Possible Changes in Milling Technology via Industry 4.0

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INTRODUCTION

This article is an updated version of the article published in *Palm Oil Engineering Bulletin Issue No. 123* which discussed about the potential changes that would be welcomed in the palm oil industry especially on the mechanical design of the unit operation inside a palm oil mill. In this article, emphasis will be given towards Industry 4.0 technologies that have great potential to improve and enhance the palm oil milling process to reach new heights and process efficiency.

INDUSTRY 4.0

The palm oil milling process has been stagnant for decades without undergoing major development, especially on process control and automation. Current palm oil mill is based predominantly on concepts developed in the early 1950s. There is no intensive upgrade in palm oil mill after the concepts stated in Mongana Report (C P, 1953) and Stork Review (1960). With the world moving towards Industry 4.0, the palm oil industry should also follow the same trajectory as they have proven to bring about positive changes in profitability, productivity, efficiency, customer experience and more for other industries. This is especially important to attract locals and younger generations to work in plantation sectors. At the moment, the palm oil industry is facing labor shortages and relies heavily on unskilled foreign labour.

There are mainly nine technology trends that form the building blocks of Industry 4.0: a) big data and analytics; b) autonomous robots; c) simulation; d) augmented reality; e) digitalisation and cloud; f) cybersecurity; g) horizontal and vertical system integration; h) additive manufacturing; i) internet of things (IoT). Most of these are not technologies that conventional palm oil mill typically utilises. Under normal circumstances, research and development on palm oil mills would normally involves topics such as oil extraction rate (OER) enhancement and free fatty acids (FFA) remediation. However, with the new norms of lower crude palm oil (CPO) price (MPOB, 2020), the palm oil industry should be looking at disruptive technologies that can change the current paradigm. Most importantly, we need to understand that Industry 4.0 is going to come regardless of our present action. Nowadays, it is the norm to see self-service kiosks which is a part of the fourth industrial revolution and Industry 4.0 at fast food restaurant and cinema. Without proper preparations and research, it could result in the palm oil industry being left further behind the curve. Hence, rather than pushing it away, it is better to prepare and embrace Industry 4.0 as part of the palm oil industry future goals.

Fresh fruit bunches (FFB) grading via machine learning

Until now, fresh fruit bunches (FFB) grading are performed manually by competent and experienced FFB graders who manually collect samples and evaluate the FFB based on *fresh fruit bunch Grading Manual* (MPOB) (2020) via visual observation. FFB grading is the front-line assessment in any palm oil mill to measure raw material ripeness and freshness. The quality of the raw material will determine the yield of oil produced at the end of the process. However, the sample size is only about 30% of the whole load which means only 50 to 100 bunches are assessed per load. In other words, there are more ungraded FFB than graded ones for each load. Besides that, most of the samples are picked from the top part of each load. If the quality of the FFB at the bottom portion of the load is significantly different from the top-half, it means that the grading quality of the load will be inaccurate and can lead to misrepresentation towards the OER of the day.

By utilising multi-spectral camera for image capture and suitable machine learning algorithm, we can teach the machine to identify the quality of each FFB which can then be sorted according to their quality. This would be beneficial during the sterilisation process where specific recipe can be chosen for the sterilisation of FFB. At the moment, most mills are using mainly triple-peak sterilisation. However, if the FFB can be segregated according to their qualities, the sterilisation process can be further optimised to operate at an energy efficient setting, hence reducing the need for triple-peak sterilisation operation. Advance analysis such as this has the potential for better accuracies and can assess 100% of the bunches inside a moving scrapper conveyor. By doing this, manpower can be reduced and less argument will take place between estates and mills. *Table 1* illustrates the hypothetical comparison between manual FFB grading and machine learning FFB grading.

TABLE 1. COMPARISON BETWEEN MANUAL FRESH FRUIT BUNCH GRADING AND MACHINE LEARNING FRESH FRUIT BUNCH GRADING

Manual FFB grading	Machine learning FFB grading
Manually operated by human	Fully automated system
30% of total load	100% of total load
No segregation	Auto-segregation
	

INLINE OIL QUALITY MONITORING VIA NIR

Other areas that can possibly be improved upon in palm oil mill are product quality and process losses analysis. Traditionally, all quality and losses analysis are carried out inside a laboratory. For example, FFA which is one of the most critical parameters in a palm oil milling process is typically measured via acid-base titration method that requires the use of chemicals as part of its Standard Operating Procedure (SOP). The method also requires tedious sample preparation and potentially include higher human error variability. However, the introduction of portable off-line near-infrared (NIR) spectroscopy has shorten the sample preparation time significantly and with less handling, human error factor has also been reduced (Yap and Abd Manaf, 2014).

Nevertheless, portable NIR is still an off-line measurement method and samples need to be taken from the production line to the laboratory. The sample travelling time delays the supervisors, engineers and managers from making a quicker response if the quality parameter is out of the control line. Recently, real-time, continuous measurement using inline NIR shows promise on delivering faster results with better data analytics (Yah *et. al*, 2018) while also eliminates sampling to be taken from the production line. Hence, operators can focus on other tasks instead of devoting too much time towards sampling. Additionally, inline measurement can also produce results at higher frequency than the other two methods which means engineers can take quicker rectification action and reduce non-conforming goods. Inline measurement coupled with suitable automation system can automatically respond to any process variation and meet the desired process optimization. *Table 2* illustrates the comparison between the three different methodologies of quality and losses analysis.

ONLINE TRAINING

Digitalisation of information including training is one of the most critical components in Industry 4.0. Training is the process of enhancing the skills, proficiencies, capabilities and knowledge of people for doing a particular work. Continuous training is crucial for organisational growth and success as employee will become more efficient and productive if he or she is well trained. Without proper training, an organisation or company can be exposed to inefficient workforce that could bring down the quality and quantity of the services or products offered. For the most part, Industry 4.0 training revolves around virtual reality (VR) and augmented reality (AR) technologies. Training using VR would be done in an entirely digital environment that shuts out the physical world whereas training via AR mixes the real world with digitally enhanced information and allows users to practice new skills in realistic settings.

Unfortunately, the palm oil industry is still a step behind the curve in the field of training. Sime Darby have yet to genuinely digitalise trainings into module that can be accessed through the internet. This type of training is also

TABLE 2. TITRATION METHOD COMPARED WITH PORTABLE AND INLINE NEAR-INFRARED (NIR)

Titration method	Portable NIR	Inline NIR
Require sampling	Require sampling	No need for sampling
Require chemical use	Do not use chemical	Do not use chemical
Tedious sampling preparation	Simpler sampling preparation	No sampling preparation
>10 min per result	<5 min per result	10 - 60 sec per result

known as online training or e-training which is a valuable and cost-effective way for employees to obtain new and continuous education. Huge corporations and multi-national companies benefited from online training in many ways, one being that all employees can take the exact same training program from anywhere they want, at any time, using any devices. This equates to decreased travel expenses since there is no longer a need for employees to travel to training site. Aside from travel expenses, other expenses such as accommodation, food and materials are no longer needed which is a big positive towards company cost-reduction initiatives.

Furthermore, everyone learns at a different pace and retains information differently. It is normal in a conventional classroom where a teacher moves too fast for some students but too slow for others. People who already know the information are bored and tuned out while those who are hearing the information for the first time struggle to keep up and get frustrated. On the other hand, when taking a course online, employee can go according to their own preference and pace. Obviously, face-to-face training is still needed but the addition of online to the existing module can increase the effectiveness of the training. Plus, refresher training can also be done at less frequency using online module as the alternative. *Table 3* illustrates the advantages and benefits of online training over solitary offline training.

TABLE 3. COMPARISON BETWEEN OFFLINE AND ONLINE TRAINING

Offline or classroom training	Digital or online training
One-pace curriculum	Self-pace curriculum
Fixed time and place	Anytime, anywhere and any devices
Limited reachability	Unlimited reachability
Limited participants	Unlimited participants
One-off class	Infinite

ONLINE LOGBOOK

The practice of writing lab analysis results into logbooks have been a longstanding exercise in any palm oil mill. These physical logbooks take a lot of space and require laborious effort for data extraction. The person also needs to be on-site and scroll open the logbook page by page to obtain the desired data. With the aid of cloud technology and software application, worker can key-in the data directly into the system while the data can be accessed by the relevant personnel from anywhere, at any time with using any devices. The data can then be used for analytics and prediction to further optimise the process. *Table 4* shows the comparison between physical logbook and online logbook.

TABLE 4. COMPARISON BETWEEN PHYSICAL LOGBOOK AND ONLINE LOGBOOK

Physical logbook	Online logbook
Write results into logbook	Key-in results into device
Require physical space for storage	Do not require physical space for storage
Difficult for traceability	Easier traceability
Need to be on-site for data extraction	Data extraction from the cloud

BIG DATA AND ANALYTICS

Traditionally, all mills record huge amount of data through various platforms and logbooks. These data are used from time to time for optimisation, review and research. With the astonishing rise of data science and analytics tools, more can be done with these data. Big data analytics is a complex process of examining and analysing huge amount of data sets in order to uncover hidden patterns, relevant trends, unknown correlation so that the organisation can make informed and data-driven based decision. Deep neural networks, TensorFlow, H2O.ai, MXNet, CNTK 2.0, Jupyter and BI tools such as Power BI and Tableau are some of the latest data analytics trends that can be used for this purpose.

MODELLING AND SIMULATION

Generally, all palm oil milling process is still not optimised at full capacity. The difficult part of this is because all mills have different design and unit operation resulted in different process flow. Hence, each mill would have different optimal process condition. In order to optimise parameter such as OER, all of the variables within the line need to be tested to the limit. However, the optimisation test would result in disruption to the OER performance of the tested mill and deteriorate the oil quality. Independent testing of each parameter would be arduous and consumed large amount of time. Additionally, the amount of possible combinations from all of the variables present within the process would be overwhelming. This is where modelling and simulation can be of service. Instead of performing actual physical experiments, all of that can be done virtually in a computer with suitable and capable software such as Aspen HYSYS, Aspen Plus, COCO and DWSIM. Software such as Aspen HYSYS contain ready-made library of unit operations that can be dragged and dropped into the layout. Then, the relevant process condition can be entered into each unit operation. Aside from that, there are also software such as MATLAB that requires the user to produce the mathematical equation and coding for the process from scratch.

Through the model, we can simulate, predict, extrapolate and manipulate all of the variables without worrying about any non-conformance goods coming out of the process as all of it is produced virtually. Additionally, once the model has reached satisfactory level of comparability with actual palm oil milling process, we can tinker with the model without lengthy process of modification or fabrication; saving precious money, time and work hours. Aside from mill optimisation, modelling and simulation can also aid in development of new technologies into the existing palm oil milling process as shown in *Figure 1*. For now, some of the new technologies are done via lab scale and then transferred to commercial mill. Most projects require additional step in the form of pilot plant stage before it can go directly towards commercialisation.

The higher the stage, the bigger the size of investment in terms of capital expenditure (CAPEX) and operating expense (OPEX). If the project goes south when it reaches the commercialisation stage, the lost would be astronomical. This will involve high CAPEX investment and disrupt mill operations along the way. Additionally, it will also require a lot of time for installation and commissioning. Instead of physically building the pilot plant, civil structure, spending lengthy amount of time on the project and performing actual experimentation; all of that can be done virtually in a work station computer with suitable and capable software. Modelling and simulation can be used in giving a tangible quantification of the project feasibility in bringing in money to the company. If it does not pass the modelling and simulation test, then it should be scrapped right away to prevent further losses. Plus, we can also extrapolate the result and test the model thousands of times before deciding on the next step.

FULLY AUTOMATED MILL WITH ONLINE MONITORING AND CONTROL SYSTEM

The palm oil industry is highly dependent on cheap manual labor. However, due to the 3D perception of it being dangerous, dirty and difficult, the locals have minimal involvement in the plantation sector. This issue has opened the door to foreign workers to work in the plantation sector especially in high labor demand operations such as harvesting, loose fruit collection and maintenance work. Nowadays, the labor shortage issue has become more serious as more Indonesians prefer to work for plantations in their hometown since they can obtain a slightly lower level of salary while being not too far away from their family. In any case, the palm oil industry cannot depend on cheap labor forever. Even China's government is pushing towards a consumption-based economy to ensure a more socially inclusive and sustainable path of economic growth. In 2013, average monthly wages in China amounted to around USD600 which implies that Chinese wages are around three times higher than wages in Indonesia and Vietnam (Donaubauer and Drege, 2014). Additionally, families nowadays have fewer kids due to economic constraint and the younger generation tend to go for jobs in the urban community which makes this matter worse. Hence, the palm oil industry needs to be prepared with a potential remedy for labor shortage problem. Automation with centralised monitoring and control system can be the answer.

An automated system typically performs the manufacturing process with less variability than human

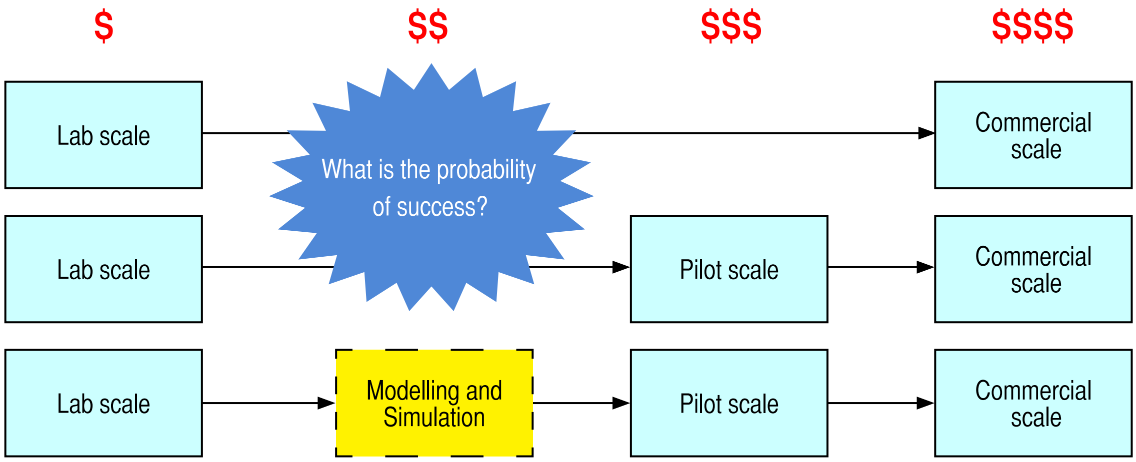

Figure 1. Research and development pathway of new technologies.

labor resulting in greater consistency and predictability of product quality and quantity. With greater control of the process, errors and redundancies can be minimised. In addition, automation with Supervisory Control and Data Acquisition (SCADA) gives more data that can be used to measure all sorts of metrics and key performance indicators of the process. In this age of data science, machine learning and artificial intelligence (Ai), these data can be utilised to find hidden patterns and unexpected trends that can be utilised to create suitable business solution for process optimisation.

This is not the first time that the palm oil industry has tried to dip its toe into automation. We should learn from previous endeavors so that we can improve our chances this time round. In the past, the technology of sensors and actuators are not robust enough to withstand the working conditions in a mill. In addition, the cost of sensors and actuators are really expensive to be implemented throughout the mill. These have improved a lot with more economical and capable sensors and actuators emerging in the market. Connectivity of mill also needs to be improved at a level where the system can operate without lag. This was a big problem back then. However, it has since improved a lot with the evolution of new technologies.

Before this, there were not enough skilled technical workers to operate and execute preventive maintenance on machineries, network and automation. Depending wholly on external vendors is no longer viable in the long run. Hence, it is also essential that we equip our workforce with proper talents in these areas. Besides that, some of the machineries are not designed for automation. Some tweaking need to be done before the process can be automated as it will create a lot of problems when we want to transition it from manual to auto-mode. Before going for automation, manual processes need to be perfected in such a way that they would be robust enough to handle various kinds of conditions.

CONCLUSION

Most of the recommendations presented in this paper have been used in other industries with incredible outcome. Even other vegetable oil producers especially from the western hemisphere are looking to improve their productions through the inclusion of Industry 4.0 technologies into their existing systems. The palm oil industry should also consider assessing the financial viability and effectiveness of these technologies in improving the eco-system of our process. For years, we have been fixated on improving the palm oil milling process through the same mechanical, chemical and biological means. These routes have literally become too saturated with only small windows of opportunity for improvement. On the other hand, Industry 4.0 technologies revolves around technologies such as digitalisation, internet, automation, modelling and process control which holds untapped potential for the palm oil industry. The palm oil industry is actually still at the edge of Industry 2.0 going to Industry 3.0 which means there is a lot of catching up to do. Some of the recommendations in this paper such as online training is actually part of Industry 3.0 talking points but it is something that we need to attain before going for bigger challenges of Industry 4.0.

It is not going to be easy but we should start somewhere by considering to introduce any of these recommendations into our palm oil mills. The journey of a thousand miles begin with the first step.

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