Risk analysis of poultry feed production using fuzzy FMEA

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Abstract

The intensity growth of chicken meat consumption in Indonesia pulls the demand of poultry feed products. Producers of poultry feed try to fulfil this higher demand. The production lines become one of critical process for succeeding the company to meet the demand. Potential failures that threat the stability and continuity of production process should be minimized. All potential failures could be considered as risk. It becomes important for the company to identify the risk that potentially threat their production process. Failure Mode and Effects Analysis (FMEA) is a robust methodology that can be used to identify, classify, and analyze potential risk. This research aims to utilize FMEA methodology to analyze the risk in the poultry production process. Handling the limitation of traditional FMEA in assessing the risk score through expert judgement, this research applies fuzzy FMEA in its methodology. There are 89 potential risks of poultry feed production could be identified by applying Fuzzy FMEA. Mitigation efforts are prioritized on 39 corrective risks. Having accurate risk analysis will enable the company to develop properly mitigation efforts and securing their production process to meet the demand schedule.

1. Introduction

The increasing consumption of chicken meat in Indonesia by the year has a positive effect on the demand of poultry feed products. The high growth of chicken meat demand is attracting new players of poultry feed producers to enter Indonesia market. According to the Indonesia Association of Fodder Producers, poultry feed...
production grew 8.7% to 13.8 million tons in 2013 from 12.7 million tons in the previous year. The total production capacity of the company’s poultry feed mills in Indonesia increased by 16.1% from 3.1 million in tons 2012 to 3.6 million tons in the following year. Existing poultry feed producers are facing higher intensity of competition now. Their production process should be well managed to meet the demand schedule or they could lose their market share. The companies have to secure their production lines from interruption or failure. Failures can take in many forms consider as risk. The existence of risk in many activities of production process should be recognized.

There have been many approach available that can be used to identify risk. Failure Mode and Effect Analysis (FMEA) is one of the methodology that can be used to identify product or process problems before they occur (McDermott et.al., 2009). Many studies have been used FMEA approach to identify risk in their case. Feili et.al (2013) adopted FMEA methodology to determine, classify and analyze common failures in Geothermal Power Plant (GPP) project. Feili et.al. (2013) concludes that FMEA becomes a useful technique to predict possible failure modes and eliminate potential failure during the design and operation of GPPs. Differ with Feili et.al. (2013), Kumru and Kumru (2012) adopted fuzzy FMEA to identify potential failures in the purchasing process of public hospital. Fuzzy FMEA is applied to overcome the limitation of conventional FMEA such as the subjective and qualitative description, in natural language, the relative importance among the risk ratings, the difference of risk representation among the same ratings, and the knowledge shared among FMEA team members (Kumru and Kumru, 2012). Applying fuzzy FMEA resulted in recommendation of some corrective action in order to improve the purchasing process of public hospital (Kumru and Kumru, 2012). Wang et.al. (2009) also proposed fuzzy FMEA in risk evaluation. Wang et.al. (2009) argues that evaluating risk factors such as the occurrence (O), severity (S) and detection (D) required by FMEA methodology precisely may not be realistic in the real application. Thus, Wang et.al. (2009) suggested fuzzy FMEA instead of conventional FMEA for risk evaluation.

This paper focuses on implementing fuzzy FMEA to identify the potential risks that may occur along the poultry feed production process. Fuzzy FMEA is adopted to minimize the subjectivity of experts’ assessment in the risk factors evaluation stage. There is still no published record that applies fuzzy FMEA approach for identifying risk in the poultry feed production process. It is expected that this study could contribute to share knowledge regarding risk profile of poultry feed production process. As the purpose of FMEA approach is preventing product and process problems before they occur, this paper also expected to result some mitigation effort that can be applied to improve poultry feed production process. PT. X is employed as the case study to implement the fuzzy FMEA methodology. Following sections will describe about poultry feed production process at PT. X. Then, next section will explain the research’s method (section 3), the application of fuzzy FMEA for risk analysis of poultry feed production process (section 4), the research’s results (section 5), and the last (section 6) is conclusion.

2. Fuzzy Failure Mode and Effect Analysis (FMEA)

FMEA firstly introduced in the mid 1960’s in the aerospace industry as a tool to prevent safety accident and incident from occurring. It focused more on safety. In the late of twentieth century, the US automotive industry adopted FMEA technique as a quality improvement tool. As required by the ISO/TS 16949 standard, the suppliers of US automotive industry should adopted FMEA technique as an effort to prevent failures before they happen (McDermott et.al., 2009). Further development shows that FMEAs are widely applied outside the safety arena (Kumru and Kumru, 2012; Feili et.al., 2013).

The FMEA methodology also recommended by the international standards as one of the risk analysis techniques. By applying this methodology, the company can have a systematic process to identify potential failures to fulfill the intended function, to identify possible failure causes so the causes can be eliminated, and to locate the failure impacts so the impacts can be reduced (Dyadem Engineering Corporate, 2003). Although this technique do not require complicated statistics as other techniques, still it can yield significant savings for a company while at the same time reducing the potential costly liability of a process or product that does not perform as promised (McDermott et.al., 2009).
FMEA identify the risk of failure and its effects as three factors: severity, occurrence, and detection. Severity (S) conveys the consequence of the failure should it occur. Occurrence (O) reflects the probability or frequency of the failure occurring. While detection (D) is the probability of the failure being detected before the impact of the effect is realized. Each potential failure mode and effect is rated in each of these three factors on a scale ranging from 1 to 10, low to high. Usually an analyst or an expert is asked to assign these scores. Risk level of a component, process, or product is obtained by multiplying S, O, D scores, called as Risk Priority Number (RPN).

\[
RPN = S \times O \times D
\]  
(1)

The risk priority number (which will range from 1 to 1,000 for each failure mode) is used to rank the need for corrective actions to eliminate or reduce the potential failure modes. Those failure modes with the highest RPNS should be attended to first, although special attention should be given when the severity ranking is high (9 or 10) regardless of the RPN. Once corrective action has been taken, a new RPN for the failure is determined by reevaluating the severity, occurrence, and detection rankings. This new RPN is called the “resulting RPN.” Improvement and corrective action must continue until the resulting RPN is at an acceptable level for all potential failure modes (McDermott et.al., 2009).

Asking an analyst or an expert to assign scores ranging from 1 to 10 (as requested to obtain RPN) for the different factors considered would produce a false and unrealistic impression. Wang et.al. (2009) also stated that precisely evaluation on S, O, and D scores may not be realistic in real applications. Although this method simplifies the computation, converting the probability into another scoring system, and then finding the multiplication of factor scores are believed to cause problems. The relations between the probabilities and the factors can be different (linear or nonlinear) (Kumru and Kumru, 2012). Directly adopted this methodology can be called as implementing traditional FMEA.

This research attempt to handle the limitation of traditional FMEA as mentioned above by applying fuzzy FMEA. Fuzzy FMEA is used to determine the RPN, or can be called as RP Fuzzy Number (RPFN). Formula 2 will be applied for calculating RPFN.

\[
\text{RP Fuzzy Number (RPFN)}_{ij} = O_{ij} \otimes S_{ij} \otimes D_{ij}
\]  
(2)

Based on formula 2, Oij, Sij, and Dij will be the trapezoidal fuzzy numbers that represent the occurrence, severity, and detection evaluations for dimension i and failure mode j. Likelihood, impact, and detection factor can be evaluated by linguistic way. Linguistic term and fuzzy number that is used in evaluating likelihood, impact, and detection is shown on Table 1, 2, and 3 respectively. Importance index of L, I, and D factors can be also assessed by using linguistic term that can be shown in Table 4. The procedures of Fuzzy FMEA assessment conducted through following steps:

a. Determining fuzzy number of L, I, and D based on Table 1 and 2
b. Calculating aggregation of fuzzy assessment for L, I, and D factors which is based equation (3), (4), and (5).
c. Calculating importance index aggregation for L, I, and D which is based on equation (6), (7), and (8).

| No | IMPACT     | LIKELIHOOD | DETECTION     | Fuzzy Number |
|----|------------|------------|---------------|--------------|
| 1  | Insignificant | Rare      | Almost Certain | 1 1 2        |
| 2  | Minor      | Unlikely   | High          | 1 2 3        |
| 3  | Moderate   | Possible   | Moderate      | 2 3 4        |
| 4  | Major      | Likely     | Low           | 3 4 5        |
| 5  | Catastrophic | Almost Certain | Almost Uncertain | 4 5 5        |

| Linguistic Term      | 0  | 0.25 | 0.5 |
|----------------------|----|------|-----|
| Very Low (VL)        | 0  | 0    | 0.25|
| Low (L)              | 0  | 0.25 | 0.5 |
3. Poultry feed production process at PT. X

The description of poultry feed production process will be depicted by using IDEFO. IDEFO represents activity that can be used to analyze function and system performance. There will be input, output, control, and mechanism for each process. IDEFO level 0 and level 1 of poultry feed production process can be show in Fig. 1 and 2 respectively.

![Fig. 1. IDEFO level 0 of poultry feed production process](image1)

![Fig. 2. IDEFO level 1 of poultry feed production process](image2)
Based on Fig. 2, the poultry feed production process consists of eight main processes, namely storage process of raw material, grinding process, mixing process, pelleting process, crumbling process, cooling process, sieving process, and packaging process. Each process entails several activities. As identifying the risk of poultry feed production process lays on each activity, thus it necessary to describe the activities in each process. Fig. 3 depicts the activities in each process respectively, started with raw material storage process and end up with packaging process.

4. Risk identification

Examining the activities in each production process, the risk that may occur, their effects, and their risk drivers were identified by brainstorming technique. The concept of fault tree analysis is used in helping risk identification at brainstorming process. This method generates risk factor by identifying any potential negative event occurred on a business process. Identification of negative event could be done by:

1. Determining the purpose of each activity in each production process.
2. Determining sub system failure.
3. Determining risk driver that causing failures

The finding of risk identification process is shown in Table 3.
Table 3. Risk identification

| Code Activity | Risk Code | Risk | Potential Effect | Risk Driver |
|---------------|-----------|------|------------------|-------------|
|               |           |      |                  |             |

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| Code Activity | Risk Code | Risk | Potential Effect | Risk Driver |
|---------------|-----------|------|------------------|-------------|
| Raw Material Storing Process |
| A1-1 | R1 | Operator do not separate raw materials into two places | Hard and soft material will be mixed | Operator feels fatigue because of repetitive work |
| A1-2 | R2 | Trolley cannot work properly | Operator must lift up the sack manually | There is no regular maintenance of company's assets |
| A1-3 | R3 | Some of material is spilled out | The raw material amount that will be processed less than required | Operator is careless in filling sack that contains raw material |
| A1-4 | R4 | Minibean machine set up time is too long | Delaying the process | Lack of operator’s knowledge |
| A1-5 | R5 | Minibean machine stops suddenly in sending raw material process | Production process will be stopped temporarily | There is no regular maintenance of company's assets |
| A2-1 | R6 | Minibean machine's valve is opened | Many materials will be spilled out | There is no regular maintenance of company's assets |
| A2-2 | R7 | Raw material temporary storage tank is too full | Some materials that can't be accommodated in storage tank | Operator doesn't check the storage tank condition before filling the material |
| A2-3 | R8 | Some material are spilled out from minibean machine | The amount of material will be decreased in production process | Minibean valve is opened |
| Grinding Process |
| A2-4 | R9 | Operator fills additional substances and CPO oil into wrong storage | Additional substances and CPO oil will be mixed | Lack of operator’s knowledge regarding the SOP |
| A2-5 | R10 | Mixing happen between additional substances and CPO oil | Additional substances and CPO oil will be mixed | Operator feels exhaustion because repetitive job |
| Mixing Process |
| A3-1 | R11 | Grinder machine set up time is too long | Delaying the process | Lack of operator’s knowledge |
| A3-2 | R12 | Grinder machine can't be set up correctly | Delaying the process | There is no regular maintenance of company's assets |
| A3-3 | R13 | Intake machine set up time is too long | Delaying the process | Lack of operator’s knowledge |
| A3-4 | R14 | Intake machine can't be set up correctly | Delaying the process | There is no regular maintenance of company's assets |
| A3-5 | R15 | Intake machine's valve of hard material is opened | Many materials will be spilled out | There is no regular maintenance of company's assets |
| A3-6 | R16 | Intake machine stops suddenly in sending hard raw material | Production process will be stopped temporarily | There is no regular maintenance of company's assets |
| A3-7 | R17 | Some of hard material are spilled out from intake machine | The amount of material will be decreased in production process | Intake valve is opened |
| A3-8 | R18 | Grinder machine stops suddenly in grinding hard raw material | Production process will be stopped temporarily | There is no regular maintenance of company's assets |
| A3-9 | R19 | Hard material is not fully ground | The product quantity will decrease | Operator oversight to arrange the grinding machine velocity |
| A3-10 | R20 | Grinder machine's valve is opened | Many materials will be spilled out | There is no regular maintenance of company's assets |
| A3-11 | R21 | Some of material are still in hard form | The amount of gross product being not same with the amount material | The grinder velocity doesn’t fit with hard material dimension that is processed |
| A3-12 | R22 | Operator doesn't check grinder machine based on SOP | Many products that’s in out of specification or still in hard form | There is less education or sharing knowledge about machine handling |
| A3-13 | R23 | Mixer machine set up time is too long | Delaying the process | Lack of operator’s knowledge |
| A3-14 | R24 | Mixer machine can’t be set up correctly | Delaying the process | There is no regular maintenance of company's assets |
| A3-15 | R25 | Too much additional substances and CPO oil is filled into minibean machine | Some material can't be filled into minibean machine | Operator doesn't check the minibean machine condition before pouring the additional substances and CPO oil |
| A3-16 | R26 | Some of additional substances and CPO oil are spilled out | The amount of materials will be decreased in production process | Minibean machine valve is opened |
| A3-17 | R27 | Intake machine's valve of smooth material is opened | Many materials will be spilled out | There is no regular maintenance of company's assets |
| A3-18 | R28 | Many smoother materials are spilled out | The amount of material will be decreased in production process | Intake machine valve is opened |
| A3-19 | R29 | Some of pollutant are mixed with the smoother material | Product will be out of specification | It is done regular cleaning for company asset especially for machine |
| A3-20 | R30 | The composition of material mixing in each poultry classification is incorrect | Product will be out of specification | Lack in education or knowledge sharing about product receipt |
| A3-21 | R31 | Mixer machine stops suddenly in mixing | Production process will be stopped | There is no regular maintenance of company's assets |
| Code Activity | Risk Code | Risk | Potential Effect | Risk Driver |
|---------------|-----------|------|------------------|-------------|
| A3-5          | R32       | Mixer machine's valve is opened | Many materials will be spilled out | There is no regular maintenance of company's assets |
|               | R33       | All material are not mixed fully on its batch | Product will be out of specification | There is faultiness in setting frequency of mixing from mixer machine |
|               | R34       | Operator make mistake in checking mixer machine | Product will be out of specification | Operator doesn't wear safety equipment when entering the workstation |
|               | R35       | Operator's accidents | Create loses not only individual level but also in company level | |
| A3-6          | R36       | Several gross product are out of composition | Gross product will be out of specification and will be reprocessed | There is pollutant inside mixer machine |
|               | R37       | Sample taker equipment are not sterile | Can contaminate or mix into the product | There is no cleaning schedule for sample taker equipment |
|               | R38       | Composition checking equipment are not sterile | Can contaminate or mix into the product | There is no cleaning schedule for sample checker equipment |
| A3            | R39       | Pellet machine set up time is too long | Delaying the process | Lack of operator’s knowledge |
|               | R40       | Pellet machine can't be set up correctly | Delaying the process | There is no regular maintenance of company's assets |
| A4-1          | R41       | Some of gross product are spilled out | The amount of product will be decreased in production process | Intake machine valve is opened |
| A4-2          | R42       | Some of pollutant substances are mixed with gross product | Product result will be out of specification | It is done regular cleaning for company asset especially for machine |
|               | R43       | Some of gross product are still stacked on intake machine surface | The amount of product will be decreased in production process | It is done regular cleaning for company asset especially for machine |
| A4-3          | R44       | Pellet machine suddenly stops on pelleting process | Production process will be stopped temporarily | There is no regular maintenance of company's assets |
|               | R45       | Pellet machine's valve is opened | Many materials will be spilled out | There is no regular maintenance of company's assets |
|               | R46       | Some of pellet products are spilled out when pelleting process is done | The amount of pellet product will be decreased in production process | Pellet machine valve is opened |
|               | R47       | Gross products are not fully form becoming pellet | Product result will become out spec | |
| A4-4          | R48       | Some pollutants stick on pellet products | The results of product will have a different color and categorized as defect product | There is no regular maintenance of company's assets |
|               | R49       | There is color difference on some pellet products' surface | Results of the product is not in accordance with the results of the finished product expectations | Possibility of many impurities that contaminate the finished product |
| A5            | R50       | Crumble machine set up time is too long | Delaying the process | Lack of operator’s knowledge |
|               | R51       | Crumble machine can't be set up correctly | Delaying the process | There is no regular maintenance of company's assets |
| A5-1          | R52       | Several pellet products stick on intake machine's surface | The production process will be slower because of the existence of duct blockage in the engine intake | There is no regular maintenance of company's assets |
|               | R53       | Many of pellet products are not castaway intentionally | The amount of pellet product will be decreasing | Intake machine's sieve is opened |
| A5-2          | R54       | Crumble machine suddenly stops when crumpling process is running | The production process will be temporarily halted, and will cause losses | Lack of regular maintenance schedule on assets of the company |
|               | R55       | Crumble machine's valve is opened | Many pellet products will be spilled out | Lack of regular maintenance schedule on assets of the company |
| A5-3          | R56       | Pellet products are not fully formed into ball form | Product result will be out of specification | There is faultiness in inputting of velocity's frequency of Crumble machine |
|               | R57       | Many of crumble products are spilled out when crumpling process was done | The number of crumble product will be reduced and resulting less | Crumble machine's valve is opened |
| A5-4          | R58       | Many of pollutant substances adhere on crumpling products | Product will have different color and categorized as defect product | Lack of regular maintenance schedule on assets of the company |
| A6            | R59       | Cooler machine set up time is too long | Delaying the process | Lack of operator’s knowledge |
|               | R60       | Cooler machine can't be set up correctly | Delaying the process | There is no regular maintenance of company's assets |
| Code Activity | Risk Code | Potential Effect | Risk Driver |
|---------------|-----------|------------------|-------------|
| A6-2          | R61       | Many of pellet and crumbling products stick on intake machine's surface | The production process is longer | Lack of regular maintenance schedule on assets of the company |
|               | R62       | Leakage exist on intake machine's pipe | The amount of product will be decreasing | Lack of regular maintenance schedule on assets of the company |
| A6-3          | R63       | Cooler machine's valve is opened | Many crumble products are spilled out | Lack of regular maintenance schedule on assets of the company |
|               | R64       | Cooler machine suddenly stops when cooling process is running | Production process will be stopped temporary | There is no regular maintenance of company's assets |
|               | R65       | Cooler machine's fan doesn't operate | Production process will be stopped temporary | There is no regular maintenance of company's assets |
|               | R66       | Pellet and crumbling products are not fully becoming colder | Production process is longer | There is faultiness in inputting the velocity's frequency of fan cooler machine |
| A6-4          | R67       | Operator makes mistake in inspecting the product | Defect products are processed | Lack of operator’s knowledge |
| A7            |           | Sieving Process |                           | |
| A7-1          | R68       | Sieve machine set up time is too long | Delaying the process | Lack of operator’s knowledge |
|               | R69       | Sieve machine can't be set up correctly | Delaying the process | There is no regular maintenance of company's assets |
| A7-2          | R70       | Some of pollutants contaminate product result that has been cold | Product will be out of specification | Many pollutants are attached to the engine intake |
|               | R71       | Sieve machine's valve is opened | Many WIP material are spilled out | There is no regular maintenance of company's assets |
|               | R72       | Sieve machine suddenly stops when sieving process is running | Production process will be stopped temporary | There is no regular maintenance of company's assets |
|               | R73       | The quantity resulted doesn’t appropriate | Production process could not fulfill the product demanded | Filters on sieve machines clogged by many impurities or pollutants |
|               | R74       | Many impurities that are drifted from the sieve | Product will be out of specification | A leak in the filter of sieve engine |
| A7-4          | R75       | Granules settles in the bottom of sieve’ surface and can’t be transferred into material storage | The product quantity less than expected | The intake machine is too moist |
| A7-5          | R76       | Operator’s failure in inspecting the product | Product will be out of specification | Lack of operator’s knowledge |
| A8            |           | Packaging Process |                           | |
| A8-1          | R77       | Packaging machine set up time is too long | Delaying the process | Lack of operator’s knowledge |
|               | R78       | Packaging machine can't be set up correctly | Delaying the process | There is no regular maintenance of company's assets |
|               | R79       | The measurement of weighing machine doesn’t accurate | The products’ weight do not fulfill requirement | The operator made a mistake in resetting the scales |
| A8-2          | R80       | Operator miss to reset the weight categories based on the type of packaging sacks | The amount of product that comes out from the faucet valve do not match the sack’s size | Lack of operator’s knowledge |
|               | R81       | Product barrier valve doesn't work properly | Production process will be stopped temporary | There is no regular maintenance of company's assets |
| A8-3          | R82       | Faucet valve is clogged | Production process will be stopped temporary | There is no regular maintenance of company's assets |
| A8-4          | R83       | Sack that is used to wrap the products is broken | Leakage in filling product into the sack | Operators do not check the sack before starting |
|               | R84       | Many products are spilled during charging products | The amount of products will be decreased | Operator’s fatigues because of repetitive work |
|               | R85       | Sack straps do not function properly | The sacks will fall and the products inside the sack will be spilled out | There is no regular maintenance of company's assets |
|               | R86       | Packaging machine suddenly stops when filling process is running | The production process time is longer | There is no regular maintenance of company's assets |
| A8-5          | R87       | Sack's product wrapping is leaked | Product volume is reduced | Operators do not check sack before charging |
|               | R88       | Operator misplaced finished goods to storage classification in warehouse | Finished goods will be mixed among each sack's class | Operator’s fatigues because of repetitive work |
|               | R89       | Hand truck machine suddenly stops when products are transferred into warehouse | Finished goods transfer process will be disturbed | There is no regular maintenance of company's assets |
5. Application of fuzzy FMEA

Fuzzy FMEA is applied to calculate Risk Priority Fuzzy Number (RPFN) for each risk that has been identified. Based on the steps and formula given in section 2, the calculation of RPFN for each risk could be shown in Table 4.

| Risk Code | Risk                                                                 | Impact  | Likelihood | Detection | RPN  |
|-----------|----------------------------------------------------------------------|---------|------------|-----------|------|
| R1        | Operator does not separate raw materials into two places            | 1.517   | 1.059      | 1.059     | 1.701|
| R2        | Trolley cannot work properly                                        | 1.517   | 1.059      | 1.059     | 1.701|
| R3        | Many materials are spilled out                                      | 1.442   | 1.442      | 1.442     | 3.000|
| R4        | Minibean machine set up time is too long                           | 1.517   | 1.059      | 1.059     | 1.701|
| R5        | Minibean machine stops suddenly in sending raw material process     | 1.517   | 1.059      | 1.059     | 1.701|
| R6        | Minibean machine's valve is opened                                  | 1.517   | 1.059      | 1.059     | 1.701|
| R7        | Raw material temporary storage tank is too full                      | 1.671   | 1.671      | 1.671     | 4.667|
| R8        | Many material are spilled out from minibean machine                 | 1.727   | 1.727      | 1.495     | 4.462|
| R9        | Operator fills additional substances and CPO oil into wrong storage | 1.149   | 1.019      | 3.096     | 3.625|
| R10       | Additional substances and CPO oil are mixed                         | 1.149   | 1.019      | 3.096     | 3.625|

**Grinding Process**

| Risk Code | Risk                                                                 | Impact  | Likelihood | Detection | RPN  |
|-----------|----------------------------------------------------------------------|---------|------------|-----------|------|
| R11       | Grinder machine set up time is too long                              | 1.346   | 1.042      | 1.346     | 1.888|
| R12       | Grinder machine can't be set up correctly                            | 1.346   | 1.042      | 1.346     | 1.888|
| R13       | Intake machine set up time is too long                               | 1.346   | 1.042      | 1.346     | 1.888|
| R14       | Intake machine can't be set up correctly                             | 1.346   | 1.042      | 1.346     | 1.888|
| R15       | Intake machine's valve of hard material is opened                    | 1.346   | 1.042      | 1.346     | 1.888|
| R16       | Intake machine stops suddenly in sending hard raw material           | 3.096   | 1.019      | 1.149     | 3.625|
| R17       | Many hard material are spilled out from intake machine               | 3.096   | 1.019      | 1.149     | 3.625|
| R18       | Grinder machine stops suddenly in grinding hard raw material         | 3.096   | 1.019      | 1.149     | 3.625|
| R19       | Hard material is not fully grinded                                   | 1.369   | 1.369      | 1.811     | 3.394|
| R20       | Grinder machine's valve is opened                                    | 1.369   | 1.369      | 1.811     | 3.394|
| R21       | Some of material are still in hard form                              | 1.369   | 1.369      | 1.811     | 3.394|
| R22       | Operator makes mistake in checking grinder machine                   | 1.369   | 1.369      | 1.811     | 3.394|

**Mixing Process**

| Risk Code | Risk                                                                 | Impact  | Likelihood | Detection | RPN  |
|-----------|----------------------------------------------------------------------|---------|------------|-----------|------|
| R23       | Mixer machine set up time is too long                                 | 1.346   | 1.042      | 1.346     | 1.888|
| R24       | Mixer machine can't be set up correctly                              | 1.346   | 1.042      | 1.346     | 1.888|
| R25       | Too much additional substances and CPO oil is filled into minibean machine | 1.346   | 1.042      | 1.346     | 1.888|
| R26       | Some of additional substances and CPO oil are spilled out            | 1.346   | 1.042      | 1.346     | 1.888|
| R27       | Intake machine's valve of smooth material is opened                  | 1.346   | 1.042      | 1.346     | 1.888|
| R28       | Many smoother materials are spilled out                              | 1.346   | 1.042      | 1.346     | 1.888|
| R29       | Some of pollutant are mixed with the smoother material               | 1.369   | 1.369      | 1.811     | 3.394|
| R30       | The composition of material mixing in each poultry classification is incorrect | 1.369   | 1.369      | 1.811     | 3.394|
| R31       | Mixer machine stops suddenly in mixing the material                 | 3.096   | 1.019      | 1.149     | 3.625|
| R32       | Mixer machine's valve is opened                                      | 1.442   | 1.122      | 2.000     | 3.238|
| R33       | All material are not mixed fully on its batch                        | 1.442   | 1.122      | 2.000     | 3.238|
| R34       | Operator makes mistake in checking mixer machine                    | 1.369   | 1.369      | 1.811     | 3.394|
| R35       | Operator's accidents                                                | 1.346   | 1.042      | 1.346     | 1.888|
| R36       | Some gross product result are out of composition                     | 1.346   | 1.042      | 1.346     | 1.888|
| R37       | Sample taker equipment is not sterile                                | 1.346   | 1.042      | 1.346     | 1.888|
| R38       | Composition checking equipment is not sterile                        | 1.346   | 1.042      | 1.346     | 1.888|

**Pelleting Process**
| Risk Code | Risk                                                                 | Impact | Likelihood | Detection | RPN  |
|----------|----------------------------------------------------------------------|--------|------------|-----------|------|
| R39      | Pellet machine set up time is too long                               | 1.346  | 1.042      | 1.346     | 1.888 |
| R40      | Pellet machine can't be set up correctly                             | 1.346  | 1.042      | 1.346     | 1.888 |
| R41      | Some of gross products are spilled out                               | 1.346  | 1.042      | 1.346     | 1.888 |
| R42      | Some of pollutant substances are mixed with gross product            | 1.442  | 1.122      | 2.000     | 3.238 |
| R43      | Some of gross product still stick on intake machine surface          | 1.442  | 1.122      | 2.000     | 3.238 |
| R44      | Pellet machine suddenly stops on pelleting process                   | 3.096  | 1.019      | 1.149     | 3.625 |
| R45      | Pellet machine's valve is opened                                     | 1.346  | 1.042      | 1.346     | 1.888 |
| R46      | Some of pellet products are spilled out when pelleting process is running | 1.346  | 1.042      | 1.346     | 1.888 |
| R47      | Gross products are not fully form becoming pellet                     | 1.442  | 1.122      | 2.000     | 3.238 |
| R48      | Some pollutants stick on pellet products                             | 1.346  | 1.042      | 1.346     | 1.888 |
| R49      | There is color difference on some pellet products' surface           | 1.346  | 1.042      | 1.346     | 1.888 |

### Crumbling Process

| Risk Code | Risk                                                                 | Impact | Likelihood | Detection | RPN  |
|----------|----------------------------------------------------------------------|--------|------------|-----------|------|
| R50      | Crumble machine set up time is too long                              | 1.346  | 1.042      | 1.346     | 1.888 |
| R51      | Crumble machine can't be set up correctly                            | 1.346  | 1.042      | 1.346     | 1.888 |
| R52      | Many pellet products stick on intake machine's surface               | 1.346  | 1.042      | 1.346     | 1.888 |
| R53      | Many pellet products are castaway intentionally                       | 1.346  | 1.042      | 1.346     | 1.888 |
| R54      | Crumble machine suddenly stops when crumbling was happening          | 3.096  | 1.019      | 1.149     | 3.625 |
| R55      | Crumble machine's valve is opened                                    | 1.346  | 1.042      | 1.346     | 1.888 |
| R56      | Pellet products are not fully formed into ball form                   | 1.289  | 1.616      | 1.919     | 3.995 |
| R57      | Many crumble products are spilled out when crumbling process is running | 1.346  | 1.042      | 1.346     | 1.888 |
| R58      | Some of pollutants adhere on crumbling products                       | 1.346  | 1.042      | 1.346     | 1.888 |

### Cooling Process

| Risk Code | Risk                                                                 | Impact | Likelihood | Detection | RPN  |
|----------|----------------------------------------------------------------------|--------|------------|-----------|------|
| R59      | Cooler machine set up time is too long                               | 1.346  | 1.042      | 1.346     | 1.888 |
| R60      | Cooler machine can't be set up correctly                             | 1.346  | 1.042      | 1.346     | 1.888 |
| R61      | Some of pellet and crumbling products stick on intake machine's surface | 1.346  | 1.042      | 1.346     | 1.888 |
| R62      | The leakage happens on intake machine's pipe                         | 1.346  | 1.042      | 1.346     | 1.888 |
| R63      | Cooler machine's valve is opened                                     | 1.346  | 1.042      | 1.346     | 1.888 |
| R64      | Cooler machine suddenly stops when cooling process was done          | 3.096  | 1.019      | 1.149     | 3.625 |
| R65      | Cooler machine's fan doesn't operate suddenly                        | 3.096  | 1.019      | 1.149     | 3.625 |
| R66      | Pellet and crumbling products are not fully becoming colder          | 1.346  | 1.042      | 1.346     | 1.888 |
| R67      | Operator makes mistake in inspecting the product                     | 1.732  | 1.189      | 1.189     | 2.449 |

### Sieving Process

| Risk Code | Risk                                                                 | Impact | Likelihood | Detection | RPN  |
|----------|----------------------------------------------------------------------|--------|------------|-----------|------|
| R68      | Sieve machine set up time is too long                                | 1.346  | 1.042      | 1.346     | 1.888 |
| R69      | Sieve machine can't be set up correctly                              | 1.346  | 1.042      | 1.346     | 1.888 |
| R70      | Some of pollutants contaminate product result that has been cold     | 1.346  | 1.042      | 1.346     | 1.888 |
| R71      | Sieve machine's valve is opened                                      | 1.552  | 1.149      | 1.552     | 2.766 |
| R72      | Sieve machine suddenly stops when sieving process is running         | 3.096  | 1.019      | 1.149     | 3.625 |
| R73      | The quantity resulted doesn’t appropriate                            | 1.552  | 1.149      | 1.552     | 2.766 |
| R74      | Many impurities are drifted from the sieve                           | 1.552  | 1.149      | 1.552     | 2.766 |
| R75      | Granules settles in the bottom sieve's surface and can't be transferred into material storage | 1.346  | 1.042      | 1.346     | 1.888 |
| R76      | Operator makes mistake in checking the sieve machine                 | 1.552  | 1.149      | 1.552     | 2.766 |

### Packaging Process

| Risk Code | Risk                                                                 | Impact | Likelihood | Detection | RPN  |
|----------|----------------------------------------------------------------------|--------|------------|-----------|------|
| R77      | Packaging machine set up time is too long                             | 1.346  | 1.042      | 1.346     | 1.888 |
| R78      | Packaging machine can't be set up correctly                           | 1.346  | 1.042      | 1.346     | 1.888 |
| R79      | The measurement of weighing machine doesn’t accurate                  | 1.552  | 1.149      | 1.552     | 2.766 |
| R80      | Operator fail to reset the weight categories based on the type of packaging sacks | 1.552  | 1.149      | 1.552     | 2.766 |
| R81      | Product barrier valve doesn't work properly                          | 1.346  | 1.042      | 1.346     | 1.888 |
| R82      | Faucet valve is clogged                                              | 1.346  | 1.042      | 1.346     | 1.888 |
| R83      | Sack that is used to wrap the products is broken                      | 1.727  | 1.727      | 1.495     | 4.462 |
| R84      | Many products are spilled during charging products                    | 1.552  | 1.149      | 1.552     | 2.766 |
| R85      | Sack straps do not function properly                                 | 1.369  | 1.369      | 1.811     | 3.394 |
| R86      | Packaging machine suddenly stops when filling process is running     | 1.346  | 1.042      | 1.346     | 1.888 |
| R87      | Sack's product wrapping is leaked                                     | 1.552  | 1.149      | 1.552     | 2.766 |
| R88      | Operator misplaced finished goods to storage classification in warehouse | 1.332  | 1.332      | 2.089     | 3.706 |
| R89      | Hand truck machine suddenly stops when products are transferred into warehouse | 1.671  | 1.019      | 1.671     | 3.625 |
6. Risk evaluation and mitigation

Observing the RPFN, it can classified the risk into corrective and non-corrective risk. Risk that has RPFN more than 2.449 are categorized as corrective risk. Further, those risks also can be classified as extreme, high, medium, and low risk based on their likelihood and impact. Mitigation efforts are proposed for risks that are classified as corrective risk. Mitigation efforts could be in form of reducing the likelihood and impact, transfer the risk, avoid the risk, and accept the risk. This research found 38 risks from 89 total risk are classified as corrective risks. Based on these 38 risk, mitigation efforts are proposed. Evaluating the existing condition, this research proposed that actually there are 59 ways to reduce the impact and likelihood, 47 ways to avoid the risk, 13 ways to transfer the risk, and 11 ways to accept the risk. Some mitigation efforts to be proposed are setting regular maintenance schedule for production machines, reinforce employee to conduct based on SOP, training for the new employee, etc. The highest proportion of mitigation efforts is reducing the impact and likelihood of the risk. This effort dominates compare to others because of the business process of poultry feed production is already running. It would be difficult for the company to implement avoid mitigation effort in the running process.

7. Conclusion

This research is applying fuzzy FMEA methodology to identify, classify, and evaluate the risk that happen in the poultry feed production process. Fuzzy approach is used to calculate the Risk Priority Fuzzy Number (RPFN). Fuzzy is adopted to handle the limitation of traditional FMEA where it is difficult for the expert to assess the risk likelihood, impact, and its detection precisely. There are 89 operational risk that are successfully identified in the poultry feed production process. Those 38 of the identified risks are classified as corrective risk. These corrective risks are classified based on their RPFN. As the function of FMEA to identify failure (risk) before it happens, this research also proposes some mitigation effort that could be taken to mitigate the risk. Mitigation efforts are dominated by reducing the likelihood and impacts effort compare to others types of mitigation. It because the reducing effort is the most realistic efforts that the company can implement when the business process have been already running. Implementing the mitigation efforts could benefit the company from the losses caused by the occurring risk.

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