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DETERMINATION OF OPTIMUM STERILIZATION CONDITION BASED ON CALCULATED HEAT TRANSFER RATE FOR PALM OIL MILL PROCESS

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ABSTRACT

The study of temperature distribution inside sterilizer cage was conducted previously in order to improve the heat transfer efficiency during sterilization process based on calculated heat transfer rate at various locations inside sterilizer cage. In this study, further research was conducted based on laboratory experiment to investigate the optimum condition to achieve satisfactory sterilization based on the temperature profile inside FFB and the percentage of total loose fruit per total fruitlet. The experiment was conducted at different sterilization time of 40, 50, 60 to 70 minutes excluding 5 mins de-aeration period. The result suggests that the optimum heat transfer towards FFB were determined to be248kJ/kg at estimated sterilization time of 60 minutes, which corresponds to 90% of total fruitlet stripped per total fruitlet in one bunch. The result obtained was used to determine the minimum sterilization time required inside the mill sterilizer cage for satisfactory sterilization condition based on the optimum heat transfer rate obtained in this study.

Keywords: temperature distribution, optimum condition, stripped, sterilization time, excess steam consumption.

1. INTRODUCTION

In any stage during sterilization, it is essential to ensure a sufficient heat penetration from the steam towards the fresh fruit bunches for good sterilization. Previously, it is mentioned that USB and oil loss are used as an indicator for sterilization efficiency. This, however, serves as a feedback indicator as the results are known much later after sterilization takes place (N Ravi Menon). It is more accurate and logical to define sterilization efficiency based on heat transfer between steam and fresh fruit bunches. By doing so, process optimization can be made possible through determination of heat transfer rate for each individual fruit bunches.

Studies to investigate the penetration of heat into the fresh fruit bunches was done by inserting a thermocouple against or into the bunch rachis and by applying steam pressure. The results suggest the heat penetration depends on the size of the bunch, amount of occluded air and also pressure or temperature of steam provided (Mongana Report, 1955). The fresh fruit bunch (FFB) must be allowed time to heat through thoroughly and become "cooked". With satisfactory sterilizing the temperature reached in the center of the stalk will be found to be at least 100°C and the time required to reach 100°C will depend on the weight of the individual bunches. It would be about 25 to 30 minutes for small bunch (3 to 6 kg) and about 50 minutes for bunches of 17 kg under normal operating conditions (Palm Oil Factory Process Handbook Part 1, PORIM, 1985).

The experimental result from Mongana Report suggests that the efficiency of stripping depends not only on the temperature reached during a sterilization cycle but also the duration the temperature was maintained. For satisfactory conditions of heat penetration after de-aeration, the time during which the temperature at bunch core is maintained above 100°C should not be less than 35 minutes even when the temperature attained is 130°C (Mongana Report, First Volume, 1955).

An experimental work involving sterilizer was conducted previously at Sime Darby East Oil Mill, Klang to investigate the temperature distribution and to determine the heat transfer efficiency towards FFB at various locations inside sterilizer cage (Arif bin Ab Hadi *et al*. 2015). This was done by using a set of temperature sensors located at various depths inside the sterilizer cage. The temperature reading from sensors represents the heating steam temperature inside the cage at various locations. A heat transfer spreadsheet modeling which was developed based on previous modeling work by Chan SY for temperature profile inside FFB (Chan SY, 1985) and was used to determine the temperature profile inside FFB and the heat transfer rate per unit kg FFB, Q (kJ/kg) towardsFFB were calculated based on the temperature profile obtained (Arif bin Ab Hadi *et al*. 2015).

However, the optimum condition of satisfactory sterilization inside the cage involving the temperature reached and the duration maintained as per reported in Mongana Report were not determined in the experiment. Furthermore, the mill indicator based on USB data which is based on average bunch data cannot be used to determine the optimum condition inside the cage as the condition for FFB located at different locations can be different. A more suitable indicator would be based on the percentage of total loose fruit per total fruit let per bunch, of which is impractical method to be used by the mill. Hence, it is crucial to determine the optimum condition experimentally in the laboratory in order to determine the optimum condition inside sterilizer cage during at the mill.

2. MATERIALS AND METHODS

In this study, further investigation was conducted to determine the optimum condition for satisfactory

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sterilization condition towards fresh fruit bunch based on the calculated heat transfer rate per unit kg FFB. The experiment was conducted at different sterilization time of 40 minutes, 50 minutes, 60 minutes and 70 minutes. The experiment consists of 5 trials for each sterilization period, with one bunch with average weight of 17kg per trial. The main indicator used to indicate the optimum condition was the temperature profile inside FFB and the percentage of total loose fruit per total fruit let for one fresh fruit bunch.

A laboratory scale experimental setup was conducted using a mini sterilizer from R and D Sime Darby Research Center, Klang. Figure-1 shows the mini sterilizer from both front and side views. The mini sterilizer operates at pressure of 2.6 bar g and saturation steam temperature at 140°C. The capacity of this mini sterilizer can only fit at the most 5-6 average size FFB during sterilization.

Figure-1. R & D Sime Darby laboratory mini sterilizer from front and side view.

During boiler start-up process, the steam inlet valve is closed. Once the pressure of boiler reaches the required value, the steam inlet valve is opened to allow steam to enter the sterilizer. The steam outlet valve is opened at both ends during boiler start-up process and de-aeration to allow steam purging. During pressure build up and cooking period, the outlet valve at right side (no bypass valve) is closed while the outlet valve at left side (with bypass valve) is opened to contain steam and opened again during exhaust. The function of the bypass valve which is to allow condensate purging during sterilization process hence is opened during the whole process. Figure-2 shows the schematic diagram of process flow for mini sterilizer for clarity.

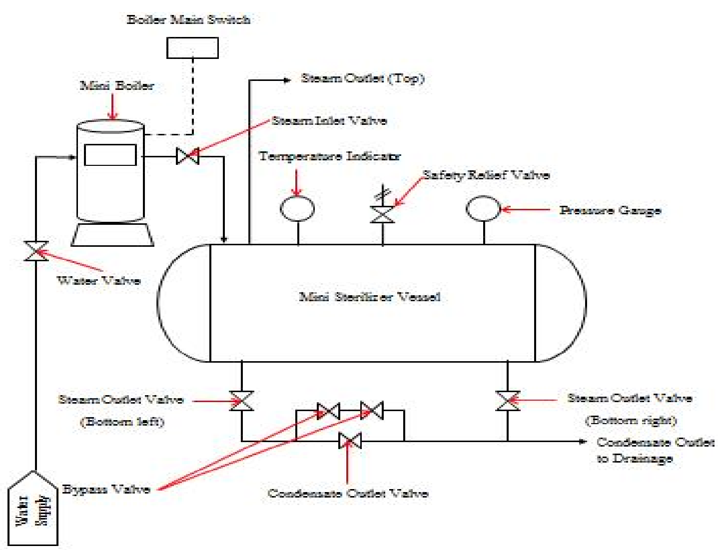

Figure-2. Schematic diagram of process flow for mini sterilizer.

The FFB sample is taken directly from the loading ramp of East Oil Mill as a sample for mini sterilization process. Note that the FFB samples were ripe in nature and taken at desirable weight at the loading ramp about 1 hour before being loaded into the mini sterilizer. The safety procedure for operating the mini sterilizer was

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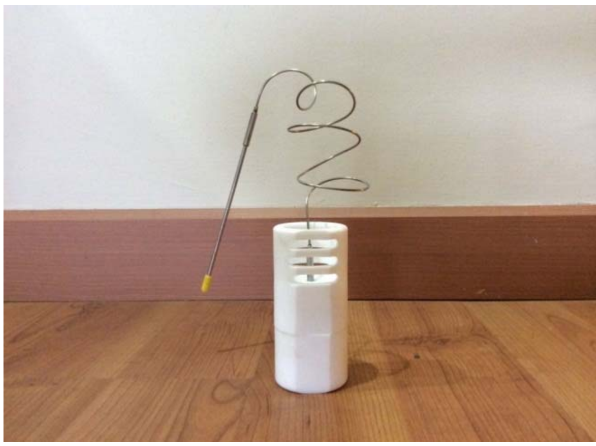
carefully being conducted which includes the insertion of tray containing FFB, the opening and closing of sterilizer door, de-aeration, start-up and shutdown of the boiler, handling the steam inlet and exhaust before, during holding period and steam blowdown. The pressure was allowed to reach 2.5 bar g at saturation temperature of 140°C and cooked based on the desired sterilization time.

The tray which contains the fresh fruit bunch is being taken out from the sterilizer and dropped to the floor from about 1 meter height from the ground few times manual with hands until no more loose fruit is detached from the bunch stalk. The total number of loose fruits which is detached from the bunch stalk was counted and total percentage of loose fruit of fresh fruit bunch is calculated accordingly. The experiment was repeated for 5 trials for each sterilization period, with one bunch per trial.



(a)

(b)

Figure-3. (a) Omega high temperature data logger sensor with thermal shield (b) Omega OM-CP-IFC400 software, USB cable and docking station

Figure-3(a) and Figure-3(b) shows the high temperature data logger (OM-CP-HITEMP140-PT) from Omega Engineering used to obtain the temperature profile inside the mini sterilizer. The OM-CP-HITEMP140-PT is submersible and can operate up to 140°C with an accuracy of ±0.1°C. This device features a 559mm flexible stainless steel probe and 121mm probe tip. The device comes with a thermal shield (optional during purchase) making it able to withstand up to 250°C. Using this device, the temperature profile inside sterilizer during sterilization process can be obtained for each trial.

3. RESULTS AND DISCUSSIONS

The experimental data obtained in this experiment based on sterilization time were used to determine the optimum sterilization condition for satisfactory sterilization process. The total number of loose fruits which is detached from the bunch stalk after sterilization process and the percentage of total loose fruit per the estimated total fruit let for one bunch were determined accordingly. The average FFB weight used around 17kg, with one bunch per sterilization. The experiment consists of 5 trials, one bunch per trial at sterilization time of 40, 50, 60 and 70 minutes. The results for loose fruit count were tabulated as per Table-1, Table-2, Table-3 and Table-4, respectively.

Table-1. Percentage of loose fruit per total fruit let per bunch (Sterilization time = 40 minutes).

	FFB weight (kg)	**Estimated no of loose fruits**	**Estimated no of total fruit lets**	**% of loose fruit per total fruit let**
1^{st} trial	17	440	730	60.27
2^{nd} trial	17	450	760	59.21
3^{rd} trial	16	400	680	58.82
4^{th} trial	16	440	690	63.77
5^{th} trial	18	510	820	62.20
Average	16.8	448	736	60.85

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Table-2. Percentage of loose fruit per total fruit let per bunch (Sterilization time = 50 minutes).

	FFB weight (kg)	**Estimated no of loose fruits**	**Estimated no of total fruit lets**	**% of loose fruit per total fruit let**
1st trial	17	610	740	82.43
2nd trial	17	550	740	74.32
3rd trial	17	640	750	85.33
4th trial	16	540	700	77.14
5th trial	18	650	820	79.27
Average	17	598	750	79.70

Table-3. Percentage of loose fruit per total fruit let per bunch (Sterilization time = 60 minutes).

	FFB Weight (kg)	**Estimated no of loose fruits**	**Estimated no of total fruit lets**	**% of loose fruit per total fruit let**
1st trial	18	640	810	79.01
2nd trial	17	650	730	89.04
3rd trial	18	740	780	94.87
4th trial	16	660	690	95.65
5th trial	17	650	730	89.04
Average	17.2	668	748	89.52

Table-4. Percentage of loose fruit per total fruit let per bunch (Sterilization time = 70 minutes).

	FFB weight (kg)	**Estimated no of loose fruits**	**Estimated no of total fruit lets**	**% of loose fruit per total fruit let**
1st trial	17	760	760	100.00
2nd trial	17	750	750	100.00
3rd trial	16	680	680	100.00
4th trial	16	700	700	100.00
5th trial	18	790	790	100.00
Average	16.8	736	736	100.00

Based on Figure-4, the result suggests that total stripping of loose fruits from the stalk after sterilizing and manual hand threshing procedure from the bunch occurs at sterilization time 70 minutes, whereas at 60 minutes the percentage of loose fruits obtained is close to 90%, followed by 80% at 50 minutes, and finally the least amount of total loose fruit detached around 60% at 40 minutes. The estimated percentage detached loose fruit obtained at 60 minutes which is 90% is considered to be adequate as the minimum amount of loose fruit remaining in the bunch to be considered as empty bunch is 10% (MPOB FFB Grading Manual, 2003).

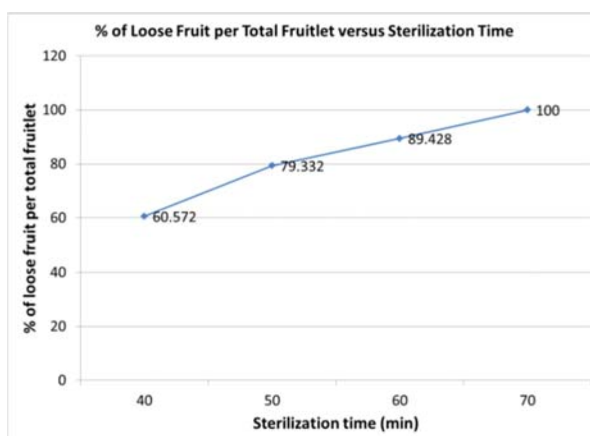

Figure-4. Percentage of loose fruit per total fruit let at different sterilization time (40-70 minutes).

To validate the results, the percentage loose fruits data in this experiment was compared with the findings from Mongana Report. Based on Mongana report, it is found that the time during which the temperature at bunch core is maintained above 100°C should not be less than 35 minutes even when the temperature attained is 130°C for satisfactory sterilization condition. Hence, the temperature profile for the heating steam in this experiment were recorded and based on the spreadsheet model, temperature profile at the FFB center were determined accordingly. The temperature profile for both heating steam and FFB core temperature based on the model obtained at different sterilization time was shown as per Figure-5(a) and Figure-5(b), respectively.

Table-5 shows the time taken at which the temperature of bunch core reached and maintains above 100°C. Based on these result, it is shown that the sterilization period at which the temperature at bunch core is maintained above 100°C for at least 35 minutes is around 60 minutes, at which the sterilization is considered adequate. The Mongana report findings which states that a more accurate representation of adequacy of sterilization condition would be the heat transfer rate towards the FFB calculated based on temperature profile as a certain temperature is reached and maintained for a certain period indicates the minimum amount of heat transferred toward the bunch. Thus, the estimated value of heat transferred, Q per unit FFB at different sterilization period were determined accordingly and tabulated as per Table-5.

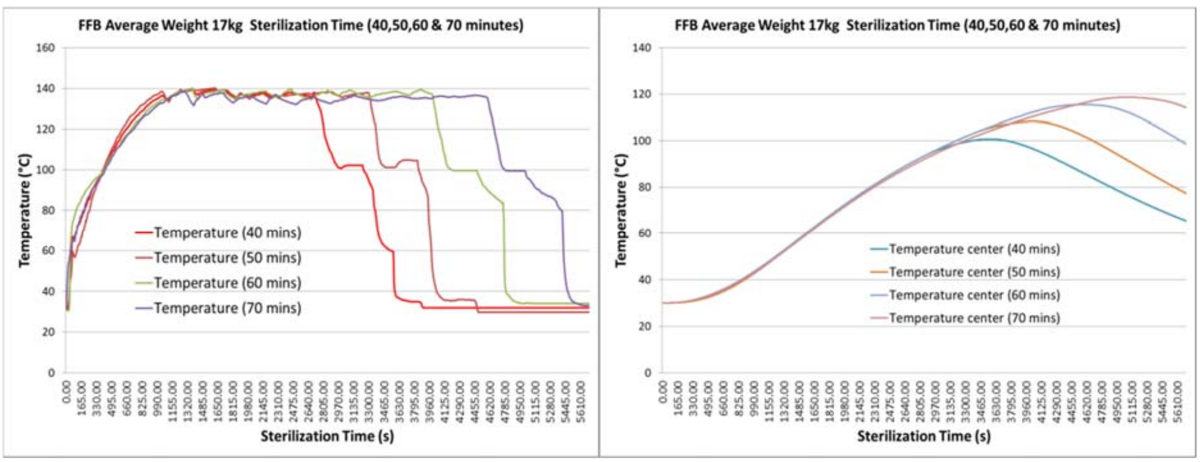

Figure-5. (a) Temperature profile of heating steam at different sterilization time (40-70 minutes) (b) Temperature profile (center) at different sterilization time (40-70 minutes).

Table-5. Time taken for FFB center to reached 100°C and maintained above 100°C at different sterilization time.

Sterilization time (min)	**Time taken to reached 100°C** (s)	**Time during which temperature is maintained above 100°C** (s)	**Q per unit FFB** (kJ/kg)
40	-	-	171.85
50	3210	3210-4235 (17.083 mins)	214.05
60	3200	3200-5300 (35.00 mins)	248.00
70	3295	3295-5970 (44.583 mins)	265.43

Based on the result as per Table-4, it is observed that the optimum heat transfer towards FFB during which the temperature is maintained above 100°C for at least 35 minutes were determined to be 248kJ/kg at estimated sterilization time of 60 minutes, which corresponds to 90% of total fruit let stripped per total fruit let. The result shows that the sterilization condition based on experiment data from Mongana Report is in good agreement as per obtained in the laboratory experimental result for percentage of total loose fruit per total fruit let in one bunch to achieved satisfactory sterilization condition.

4. CONCLUSIONS

The optimum conditions for satisfactory sterilization in terms of percentage of loose fruit in this experiment were in good agreement with the result findings from Mongana Report. The estimated value of heat transferred, Q per unit FFB calculated above were used to determine optimum rate at which heat is transferred towards FFB inside mill sterilizer cage.

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