Feature Article

Process Review: Part 1

N Ravi Menon*

INTRODUCTION

The *Mongana Report* can be called the treasure house of knowledge that has not been challenged by anyone yet. Most of the best milling we practice have principles descended down from the research finding of the *Mongana Report* or the *Stork Review*. This article is an abridged version of the *Mongana Report* plus some input from the *Stork Review*. The readers are urged to read the full report to gain more insight in this interesting topic. If a palm oil mill engineer wants to be an expert in milling, get hold of the *Mongana Report* as well as *Stork Review* and keep reading a number of times if needed to grasp the knowledge that is presented there. In this series of articles, we shall carry out a critical review of the processes. This is particularly needed now especially when the industry is pressurised to go modern. If modernisation is carried out without a good grasp of the fundamentals, money will be wasted on projects that will not work as the fundamentals will be missing. So articles of this nature could help innovation oriented engineers who may unknowingly plunge into expensive ventures that may end up as failures. Process Review is intended to encourage the millers to review, in depth, all our milling processes so that they may stumble upon new ways of processing. For doing that we may have to probe into some pages in history.

* *Malaysian Palm Oil Board, 6, Persiaran Institusi, Bandar Baru Bangi, 43000 Kajang, Selangor, Malaysia. E-mail: nravi@mpob.gov.my*

SPONTANEOUS AUTOCATALYTIC HYDROLYSIS AND ENZYMATIC HYDROLYSIS

In 1952, Loncin declared that the increase in the percentage of free fatty acid (FFA) in palm oil was due to spontaneous autocatalytic hydrolysis and not due to the enzymatic hydrolysis, a view that was held until then. Later it was found that autocatalytic hydrolysis may occur side by side with enzymatic hydrolysis under the following favourable conditions (Storks Review, 1960):

- temperature below 50°C;
- presence of moisture or dirt; and
- infection by certain microbes.

The microorganism known as *oospora pseudomonas flurorescens* and *geotrichum candidum* are capable of splitting fat; the latter being capable of raising the FFA content of palm oil from 6% to 21% in 21 days if the oil contains enough moisture and dirt for the microorganism to multiply.

Note 1

Care should be taken to ensure that fruit and oil storage points are kept clean. Dur-

ing non-processing period, cooled down oil in tanks or pipelines can experience enzymatic hydrolysis resulting in increased acidity.

Note 2

Contamination can also take place in road tankers. Make sure the internals are clean before pumping oil into them.

Note 3

Mixing dirty and high moisture/FFA oil with clean and dry oil with low FFA oil will not only cause a rapid rise of FFA in the mixed oil, the refineries will also not be able to refine this oil. The oil recovered from the sludge should not be added to the despatch oil which is not encouraged by MPOB. If any mill continue with this unruly practice, please discontinue.

Note 4

A moisture content of 0.25% will be sufficient to cause a rise in the FFA of palm oil.

Sterilisation (*Mongana Report*, p. 27)

One basic fact that we have to constantly bear in mind at all times is that we must have *wet heat* to accomplish proper sterilisation of fresh fruit bunch (FFB). So it is not logical to waste time and money to use microwave heating for the sterilisation of bunches. The other reason is that microwaves have short wavelengths that will not permit the heat to penetrate deep into the bunch. In *Mongana Report*, it was mentioned that the best heating suitable for sterilisation is wet steam.

The sterilisation process done by heating the bunches was originated by Fiekendy, Annam and Van Heurn by accident with the initial objective to inhibit the lipase activity in the pulp that caused the hydrolysis of the oil. Very soon they recognised other useful effects of wet or dry steam heating of the bunches. The application of this heat was found to increase greatly the settling ability of the crude oil. This gave birth to the still ongoing steam sterilisation system.

The following findings by Mongana researchers will be very useful for the millers to remember when considering the development of new ways of sterilisation.

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In the early days, heat was applied as steam at atmospheric pressure, dry heat or hot water and later steam under pressure became popular as the sterilisation cycle could be made shorter especially when the crop started being processed as bunches instead of loose fruits. With the advent of pressurised steam sterilisation becoming popular for processing bunches, other phenomena were observed.

Heat not only affected the lipase activity and the ability for the oil to settle but also the efficiency of the oil recovered from the digested mash, the recovery of the oil from the solids present in the crude oil, nut breakage in continuous presses, the nut cracking efficiency, the oil bleach ability and other characteristics. The objective of sterilisation broadened considerably so that it may be said that sterilisation is the precursor of all the subsequent processing operations.

THE EFFECTS OF DRY AND WET HEATS

When dry heat in the form of hot air was used the desiccation of a ripe bunch failed to induce the loosening of fruits even when kept in a furnace at 100°C for 128 hr. They became brittle but did not shed fruits. An increase in temperature did not improve the fruit detachment but had an impact on the colour of the fruit. After 3 to 4 hr, the dark red colour changed uniformly to brown. A slowing down of the natural fruit abscission was noted in bunches stored in dry air at 50°C to 60°C.

The prolonged storage of fruit bunches under water at high temperature has the property to split the fruit connection to the

bunch, a property that was made use of in the continuous sterilisation trials done at Mongana (*Mongana Report*, p. 33).

Quarter bunches and spikelet stored at temperatures between 3°C and -10°C remained firmly attached to the bunch, while the control bunches kept at an ambient temperature of 28°C stripped completely after 24 hr. Also samples lightly sterilised for 1 hr in water at 45°C - 50°C did not strip at all after 24 hr but stripped completely after five days, whilst the fruits of unsterilised bunches kept at a low temperature during the same period did not detach themselves from the bunch.

This indicates that the natural process of fruit abscission is of enzymatic origin and its intensity decreases as the temperature departs from the ambient levels. It practically comes to a standstill at 100°C and 0°C (*Mongana Report*, p. 34).

The spikes immersed in hot water at different temperatures and at different durations indicated that for a bunch soaked in hot water at 90°C stripped completely in 90 min, whereas at 100°C and 110°C, they stripped fully in 50 min and 20 min, respectively. It was found that the addition of surfactants like caustic soda or alkyl-aryl sulphonate at 0.5% concentration levels could accelerate the stripping process significantly. This is something interesting that the industry do not seem to have pursued further. There is provision here for further research into the impact of surfactants in stripping.

The stripping of fruits from the spikes did not seem to involve difficulties since it only required heating up the connecting tissues to 110°C for approximately 20 min and at 100°C complete stripping was achieved in 45 min. The same was possible by using steam at atmospheric pressure (*Mongana Report*, p. 35).

The artificial abscission process is found to be directly governed by the temperature and following the law: $\log t = K (T-T1)$ (*Mongana Report*, p. 36). *Table 1* shows the relationship between the time and the temperature. Where, *t* is the time of sterilisation in minutes, T_1 temperature of sterilisation and T a temperature approximately equal to 140°C and the constant K = 0.04.

If the same technique is applied to bunches instead of the spikes, the percentage of stripping was found to be extremely low. The soaking of spikes in water at 100°C for 1 hr ensures rupture of all insertion points but if the same conditions are applied to bunches the result is very high percent of hard bunches. The study of heat transfer into the bunch indicates that the theoretical conductivity is extremely low.

For instance, the core of a 15 kg bunch kept in an oven at 100°C reach a temperature of 48°C only after a dwelling time of 6 hr (*Mongana Report*, p. 37). If the temperature is 140°C corresponding to the saturation temperature of steam at about 2.6 bar (38 psig), the core of an identical bunch reaches a temperature of only 51°C after the same period of 6 hr. The low thermal conductivity is inherent in the very nature of the bunches and in the air occluded in them (*Mongana Report*, p. 39). The thermal conductivity of air is about 10 times lower than that of oil and 30 times lower than water. Therefore, it is important to remove as much air as possible during sterilisation and this can be

TABLE 1. THE TIME *vs.* TEMPERATURE TO ACHIEVE 100% STRIPPING

Temperature (°C)	80	90	100	110	120	130	140
Time (min)	250	100	40	16	8	2	1

done by one of the following: extraction, diffusion or displacement but in actual practice the last one is found to be the most practical one.

The air extraction method consists in applying a vacuum either before sterilisation proper or after the heating of bunches. But this was found to be very time-consuming and moreover the steriliser is designed as a pressure vessel rather than a vacuum chamber and this poses some problems related to safety.

In the case of a small vertical steriliser of 1 t capacity (*Mongana Report*, p. 43), the theoretical time of diffusion is about 10 hr but in a horizontal 7.5 t steriliser, which provides a larger surface of contact the diffusion time is shortened to about 3 hr. The straight diffusion technique cannot be applied to mix steam to a large volume of air in a steriliser with a view to expel them through the pressure release valves.

The displacement of air under the effect of steam may be complete in a vessel of large dimensions (*Mongana Report*, p. 47). Steam is admitted slowly at the top of a horizontal steriliser and the air swept away from the steriliser. It is actually possible to observe in a horizontal steriliser the door of which is open that the steam remains at the top and shows no tendency to mix with air due to the marked density difference between the steam and air: 0.598 g dm^{-3} for dry saturated steam at 100°C against 1.043 g dm^{-3} for wet saturated air at 50°C. The compositions of the air/steam mixture determined simultaneously at various points of the steriliser after a short time of sweeping are found to be as follows: 0.1 litre of air/kg of steam at the top, 10.1 litres of air/kg of steam in the middle and more than 200 litres of air/kg of steam at the bottom.

In a steriliser full of bunches, the expelling of air by steam sweeping is slower and less complete (*Mongana Report*, p. 49). It is practically necessary to maintain a continuous bleed off of steam owing to the fact that the de-aeration of the bunches proceeds slowly and progressively. In order to study the impact of de-aeration, three trials were conducted on a homogeneous batch of bunches: (a) the steriliser was swept for 10 min and the bunches sterilised for 40 min at 3 bar steam pressure with continuous bleeding of 200 kg steam per hour, (b) no sweeping or continuous bleeding or condensate discharge carried out and sterilised the same way, and (c) triple peak sterilisation carried out with neither sweeping nor steam bleeding.

The results were as follows (*Mongana Report*, p. 49) in (a) the bunches were completely stripped. In (b) 43% completely unstripped bunches and 20% partly stripped bunches. In (c) 4% completely un-stripped and 28% partially stripped bunches. The Mongana researchers summed up their observations which should serve the mill engineers as a very good benchmark before they venture into any modifications of their sterilisation system (*Mongana Report*, p. 50-51).

- A 10 min air sweeping with steam at the rate of 100 kg hr^{-1} expels 80% to 90% of the air from the steriliser.
- After the steam sweeping the air content of the steam is limited to 0.2 litre kg^{-1} of steam.
- During the first pressure build up and during the pressure release, some de-aeration takes place as a result of the condensate discharge that expels 9% to 18% of the total air.
- During the second and third pressure build up, 1% to 5% of the air will still find its way out provided the preliminary sweeping was effectively done.
- If, after the pressure release, the pressure is maintained at the atmospheric level, the de-aeration increases slightly during that period and after a period of 5 min to 15 min, the steam condensates through cooling causing some external air to be sucked in.

see page 31

from page 24

- It is not possible to assess the efficiency of air removal without carrying out at least a semi-quantitative determination of the air content of the steam. This is an important point to remember. The assessment is done by drawing out a certain amount of steam, weighed and condensed. Simultaneously the air is also measured.
- The de-aeration of bunches takes place only after they have been heated up for some time at high temperature. It is useless to try and improve the de-aeration by prolonging the steam sweeping of air at atmospheric pressure.
- It is essential that there is a continuous discharge of air laden steam during the whole sterilisation cycle.
- For complete displacement of air, the steam must be admitted slowly into the sterilisers.

THE EFFECT OF TEMPERATURE

The efficiency of stripping depends not only on the time reached during a sterilisation cycle but also the duration the temperature was maintained (*Mongana Report,* p. 52). In practice, it was observed that with an adequate sterilisation regime it takes an hour for the bunch core to reach a temperature of 130°C to 135°C. For satisfactory conditions of heat penetration after efficient de-aeration, the time during which the temperature is maintained above 100°C should not be less than 35 min even when the temperature attained is 130°C.

It is possible for the steam temperature to exceed the saturation temperature of the incoming steam due to the effect of wire drawing that superheats the steam. When saturated steam at a pressure of 5 - 6 bar is throttled to 4 bar, the steam will tend to superheat and the temperature may rise to 148°C to 150°C instead of remaining at the saturation temperature of 143.6°C.

THE EFFECT OF PRESSURE

The rate of heat penetration into a bunch is proportional to the temperature difference between the steam and the bunch and not the pressure (*Mongana Report,* p. 52) and as such a higher steam pressure will not be able to shorten the sterilisation cycle as for example the temperature difference of steam between steam at 3 bar and 4 bar is (151.8 - 143.6 = 8.2°C) not significant enough to cause a dramatic improvement in sterilisation efficiency. In addition, the disadvantage in the indiscriminate increase of steam temperature is the reduction in the deterioration of bleachability index (DOBI) value of crude palm oil (CPO). A decrease in the sterilisation pressure must be compensated by an increase in the time of sterilisation. If the sterilisation time needed is 25 min at 3 bar and if the pressure is reduced to 1.5 bar, the sterilisation time must be extended by 30 min making the total sterilisation time 55 min to achieve the same stripping efficiency as with the higher pressure.

SWEEPING OPERATION

Since the density of steam is lower than that of air (*Mongana Report,* p. 54), the steam required for the displacement of air must be admitted into the steriliser from the top to the bottom. Also the sweeping must be effected without creating eddies in the steriliser as that would impair the complete evacuation of the air and/or would increase the steam consumption.

Theoretically, the ideal shape for de-aeration by displacement is the vertical cylinder and in practice vertical sterilisers closely conform to that shape and can effect good de-aeration provided that the steam is admitted at a relatively low rate into the dome. In a horizontal steriliser fitted with only one steam inlet, the de-aeration takes longer time and also not complete. But with multiple steam inlet points, the performance can be brought to the same level as the vertical units.

Whatever the cycle, long or short, single or multiple peak, it is always an advantage to ensure the evacuation of most of the air by sweeping it from the top to the bottom by the incoming steam (*Mongana Report*, p. 54).

The first pressure release may be of relatively short duration of 3 min to 4 min during which the air is swept out of the steriliser by the steam but the intermediate pressure releases are performed after diffusion of steam into air. It is therefore necessary to allow diffusion to take place and to avoid blowing down after an extremely fast pressure build up as diffusion requires certain time to be effective.

EFFECT ON OIL EXTRACTION

As a result of the ageing of the fruit, the oil bearing cells appear to acquire a special permeability, which leads to unimpeded oil flow (*Mongana Report*, p. 62). The permeability eventuates at any temperature of sterilisation, but in addition, high temperature induces the breaking up of the cells. The result is that upon digesting aged fruit sterilised at a temperature lower than 100°C a large flow of almost pure oil, so called 'virgin oil', will be observed. At a temperature higher than 100°C and for a longer time of sterilisation, cells or cell debris will find their way into the crude oil during digestion. The weakening of the intercellular cement which causes the breaking up of the cells may be due to liquefaction, solubilisation, hydrolysis, *etc.* It increases the intensity as the temperature rises but remains negligible as long the temperature does not exceed 98°C and is not maintained for more than 20 min.

It was observed that the sterilisation process done under pressure leads to a higher loss of oil on nuts in addition to increased oil losses in the fibre than when done at atmospheric pressure (during centrifugal extraction). Sterilisation done under pressure indicated a sharp increase in dehydration when compared to sterilisation at atmospheric pressure (30%). This moisture loss during sterilisation under pressure is equally distributed in fruits, spikes and the stalk.

Life steam at atmospheric pressure (*Mongana Report*, p. 68-69) does not seem to have a marked effect on the moisture content of the fruit bunches. The desiccation occurs abruptly when the steam is blown off and during sterilisation. Exposure of the fruit to air after the blow off also contributes to the loss of moisture. The quantity of moisture evaporated is closely related to the temperature. The volume removed has a limit called the limit of desiccation (approximately 20% moisture) after which no more moisture can be evaporated even by repeated sterilisation. This contradicts some elementary principles as when the steam pressure is reduced abruptly like during blow off the bunches are expected to shed a portion of its moisture.

The assumption is that the bunches reabsorb from the steam the moisture it lost during the blow off or during the pressure build up to restore the equilibrium. This point is important as it is customarily acknowledged that the oil extraction, especially by the press, is affected by the degree of de-hydration of the fruit even though on industrial scale this could not be confirmed.

In general, the heat penetration was found to be directly linked to the efficiency of oil extraction up to a certain limit beyond which an equilibrium is established between the capillary forces retaining the oil and the applied mechanical forces to extract it. The heat penetration acts on the tissues connecting the fruit to the stalk and also has a marked effect on oil extraction efficiency.

Stripping and oil extraction efficiency are closely related. If the stripping efficiency is low the oil extraction efficiency is also likely to be low and double stripping does

not address the real problem other than recovering the fruits lost in un-stripped bunches. This indicates that when stripping is not efficient, sterilisation is the culprit. Rectify this and all other problems will be addressed.

Multiple pressure build ups and releases have a detrimental (*Mongana Report*, p. 71) effect if it entails a drop in the average temperature in the steriliser or in the fruit. This happens when the repeated pressure releases reduce the time of contact between the steam and the bunches despite a continuous increase in steriliser temperature in the initial stages. Then temperature profile for a sterilisation cycle with seven blow downs after the 20 min to the 40 min gets through a plateau and the contact heating time (21 min at above 100°C) will be significantly less than that recorded (28 min) for a cycle without any blow down at all. With one blow down, the contact time was 40 min.

IMPACT ON NUTS

There is no doubt about the fact that a freshly de-pulped nut cracks under the effect of a blow and as the shell and the kernel are bound together in the fresh nut, the cracking of the shell necessarily means the cracking of the kernel as well. The nut cracker machinery designers should always remember this basic principle when they design nut crackers. The desiccation of nuts separates the shell from the kernel. It is generally believed that the cracking can be efficient only on nuts with a moisture content of 7.5% on nuts and 12% on kernel. However, if the fruits are well cooked using triple peak sterilisation, wet nuts with 15% moisture in nut and 20% moisture in kernel also can be cracked with 98% cracking efficiency. The cracking efficiency depends a great deal on de-aeration as can be seen in *Table 2* (*Mongana Report*, p. 73).

The two results indicate that the de-aeration process reduces the percentages of un-cracked nuts significantly. The de-aeration and steam bleed off technique affect not only the proportion of un-cracked nuts but also that of broken kernels.

NUT BREAKAGE

Nut breakage (*Mongana Report*, p. 75) is considerably reduced by pressing the fruit at a temperature close to 100°C. But if the bunches are sterilised at atmospheric pressure and then heated up to 100°C during pressing nut breakage is more pronounced than when it is subjected to triple peak sterilisation and heated to 100°C during pressing. This is due to the shrinkage of the kernel caused by the penetration of heat into the core of the kernel that also allows the shell to undergo greater deformation.

TABLE 2. THE EFFECT OF DIFFERENT STERILISATION REGIMES ON NUT CRACKING EFFICIENCIES

	With de-aeration (%)	Without de-aeration (%)
Blow down > 30 s		
Cracked nuts	98.2	56.2
Split nuts	0	16.5
Without blow down		
Cracked nuts	89.0	37.9
Slit nuts	0.7	4.4

Wet kernel does not appear to offer great resistance to pressure and torsion. They certainly do not resist the kind of pressure that may be applied to the nuts without breakage. This may be explained as follows. Fruits sterilised with live steam at atmospheric steam is heated up and pressed hot. After a period of rest the nuts are cracked. In that case, nuts with no apparent damage yield broken kernels, the appearance of which indicates that the kernel splitting occurred before the cracking operation. The kernel still sticking to the shell was therefore crushed open although the more elastic shell resisted cracking perfectly. Adequate sterilisation therefore free the kernel from the shell and allows a more important deformation of the latter without the risk of kernel crushing.

REFERENCES

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