating the bunches also facilitates deaeration and minimizes the amount of air entering the continuous sterilization chamber, thereby ensuring that the temperature in the continuous sterilization chamber is close to that of saturated steam. An additional pre-heating step may be used if the delay between crushing and steam heating is enough to cause oil quality deterioration. In this case, the bunches are heated immediately after they are crushed using hot water at above 60ºC.

The bunches are further heated after they leave the continuous sterilization chamber using steam that bleeds from the discharge at the end of the continuous sterilization chamber.

The bunches enter and leave the continuous sterilization chamber through one or more rotary valves, flap valves or gate valves to minimize the steam loss. The base of the feed conveyor can also be filled with water to seal against steam loss. This water bath can be heated to above 60ºC to enable simultaneous deactivation of the lipolytic enzymes.

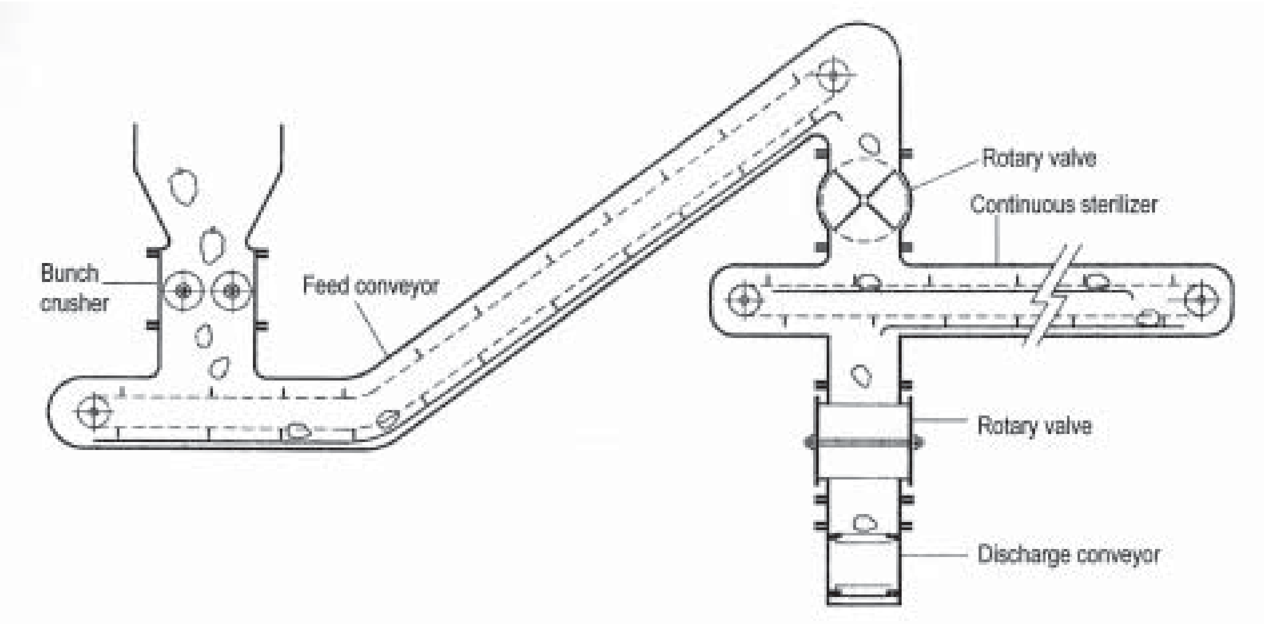

Figure 2. Proposed system for continuous sterilization.

PILOT PLANT

The continuous sterilization pilot plant set-up (*Figures 3* and *4*) was specifically designed for heating using steam at atmospheric pressure. By making use of both the forward and return paths for conveying, it was possible to achieve a total conveyor length of only approximately 20 m.

The crushing was carried out using a double-roll bunch crusher with a fixed clearance of 15 mm between the rollers. The speeds of rotation of the rollers were 22 and 32 rpm.

A steam-sealed inclined scraper conveyor was used for conveying the bunches to the continuous sterilization chamber. A simple double-flap door was used at the entrance of the continuous sterilization chamber to minimize steam loss. The hinged flaps were kept in the normally closed position by counter-weights and opened by the impact of the bunches. This simple steam-locking mechanism was sufficient to accommodate the low throughput of the pilot plant, which was approximately 1.2 to 2.4 t hr^{-1}. The bunches were hand-fed to the crusher one at a time at 30 to 60 s intervals. The steam that escaped through the inlet valve was used to pre-heat the bunches in the feed conveyor.

The crushed bunches were pre-heated for 6 min in the feed conveyor and then a further 56 min in the continuous sterilization chamber.

Steam was introduced at a number of points at both decks. The rate at which steam was introduced was manually adjusted to minimize loss from the entrance and discharge ends. It was observed that the temperature in the continuous sterilization chamber could be quite easily maintained close to 100ºC.

The continuous sterilization chamber was insulated to minimize heat loss and slightly tilted to facilitate condensate discharge.

The bunches leaving the continuous sterilization chamber were held in a hopper and periodically discharged by a hydraulically controlled sliding door.

The cooked bunches were stripped by a typical drum stripper in the mill where this study was carried out.

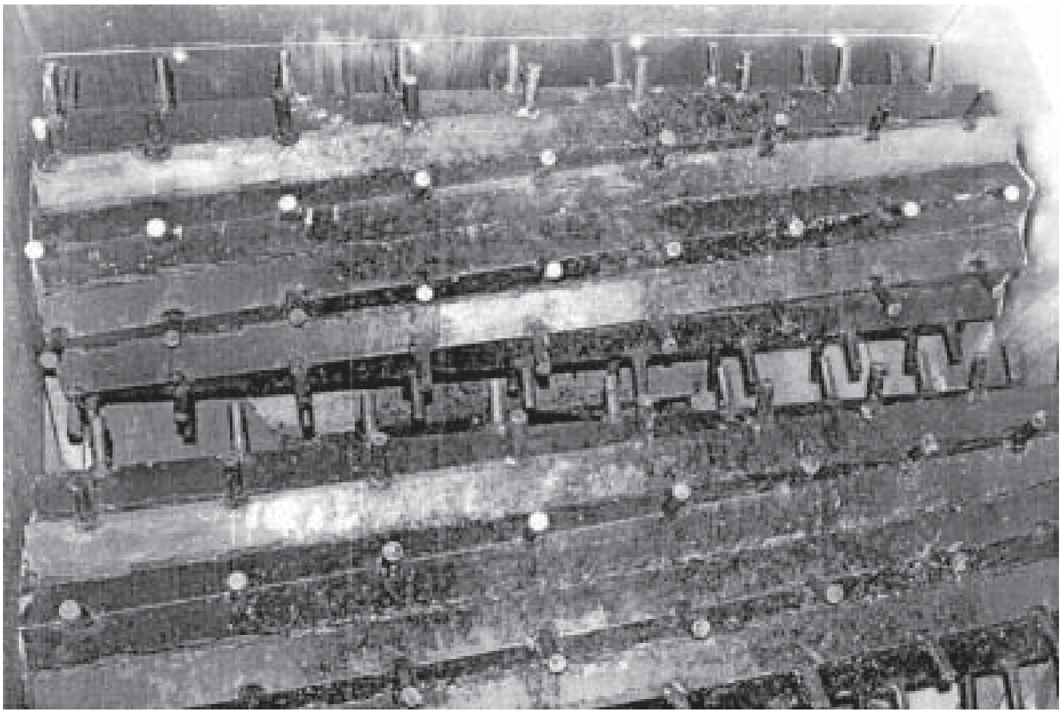

Figure 3. Fresh fruit bunch crusher.

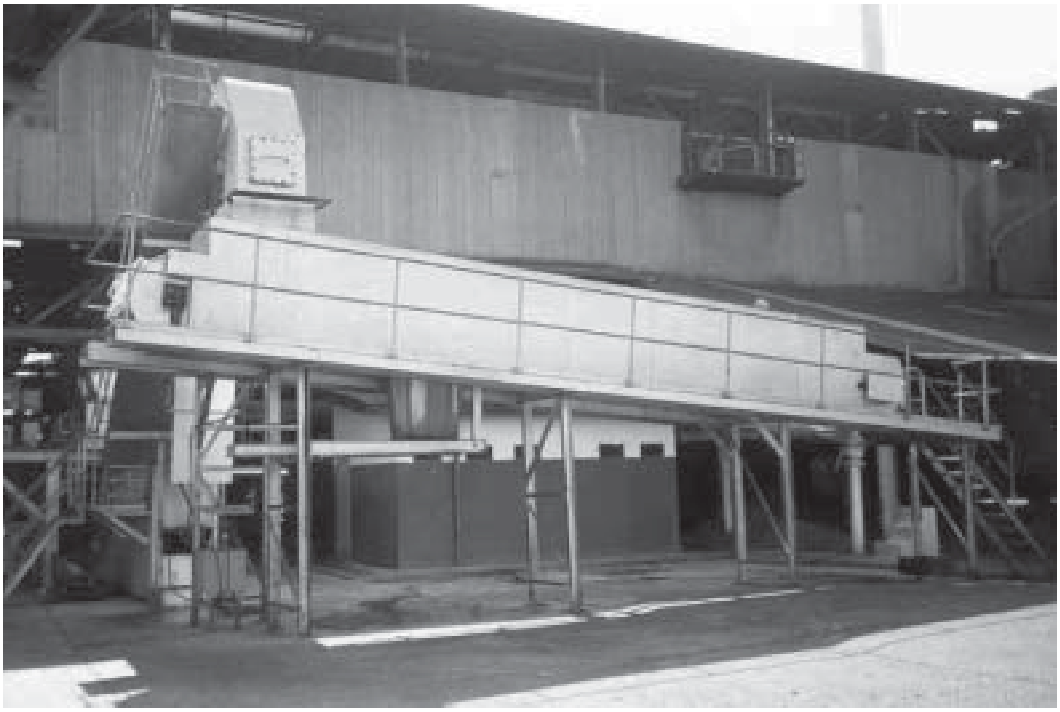

Figure 4. Continuous sterilization pilot plant.

BUNCH STRIPPABILITY

The strippability of bunches achieved by heating using a laboratory-scale batch steam autoclave (Sivasothy *et al.*, 2000) was comparable to that achieved under continuous processing in the pilot plant under similar process conditions. Both the autoclave and pilot plant allowed good contact between steam and bunches. The study provided conclusive evidence that crushed fruit bunches sterilized in a continuous manner using steam at atmospheric pressure for about 1 hr can be stripped using a conventional drum stripper. Only a small percentage (approximately 8.3%) of bunches still had unstripped fruits after passing through the stripper. Even the unstripped bunches had only very few fruits left. There were none of the highly unstripped bunches commonly observed with the batch sterilization process.

Examination of the unstripped bunches showed that many of the fruits could be easily stripped by hand, indicating that the stripping efficiency of the drum stripper was less than 100%. To maximize the stripping effectiveness, it is important that the bunches should have sufficient mass so that the force generated by the impact after their fall in the stripper is sufficient to dislodge the fruits. This may be a problem with small pieces of crushed bunches.

Another factor responsible for the unstripped bunches could be poor crushing effectiveness. Large variations in the effectiveness of opening up of the bunches to facilitate steam penetration during sterilization were observed. Very small bunches were also not effectively opened up by the crusher because the gap between the rollers was too large. This problem can probably be rectified by fine-tuning the crusher operation or by using more than one crushing step (either in series or in parallel).

It was observed that there was a tendency for small pieces of stripped spikelets to pass through the bars in the stripper drum and end up with the fruits and subsequently pass through the digester and screw press. It may be necessary to modify the stripper to prevent this.

ASSESSMENT OF COOKING EFFECTIVENESS

Sterilization is one of the key processes in the palm oil mill. It is believed that heating during batch sterilization results in: (i) deactivation of the oil-splitting enzymes to prevent an increase in free fatty acids (FFA); (ii) loosening of the fruits in the bunch to facilitate stripping; (iii) softening of the fruit pulp to facilitate further treatment of the fruit during digestion and pressing; (iv) heating and partial dehydration of the nuts to enable the nuts to be cracked more readily; (v) coagulation of protein in the oil-bearing cells to prevent formation of colloidal complexes to facilitate the separation/clarification of the oil; and (vi) hydrolysis/decomposition of mucilaginous material to also facilitate the oil clarification process.

Heating crushed bunches for about 60 min using steam at atmospheric pressure appears to be insufficient to achieve all the above objectives of batch sterilization. *Table 1* summarizes the results of a comparative study of the cooking effectiveness of batch and continuous sterilization based on the ease of peeling off of the mesocarp from the nuts. The mesocarp was peeled off by a simple squeezing action using our fingers without applying too much pressure. Although the mesocarp was soft enough to be quite easily peeled off by scraping, for the purpose of this qualitative test, the peeling was achieved without the use of scrapers.

It can be observed from *Table 1* that the mesocarp could not be peeled off from 2.13% of the fruits from batch sterilization. These fruits were mainly from the inner layers of the bunch and had a very thin mesocarp. On the other hand, the mesocarp could not be peeled off from 24.10% of the fruits from continuous sterilization. It can also be observed from *Table 2* that the peeled mesocarp constituted 45.47% of the initial weight of peeled fruits in the case of batch sterilization, whereas it was 37.68% in the case of continuous sterilization. The above test clearly shows that the fruits from continuous sterilization were not as well-cooked as the fruits from batch sterilization.

TABLE 1. ASSESSMENT OF COOKING EFFECTIVENESS

Source	Hard fruits (%)	Peeled mesocarp (%)
Batch sterilization (*i.e.* fruits from mill)	2.13	45.47
Continuous sterilization	24.10	37.68

Exploratory studies were carried out using a laboratory-scale batch autoclave to assess the extent of further heat treatment that will be required to fully cook the fruits to a comparable standard as batch sterilization as gauged by the peeling test. A few kilograms of fruits from continuous sterilization were cooked in an autoclave using steam at atmospheric pressure and at a pressure of 10 psig.

It can be observed from *Tables 2* and *3* that about 60 min of further heating using steam at atmospheric pressure were necessary, whereas 20 to 30 min were sufficient at 10 psig.

TABLE 2. EFFECT OF FURTHER HEATING ON FRUITS USING STEAM AT ATMOSPHERIC PRESSURE

Heating time (min)	Hard fruits (%)	Peeled mesocarp (%)
0	24.10	37.68
20	6.48	39.36
40	2.48	40.81
60	1.04	43.51

TABLE 3. EFFECT OF FURTHER HEATING ON FRUITS USING STEAM AT 10 psig

Heating time (min)	Hard fruits (%)
0	20.61
10	14.85
20	4.32
30	0

FURTHER PROCESSING

Although the fruits from continuous sterilization were not as well cooked as the fruits from the batch process, trials were still conducted on further processing using the conventional milling process. About two to three sterilizer cages of bunches were stripped using a drum stripper, the fruits heated using a conventional digester and the oil extracted using a twin-screw press. It was possible to achieve about 20 to 45 min of continuous processing by the screw press. Samples of the oil and press cake were collected from the same screw press when processing fruits from continuous sterilization as well as fruits from batch sterilization.

The study showed that it was possible to extract oil from fruits by screw pressing in spite of the reduced cooking effectiveness of the continuous sterilization process. The moisture and oil content of the pressed fibre (*Table 4*) were higher than with batch sterilization. Further studies are needed to gauge if the oil loss in fibre can be reduced by changing the operating and design parameters of the screw press.

The generally low FFA content of 2.1% in the oil from continuous sterilization (*Table 5*) shows that there is no significant increase in FFA due to bruising by the crusher. This can be attributed to the short delay between the crushing and heating steps.

TABLE 4. ANALYSIS OF PRESS CAKE

Parameter	Batch sterilization	Continuous sterilization
Percentage fibre	-	49.21
Percentage broken nuts	-	6.17
Percentage whole nuts	-	44.62
F/N ratio	-	1.00
Percentage moisture in fibre	33.18	44.41
Percentage oil in fibre (wet basis)	4.07	4.65
Percentage oil in fibre (dry basis)	6.09	8.49

TABLE 5. EFFECT OF STERILIZATION PROCESS ON OIL QUALITY

Parameter	Batch sterilization	Continuous sterilization
FFA content (%)	2.68	2.10
Peroxide value (meq)	0.30	0.29
DOBI	2.77	3.22
Carotene content (ppm)	598	546
Iron content (ppm)	4.24	6.18

From *Table 5*, the FFA content in the oil from the continuous sterilization was slightly lower than that in the oil from batch sterilization. This could be due to the fact that the bunches used in our continuous sterilization were generally fresher than the bunches processed by the mill. Typically, fresh fruit bunches are stored in hoppers for at least a few hours before they are processed by the mill, whereas the bunches processed by the pilot plant were mainly freshly brought to the mill.

Table 5 shows that although the peroxide value was approximately the same for both processes, the DOBI value of the oil from continuous sterilization was higher by 0.5. This may have been due to reduced oxidation due to the sterilization being carried out at a lower temperature.

The carotene content of the oil from continuous sterilization (*Table 5*) was lower by about 50 ppm. The oil and press cake were lighter coloured in the case of continuous sterilization. There is probably a correlation between the cooking effectiveness and carotene content of the oil. There may also be a correlation between the pressure applied during pressing and the carotene content of the oil. Studies on double pressing (Choo and Yap, 1991) showed that the oil from the second press generally had a higher carotene content than the oil from the first press. It is likely that lower pressure was applied when pressing the fruits from continuous sterilization (reflected in the higher moisture and oil contents of the fibre).

The iron content of oil from continuous sterilization was about 2 ppm higher than that from batch sterilization. The higher iron content may be due to increased contact with the metal surfaces during the conveying. The pilot plant was not operated daily and often left idle for several days. Rust was observed to have formed on the inside surfaces of the conveyors and this could easily have been scraped off by the bunches. Further studies are required to establish if a comparable increase in iron content can be expected in a plant operated commercially.

CONCLUSION

The pilot plant study has demonstrated the technical viability of the proposed continuous sterilization system and provided the information needed for scaling up to commercial-scale and integrating with the rest of the palm oil milling process.

It has also demonstrated the possibility of sterilizing crushed bunches in a continuous manner using steam at atmospheric pressure to an extent sufficient for most of the fruits to be quite easily stripped by a conventional drum stripper. The pilot plant study has also demonstrated that the bunches can be heated using steam at atmospheric pressure without difficulty. Uniform temperature was achieved throughout the continuous sterilizer in spite of the very low pressure. Steam loss from continuous feeding of bunches to the continuous sterilization system was minimized by incorporating a pre-heating section. The effect of bruising by bunch crushing on FFA formation was also observed to be insignificant, especially if the bunches were pre-heated immediately after crushing.

The study has also shown that there should be no major problems integrating the proposed continuous sterilization process with the rest of the milling process in a conventional mill. The focus in this study has been on the processes that immediately follow sterilization, *i.e.* stripping, digestion and pressing. It appears that slight changes in the design of the stripper, digester and probably even the screw press may be needed. The effect of the new process on milling processes further downstream, such as clarification and nut cracking, were, however, not properly evaluated.

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