International Journal of Basic and Applied Sciences, 5 (2) (2016) 151-156

International Journal of Basic and Applied Sciences

Website: www.sciencepubco.com/index.php/IJBAS
doi: 10.14419/ijbas.v5i2.5900
Research paper

An analysis for providing safety in the cooking oil production process through FMECA approach

Benedictus Rahardjo [1]*, Bernard C. Jiang [2]

[1] *Department of Industrial Engineering, Faculty of Industrial Technology, Petra Christian University, Surabaya, Indonesia*
[2] *Department of Industrial Management, School of Management, National Taiwan University of Science and Technology, Taipei, Taiwan*
**Corresponding author E-mail: beni@petra.ac.id*

Abstract

This study attempts to apply Failure Mode Effects and Criticality Analysis (FMECA) to improve the safety of production system, especially on the production process of an oil company in Indonesia. Since food processing is a worldwide issue and the self management of a food company is more important than relying on government regulations, so the purpose of this study is to identify and analyze the criticality of potential failure mode on the production process, then take corrective actions to minimize the probability of making the same failure mode and re-analyze its criticality. This corrective actions are compared with the before improvement condition by testing the significance of the difference between before and after improvement using two sample t-test. Final result that had been measured is Criticality Priority Number (CPN), which refers to severity category and probability of making the same failure mode. Recommended actions that proposed on the part of FMECA give less CPN significantly compare with before improvement, with increment by 48.33% on coconut cooking oil case study.

Keywords: *Coconut Cooking Oil; Criticality Priority Number; Failure Mode Effects and Criticality Analysis; Potential Failure Mode and Effect; Severity and Occurrence Classification.*

1. Introduction

Food processing is a very important worldwide issue. Processing may have either beneficial or detrimental effects on these different properties of food, so each of these factors must be taken into account in the design and preparation of complementary foods. Food quality is frequently associated with food safety. Food safety encompasses a whole series of processes and activities both within and outside the food processing plant that will ensure that the food is free of potential chemical, physical, and biological hazards. Quality within a food processing plant may also be related to the notion of quality control. In this regard, quality control has many objectives within a food processing plants, mainly being to maintain the nutritional value of the processed product, to protect customers from the dangers of contaminated food and associated food borne diseases, and to ensure that all food laws and regulations are met.

Quality assessment of processed food has become an emerging issue in the present era. The quality factor has broadened and covers all the aspects which satisfy consumer expectations. The terms “food quality” and “food safety” mean different things to different people. Quality has a vast number of meanings and can encompass parameters as diverse as organoleptic characteristic, physical and functional properties, nutrient content, and consumer protection from fraud. Safety is more straightforward, relating to the content of various chemical and microbiological elements in food. Clearly, food quality and safety issues need to be addressed along the entire food chain.

Food safety is the responsibility of everyone involved with the food chain from regulators to producers to consumers. A modern food safety system, with the new risk analysis approach has the ability to much sharper diagnose the problems and also to suggest focused interventions to properly deal with them.

A number of developing countries are already taking steps to improve and strengthen their systems for food safety management. Several are moving away from the traditional approach focused on end-product control toward a process and science-based approach. There is an example of science-based activities using risk assessment to support food safety regulations [1]. A science-based approach enhances the ability of food safety regulators to estimate the likelihood and magnitude of the resulting risks and impact on human health.

In contrast, there are many cases deal with violation objectives of quality control, especially in the case of protecting customers from the dangers of contaminated food. One of recently case happened in Taiwan last two years is about food scandal involving edible oils. For sure, this issue is a worldwide problem, because it is related with trust damage in entire industry trying to rebuild its reputation. Besides that, not only in local area that affected from this case, but it also spread around the world because of trading process, export and import matter.

The objectives of this study are described as follows.

i) Identify and analyse the criticality of potential failure mode on a system, especially on the production process of coconut cooking oil.
ii) Take corrective actions to minimize the probability of making the same failure mode and analyse its criticality.
iii) Compare and test the significance of the difference between before and after improvement.

The final result leads to criticality priority number, which contains severity category and probability of failure mode occurrence. All the objectives of this study are met through an application of industrial engineering tool called Failure Mode Effects and Criticality Analysis.

2. Failure mode effects and criticality analysis

A safety analysis tool called Failure Mode Effects and Criticality Analysis (FMECA) is a visibility tool that can easily be understood and used to detect the possible critical points (failures) of its traceability system. It is useful in design comparison. FMECA is characterized by a bottom-up approach. It breaks down any system (product and/or production process) into its fundamental components to detect all potential failure modes and their effects. Some major benefits derived from a properly implemented FMEA effort are as follows [2]:

1) It provides a documented method for selecting a design with a high probability of successful operation and safety.
2) A documented uniform method of assessing potential failure mechanisms, failure modes and their impact on system operation, resulting in a list of failure modes ranked according to the seriousness of their system impact and likelihood of occurrence.
3) Early identification of Single Failure Points (SFPS) and system interface problems, which may be critical to mission success and/or safety. It also provides a method of verifying that switching between redundant elements is not jeopardized by postulated single failures.
4) An effective method for evaluating the effect of proposed changes in the design and/or operational procedures on the mission's success and safety.
5) A basis for in-flight troubleshooting procedures and for locating performance monitoring and fault-detection devices.
6) Criteria for early planning of tests.

FMECA involves two sub-analysis, they are Failure Mode and Effects Analysis (FMEA) and Criticality Analysis (CA). FMEA analysis is used to identify the main causes for effectiveness or efficiency loss. On FMEA part, some information that provided are critical process, sub process, and its function identification, potential failure mode and potential effect of failure for every sub process analysis. CA is the tool that can be used to improve reliability and manage failures based on risk instead of perception. Criticality number technique is used mostly in the chemical industries or some other daily product companies [3]. The criticality number calculation is described in US MIL-STD-1629A: Procedures for performing a failure mode, effects and criticality analysis [4]. The criticality number calculation is described in US MIL-STD-1629A: Procedures for performing a failure mode, effects and criticality analysis. The procedure consists of determining the failure-effect probability (β), the failure mode ratio (α), the part failure rate (λ_p), and its operating time (t), and using these values to compute a failure mode Criticality Number (CN) for each item failure mode. Failure mode ratio may be taken from a database source such as Failure Mode/Mechanism Distributions (FMD-91) [5]. By identifying the characteristics that make each failure critical, the analysis will also provide valuable information to decide what actions will reduce risk for all failures. There is much information that can get from FMECA [6]:

1) The subsystems and final items of the system in a hierarchical arrangement.
2) Any failure or generic malfunctioning, with a list and description of all potential failure modes for the process/product being analysed.
3) The probability, severity, and detection ability of each failure mode's occurrence.
4) The criticality analysis, which ranks all failure modes in order of importance.

The criticality assessment, to assess the risk, involved in each failure mode previously recognized in FMEA analysis, has been performed by either developing a Risk Priority Number (RPN), or calculating an item criticality number. The RPN method is preferred mostly by the manufacturing industries such as automotive companies [7], domestic appliance firms [8], and tire companies [9]. There are two approaches of using the RPN method, in quantitative (number) and qualitative (code) manner. RPN method with quantitative approach is only based on three factors: occurrence, severity, and detection. Other manner of using the RPN method is qualitative approach, that utilizing code instead of number, such in quantitative approach.

Some drawbacks can be found of using the RPN method. It is based on a simple multiplication of the factors' scores is a debatable method. For example, it is not certain that all designers in every situation want to assign the same importance (weight) to each criterion. This situation may need a subjective assessment. The detection ranking in the RPN approach should be dropped, which the ranking is a measure of whether subsequent testing will show the failure mode exists rather than whether the failure will be detected when it occurs [10].

There are some findings related with FMECA. One of them is an application of the method in a pasta production plant [6]. The results obtained through the application of the method proposed to the specific case study of a durum wheat pasta production process demonstrate that FMECA application to the analysis of the internal traceability system for food processing companies can grant valuable results. A valuable safety analysis tool should be efficiently used to analyze, improve and, if necessary, re-engineer a food product's internal traceability system. If reliable quantitative judgments are available for some criteria, they can easily be included in Analytic Hierarchy Process (AHP) analysis [3]. This possibility means that Multi-attribute Failure Mode Analysis (MAFMA) can also eventually easily replace or integrate in a more complete manner FMECA studies already executed by maintenance staff.

The extension of FMECA using fuzzy logic is performed [11]. Fuzzy logic provides a tool that can be used throughout the design process for performing a criticality analysis on a system design and prioritizing the failures identified in a FMECA for corrective actions. The result allows appropriate actions to correct or mitigate the effects of a failure to be prioritized. There are some comments of using the RPN methodology [10]. The fundamental problem is that ordinal scales are used to rank the failure modes in terms of severity, occurrence, and detection, but the scales are treated as if numerical operations on them, most notably multiplication, are meaningful. Bowles recommended if a cost could be associated with each failure effect, failures could be placed on a dollar scale (a ratio scale). Multiplying the cost of the failure effect and the probability of occurrence of the underlying failure mode could produce an "expected cost" of the failure. Finally, proposed design changes could then be evaluated by their effect on the expected cost.

3. A case study: FMECA application for coconut cooking oil production process

XYZ oil company has a main product, coconut cooking oil. All of the data in this study, including production process of palm and coconut oil and the numbers which are determined on the part criticality analysis of FMECA, are obtained from direct observation on the production floor, measure it as accurate as possible, and then consult the observation result with company's process engineer. At the beginning, start with production process description of coconut cooking oil.

3.1. Production process of coconut cooking oil

Figure 1 depicts the flow production process of coconut cooking oil, start with copra as raw material then goes into cutting process. In cutting process, there are two sub processes, cleaving and chopping. Cleaving is cutting the whole copra into two portions, in purpose to be easy while chopping by machine, so can get the maximum yield. The equipment used for cutting the whole copra is knife. After getting two portions of whole copra, then goes into chopping process.

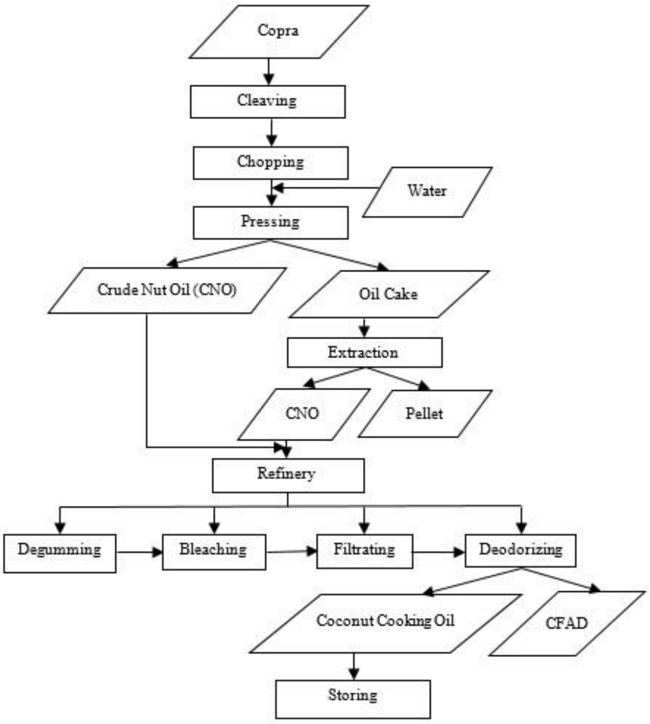

Fig. 1: Flow Chart of the Production Process of Coconut Cooking Oil.

Chopping is grating copra flesh into small parts, with chopper used as main equipment to deal with it. Small parts of copra flesh will be added with water in purpose of getting liquid form. Pressing is a process which press copra flesh to release two kinds of product, Crude Nut Oil (CNO) as the main outcome and oil cake. An oil cake is the solids remaining after pressing copra flesh to extract the liquids. To achieve company's target that is maximizing yield, so there is an additional process taken into oil cake to extract more to get CNO. Result of extracting process on oil cake is CNO yield added and its side product called pellet. Pellet most common use is in animal feed, also it is possible to use for culinary purposes and applied to the forehead to threat headaches [12]. In some regions of the world, it is used as boiler fuel as a means of reducing energy costs, for which it is quite suitable [13].

CNO as the main outcome from copra will treat further in refinery process become coconut cooking oil. Refinery process consists of four sub processes: degumming, bleaching, filtrating, and deodorizing. Start from degumming process is to relieve the gum which still contain a little bit in CNO. Then, next process after degumming is bleaching. The purpose of bleaching process is to purify the oil color from brown as copra color into clear to be good looking as a coconut oil. To purify oil color, the company uses chemistry substance to change from brown color into clear. After bleaching process, the CNO goes into filtrating process, which filtrate the residue as a result of previous process. The residue will be filtrated using a mesh. Continue to the last process on refinery process is deodorizing. On this process, it relieves the oil odor and moisture levels using deodorized material fill into the mixture. There are two results of deodorizing process: coconut cooking oil and Coconut Fatty Acid Distillate (CFAD). Coconut cooking oil is one of main product at XYZ oil company. CFAD is a by-product of coconut cooking oil production. This oil can be used as raw material to produce soap. Coconut cooking oil will treat into storing process, which is filling oil into the bottle, then storing it on particular place, away from light and airflow.

3.2. FMEA description

From Fig. 1 that depicts the production process of coconut oil, there are many processes that copra as raw material has been treated along the production line, starts from cleaving until deodorizing through refinery process. There are some processes that had been found and detected as critical process, which the company should take notice on it. The following discussion will discuss about critical process and its description, including their function, potential failure mode, and potential effect of failure.

1) Cutting process consists of two sub processes: cleaving and chopping. In cleaving process, the potential failure mode that might be happened is knife is not sharp enough to cut the whole copra (coded by failure ID 1.10), and the potential effect if the failure occurs is not all copra can be completely cut into two portions. Another potential failure that might be happened is knife is rusty (1.20), so it affects to the deterioration of oil, which lead to change taste and decrease shelf life time. Chopper as the equipment used in chopping process may have the similar potential failure effect with the knife which is used in cleaving process. Chopper might not be sharp enough to grate the copra flesh (1.30) and could be rusty (1.40) in a long-term use. The potential failure is not all copra flesh can be completely grated, so it decreases the yield. Rusty chopper can deteriorate the oil (change taste and decrease shelf life time), also may affect to the copra flesh's color, which lead to change the oil color into brown like rust.
2) The potential failure mode that might be happened in pressing process is pressing force is not strong (2.10), so it causes CNO yield that the company want to achieve as their target can't be maximum.
3) Among four sub processes on refinery process, the following three sub processes: bleaching, filtrating, and deodorizing, are indicated as potential failure might be happened on it. On bleaching process, filling up the chemistry substance into mixture is a kind of potential failure mode, which leads to inappropriate composition used (3.10). If too much chemistry substance, it will affect to the oil taste, while if too less, the oil color is still in brown as copra color and it should be reprocessed to get the appropriate color such as coconut oil in general. A failure like the mesh is already full of residue (3.20) on filtrating process can be happened if there is no schedule to change it. If that condition happens, it may cause much oils are stopped on the mesh and of course, it decreases the CNO yield. Deodorized material used on deodorizing process must be in appropriate composition as well as using chemistry substance on bleaching process. Similar with bleaching process that inappropriate composition of deodorized material (3.30) may lead to the failure mode that might be happened in deodorizing process. If too much, deodorized material will be tasted in coconut oil as the final product. In contrast, if it is too less can deteriorate the oil (change taste and decrease shelf life time).
4) On the storing process, one thing that should be noticed is keep away the bottle from light and airflow. The potential failure mode that might be happened is bottle places carelessly (4.10), not on the right place, so that early oxidation can be occurred. If oxidation occurs, it may decrease shelf life time.

3.3. CA description

After determining the critical process of making coconut and palm oil, then analyze the criticality of each potential failure. There are two approaches for analyzing criticality of potential failure, quantitative and qualitative approach. In quantitative approach, failure effect probability (β), failure mode ratio (α), failure rate (λ_p), and operating time (t) are assigned on each potential failure to get the final failure mode (C_m) by multiplying that four factors. Failure effect probability will be assigned in total value of 1 on each potential failure mode. In case of a potential failure have two potential effects, so that each potential effect will be weighted as conditional probability that the failure effect will result, given that the failure mode occurs, and sum of the weight is equal to 1. Each weight value comes from analyst's judgment based on number of complaints from customer to marketing within one year, and also observation data obtained from process engineer. For example, chopper is rusty may cause two effects. The first effect is deterioration of oil (change taste and decrease shelf life time), while the second effect is related with copra flesh's color, which can be going into brown color like rust. Based on historical data recorded from company, there are total 223 records, contain with 2 complaints from customer because of rusty flavor and 221 defectives from process quality data because of the oil still in brown color. According to that result of two effects, the failure effect probability assigned for first effect is 0.009, and for second effect is 0.991, as the literature states that sum of the potential failure effect must be equal to 1.

Failure mode ratio has the similar scoring as failure effect probability, which is must be assigned in total value of 1, but in terms of each process, not on each potential failure mode as well as in failure effect probability. For example, cutting process consists of two sub processes: cleaving and chopping. Cleaving itself consists of two potential failure modes, knife is not sharp enough to cut the whole copra and knife is rusty. Knife is not sharp has failure mode ratio is 0.48, while knife is rusty 0.02. That two ratio numbers come from contact failure and coil failure, respectively on chopper device in FMD-91 standard. Chopping also consists of two potential failure modes, chopper is not sharp enough to grate the copra flesh and chopper can be rusty in a long-term use. Similar with knife, chopper is not sharp has failure mode ratio is 0.48, while chopper can be rusty is 0.02. Totally, sum of the failure mode ratio from all four potential failure modes in cutting process is equal to 1.

Failure rate should be the most noticeable factor, because it is determined by how often a potential failure mode might be happened during the process occurs. Failure can be described as waste or defective product. For instance, potential failure mode knife is not sharp has failure rate equal to $5.4*10^{-3}$ failures per million hours. This number is obtained from within 8 hours observation, the knife can cut the whole copra 4000 kg, but in that whole quantity, there are 21.6 kg copra not be cut, so that quantity can be treated as failure rate.

The last factor that determines the final failure mode is operating time, which represents the time taken for doing observation to get number of failure rate. In this case study, total observation time taken is 8 hours. In usual way, this factor is shown in "seconds" time scale, so convert it become 28800 seconds. After gathering failure effect probability, failure mode ratio, failure rate, and operating time, then multiply that four factors become a new value called final failure mode. In calculating the final failure mode, for failure effect probability which divide into two effects, it will be added up to 1, after that multiply with the other factors, so only has one value for its potential failure mode. For example, potential failure mode chopper is rusty with first effect is deterioration of oil has failure effect probability 0.009 and second effect is affect to the copra flesh's color has failure effect probability 0.991, add up together become 1, then multiply with failure mode ratio equal to 0.02, failure rate equal to $3*10^{-2}$ failure per million hours, and operating time equal to 28800 seconds, it become final failure mode equal to $1.728*10^{-5}$. Detail for failure effect probability, failure mode ratio, failure rate, operating time, and final failure mode of each potential failure mode on coconut cooking oil case study is described on Table 3.

In qualitative approach, only two factors that are assigned on each potential failure mode, they are severity and occurrence. Those two factors are indicated as Criticality Priority Number (CPN). Severity description is related with potential effect of failure as a result from potential failure mode that might be happened on every process. While, occurrence description is related with failure rate, that represents number of expected failures happened during the process occur. Assigning severity and occurrence category is based on Table 1 and 2, which had already adjusted with the case study at XYZ oil company. After assigning the severity and occurrence category on every potential failure mode, then convert it in terms of number, based on Table 1 and 2, to get CPN. For instance, for potential failure mode knife is not sharp with severity category III, means potential effect of failure not all copra can be completely cut into two portions is a kind of marginal failure, that is a failure which may cause minor inefficiency and/or ineffectiveness in the reconstruction of product, may takes time to reprocess it. On the same potential failure mode knife is not sharp with occurrence category B, is a kind of reasonably common failure, means a moderate probability of occurrence with failure rate more than 0.005, but less than 0.03 per million hours. Then, severity category III convert become CPN of 2, while occurrence category B convert become CPN of 4, and take average on both of them, become CPN of 3.

After getting all CPN for every potential failure mode, then rank it from smallest to largest number to determine which potential failure mode should be prioritized to take actions on it. CPN with smallest number means the potential failure mode has least importance rate to be noticed, while largest number means the potential failure mode has most importance rate to be noticed. Table 3 shows priority of each potential failure mode from the most important to the least one on coconut cooking oil case study. It gives information that which potential failure mode should be prioritized to take actions on it, start from the most important to be noticed is chemistry substance is not in appropriate composition until the least one is mesh is already full of residue.

Table 1: Severity Classification and Description

Category	Description	Definition	Conversion
I	Catastrophic	A failure which may cause total loss of product (threaten the human's life)	4
II	Critical	A failure which may cause severe inefficiency and/or ineffectiveness in the reconstruction of product (change the taste, decrease shelf life)	3
III	Marginal	A failure which may cause minor inefficiency and/or ineffectiveness in the reconstruction of product (reprocess)	2
IV	Minor	A failure which may be overcome with an unscheduled measure	1

Table 2: Occurrence Classification and Description

Category	Description	Definition	Conversion
A	Frequent	A high probability of occurrence (equal to or greater than 0.03 of the overall probability of failure)	5
B	Reasonably common	A moderate probability of occurrence (more than 0.005, but less than 0.03)	4
C	Occasional	An infrequency probability of occurrence (more than 0.0005, but less than 0.005)	3
D	Rare	An unlikely probability of occurrence (more than 0.00005, but less than 0.0005)	2
E	Extremely rare	A failure whose probability of occurrence is essentially zero (less than 0.00005)	1

3.4. Recommended actions

This section will discuss about some recommended actions that propose to reduce the probability of making the same failure mode as already described on Section 3.1. Recommended actions are proposed and discussed together with the process engineer of XYZ company, because that actions should be applicable on the production process of making coconut oil. As example, for potential failure mode knife is not sharp enough to cut the whole copra and knife is rusty might be anticipated by scheduling the appropriate time to sharpen and replace the knife. Mean Time Between Failures (MTBF) and Mean Time To Repair (MTTR) are one helpful time calculation as the input to find the appropriate time to sharpen and replace the knife. In coconut oil case study, MTBF can be calculated as the average time between failures (knife is not sharp and rusty) of a system, while MTTR represents the average time required to repair a failed component or device, that is to sharpen and replace the knife, done by technician.

Recommended actions will be done based on the prioritization that already made, since CPN with largest number means the potential failure mode has most importance rate to be noticed and anticipated as soon as possible to prevent become more severe and frequent. Recommended actions that already proposed will also be evaluated by assigning CPN of its potential failure mode. CPN is based on severity and occurrence factors as well as discussion on Section 3.2, which assigning severity and occurrence category, also its conversion become CPN are based on Table 1 and 2. There are some reasons on assigning severity and occurrence category in its recommended actions. For instance, potential failure mode pressing force is not strong might be anticipated by scheduling the appropriate time to do resetting the pressing machine, is assigned on severity category III and occurrence category C, because if only do resetting, the setting might be changed automatically again, because of the life age of pressing machine itself. Table 3 shows potential failure mode in failure ID term and its recommended actions, followed by severity and occurrence category, also the CPN assigned on them.

3.5. Process comparison before and after improvement

After gathering CPN before and after improvement, the next step is making comparison between that two conditions, in purpose to know whether there is a change condition before and after improvement. Fig. 2 shows the CPN before and after the improvement for the coconut cooking oil case study.
The numbers shown on the bar chart are come from average of CPN that obtained from severity and occurrence category. Using statistical two sample t-test to check whether after improvement is better significantly compared with before improvement. Result of two sample t-test is rejecting null hypothesis with P-value is 0.000, less than α-risk (0.05). It concludes that mean of CPN before improvement is significantly greater than mean of CPN after improvement, or in the other words say that recommended actions as proposed improvement gives less CPN significantly compare with condition before improvement. The result shows less severity category and probability of making the same failure mode.

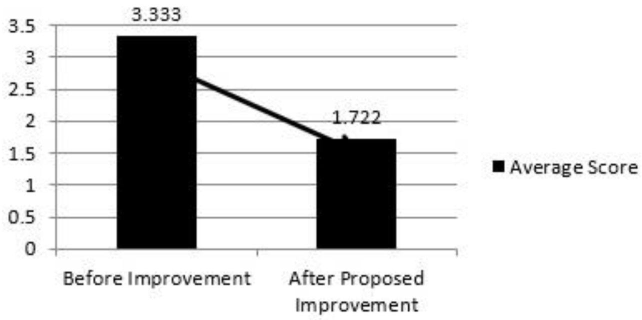

Fig. 2: CPN Before and After the Improvement for the Coconut Cooking Oil Case Study.

3.6. FMECA and criticality matrix

Information about process, sub process, description or function of its process or sub process, potential failure mode, potential effect of failure, failure ID, criticality analysis (both in quantitative and qualitative approach), CPN and its rank, and recommended actions, criticality analysis in qualitative approach and its CPN are used as the input to build Failure Mode Effects and Criticality Analysis (FMECA). Table 3 is for the FMECA of coconut cooking oil case study.
After FMECA is built, next step is building criticality matrix. In this matrix, it uses criticality analysis with qualitative approach as the input, which is severity and occurrence category. On x-axis depicts severity classification with four categories (I to IV), while on y-axis depicts occurrence classification with five categories (A to E). Criticality matrix includes failure ID both on condition before improvement (bottom-left) and after improvement (top-right), so it can show the change between that two conditions. Each failure ID, which represents potential failure mode, will be depicted based on its severity and occurrence category that already determined on Table 3. Criticality matrix on coconut cooking oil case study is depicted on Fig. 3.

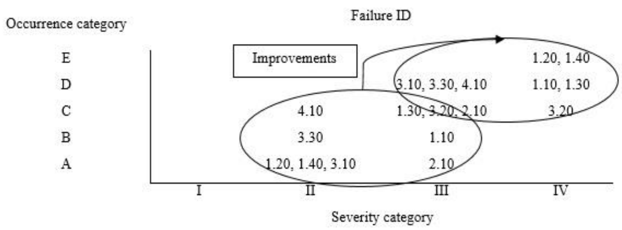

Fig. 3: Criticality Matrix for the Coconut Cooking Oil Case Study.

Table 3: FMECA on Coconut Cooking Oil Case Study

Failure ID	Process	Sub Process	Description	Potential Failure Mode	Potential Effect of Failure
1.10	Cutting	Cleaving	Cutting whole copra into two portions	Knife is not sharp enough to cut the whole copra	Not all copra can be completely cut into two portions
1.20				Knife is rusty	Deterioration of oil
1.30		Chopping	Grating copra flesh into small parts	Chopper is not sharp enough to grate the copra flesh	Not all copra flesh can be completely grated
1.40				Chopper is rusty	Deterioration of oil It affects the copra flesh’s color, which has brown color as rust
2.10	Pressing		Pressing copra flesh to release Crude Nut Oil (CNO) and oil cake	Pressing force is not strong	CNO yield is not maximum
3.10	Refinery	Bleaching	Purifying the oil color (from brown as copra color into clear)	Chemistry substance is not in appropriate composition	Too much: it affects to the oil taste Too less: the oil color is still in brown as copra color
3.20		Filtrating	Filtrating the residue from the bleaching process	Mesh is already full of residue	Much oils are stopped on the mesh
3.30		Deodorizing	Relieving the oil odor and moisture levels	Deodorized material is not in appropriate composition	Too less: deterioration of oil Too much: the deodorized material will be tasted
4.10	Storing		Fill oil into the bottle, store and keep away from light and airflow	Bottles place carelessly	Early oxidation can be occurred

Table 3: FMECA on Coconut Cooking Oil Case Study (Cont'd)

Failure ID	FEP (β)	FMR (α)	FR (λ_p)	OT (t)	FM (C_m)	SB	OB	CB	Rank	Recommended actions	SA	OA	CA
1.10	1	0.48	5.40E-09	28800	7.46E-05	III	B	3	6	Scheduling the appropriate time to sharpen and replace the knife (adopt MTBF and MTTR)	IV	D	1.5
1.20	1	0.02	3.00E-08	28800	1.73E-05	II	A	4	3		IV	E	1
1.30	1	0.48	1.00E-09	28800	1.38E-05	III	C	2.5	8	Scheduling the appropriate time to sharpen and replace the chopper (adopt MTBF and MTTR)	IV	D	1.5
1.40	0.009 0.991	0.02	3.00E-08	28800	1.73E-05	II	A	4	2		IV	E	1
2.10	1	1	1.20E-07	28800	3.46E-03	III	A	3.5	4	Scheduling the appropriate time to do resetting the pressing machine (adopt MTBF and MTTR)	III	C	2.5
3.10	0.004 0.996	0.39	3.00E-08	28800	3.37E-04	II	A	4	1	Finding the appropriate composition of chemistry substance by doing design of experiment	III	D	2
3.20	1	0.22	6.25E-10	28800	3.96E-06	III	C	2.5	9	Scheduling the appropriate time to replace the mesh (adopt MTBF and MTTR) and add process	IV	C	2
3.30	0.571 0.429	0.39	2.00E-08	28800	2.25E-04	II	B	3.5	5	Finding the appropriate composition of deodorized material by doing design of experiment	III	D	2
4.10	1	1	1.25E-09	28800	3.6E-05	II	C	3	7	Provide the suitable place and increase operator's awareness	III	D	2

FEP: Failure Effect Probability; FMR: Failure Mode Ratio; FR: Failure Rate; OT: Operating Time; FM: Failure Mode; SB: Severity Before improvement; OB: Occurrence Before improvement; CB: Criticality priority number Before improvement; SA: Severity After improvement; OA: Occurrence After improvement; CA: Criticality priority number After improvement

4. Conclusion

This study has used a concise and clear methodology on applying Failure Mode Effects and Criticality Analysis (FMECA) approach in an Indonesian oil company. This approach begins with direct observation about the production process to make coconut cooking oil, then map its flow process. Next is going into FMECA analysis, that describes the detail about critical process and perform criticality analysis for each of it. Recommended actions are proposed to have improvement on reducing the criticality risk. Evaluate recommended actions by performing criticality analysis as well as on the initialization step and compare its changes. At the end, recommended actions give better result significantly compare with before improvement. The result is related with safety improvement, which refers to lesser severity category and probability of making the same failure mode. Criticality priority number might be improved by 48.33% (from average CPN 3.333 to 1.722) on coconut cooking oil case study.

As explained before, this study has succeeded to apply FMECA in an oil company case study. However, FMECA is not a tool that can only be applied in an oil company, but it's also feasible to apply in another field, such as use before design commences in order to influence the design and uncover design risk. FMECA can be applied in electricity component design, food industry, automotive industry, and even for daily needs industry related with customer satisfaction.

Acknowledgement

The language usage in this manuscript was checked and refined by Elsevier Language Editing Services.

References

[1] Malik, A., Masood, F., & Ahmad, S. (2014). *Food processing: Strategies for quality assessment, a broad perspective*. New York: Springer.

[2] Muralidharan, K. (2015). *Six sigma for organizational excellence: A statistical approach*. New Delhi, India: Springer (pp. 241).

[3] Braglia, M. (2000). MAFMA: multi-attribute failure mode analysis. *International Journal of Quality & Reliability Management, 17*(9), 1017-1033. http://dx.doi.org/10.1108/02656710010353885.

[4] US Military Standard, MIL-STD-1629A. (1983). *Procedures for performing a failure mode, effect and criticality analysis*. USA: Department of Defense.

[5] Chandler, G., Denson, W., Rossi M., & Wanner, R. (1991). *Failure mode/mechanism distributions*. Rome, NY: Reliability Analysis Center.

[6] Bertolini, M., Bevilacqua, M., & Massini, R. (2006). FMECA approach to product traceability in the food industry. *Food Control, 17*(2), 137-145. http://dx.doi.org/10.1016/j.foodcont.2004.09.013.

[7] Ford. (1988). *Potential failure mode and effects analysis in design (Design FMECA) and for manufacturing and assembly process (Process FMECA) instruction manual*. Detroit, MI: Internal Report.

[8] Zanussi. (1989). *FMEA: Guida all'analisi del guasto*. Italy: Internal Report.

[9] Pirelli. (1988). *FMEA-FMECA: Analisi delle modalita degli effetti e delle criticita dei guasti*. Milan: Internal Report.

[10] Bowles, J. B. (2004). An assessment of RPN prioritization in a failure modes effects and criticality analysis. *Journal of Institute of Environmental Sciences & Technology, 47*(1), 51-56. http://dx.doi.org/10.17764/jiet.47.1.y576m26127157313.

[11] Bowles, J. B. & Pelaez, C. E. (1995a). Fuzzy logic prioritization of failures in a system failure mode, effects and criticality analysis. *Reliability Engineering and System Safety, 50*(2), 203-213. http://dx.doi.org/10.1016/0951-8320(95)00068-D.

[12] Manandhar, N. P. (2002). *Plants and people of Nepal*. Portland, OR: Timber Press.

[13] Clay, J. W. (2004). *World agriculture and the environment.* Washington, DC: Island Press.