A FMEA-based Approach to Identify Risk of Damage for Besuki Na-Oogst Tobacco Leaves

Identifikasi Risiko Kerusakan Daun Tembakau Besuki Na-Oogst Menggunakan Pendekatan berbasis FMEA

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ABSTRACT

Besuki Na-Oogst tobacco is a type of plantation commodity that requires special handling. Improper post-harvest handling increases the risks of being damaged. This study aimed to identify the types of damage to Besuki Na-Oogst tobacco leaves, analyze the risk level of damage to Besuki Na-Oogst tobacco leaves, and provide recommendations for risk control of tobacco leaves damage. The Failure Mode and Effect Analysis method was applied to Identify the Besuki Na-Oogst tobacco leaves risk damages. This method can determine the value of severity, occurrence, and detection to obtain a critical Risk Priority Number (RPN) that indicates the most critical level of risk. The results showed that the types of damage to Besuki Na-Oogst tobacco leaf classified as having a high-risk impact were perforated leaves, oily leaves, white spots, blue spots, and moldy leaves indicated by RPN values greater than the critical value. If these risks are not appropriately handled, it can decrease the quality of the tobacco leaves, resulting in losses. The risk control of leaf damage is based on risk-causing factors in suggestions for improvements that the management can follow up.

Keywords: Besuki Na-Oogst tobacco leaves; critical value; FMEA; risk; RPN

ABSTRAK

Tembakau Besuki Na-Oogst merupakan jenis komoditas perkebunan yang memerlukan penanganan khusus. Penanganan pasca panen yang tidak tepat menimbulkan risiko yang tidak diinginkan yaitu daun tembakau menjadi rusak. Penelitian ini bertujuan untuk mengidentifikasi jenis kerusakan daun tembakau Besuki Na-Oogst, menganalisis tingkat risiko kerusakan daun tembakau Besuki Na-Oogst, dan memberikan rekomendasi pengendalian risiko kerusakan daun tembakau. Identifikasi risiko kerusakan daun tembakau Besuki Na-Oogst menggunakan metode *Failure Mode* and *Effect Analysis*. Metode ini dapat digunakan untuk menentukan nilai keparahan, kejadian, dan deteksi untuk mendapatkan *risk priority number* kritis yang menunjukkan tingkat risiko paling kritis. Hasil penelitian menunjukkan bahwa jenis kerusakan pada daun tembakau Besuki Na-Oogst yang tergolong berisiko tinggi adalah daun berlubang, daun berminyak, bercak putih, bercak biru, dan daun berjamur yang ditunjukkan dengan nilai RPN lebih besar dari nilai kritis. Jika risiko tersebut tidak ditangani dengan baik, maka daun tembakau akan mengalami penurunan kualitas yang dapat mengakibatkan kerugian. Pengendalian risiko kerusakan daun tembakau didasarkan pada faktor penyebab risiko berupa saran perbaikan yang dapat ditindaklanjuti oleh pihak perusahaan.

Kata kunci: Daun tembakau Besuki Na-Oogst; FMEA; nilai kritis; risiko; RPN

INTRODUCTION

Jember Regency is one of the largest tobacco producers in East Java Province, Indonesia. Based on Indonesian Plantation Statistics data in 2017, tobacco production in Jember Regency was 3,949 tons (BPS, 2017). One of the most widely developed tobacco types in the Jember Regency is Besuki Na-Oogst Tobacco.

Besuki Na-Oogst tobacco is a fancy product and has become a leading export-oriented commodity, especially as a raw material for making cigars (Wardhono *et al*., 2021; Pratama *et al*., 2018). Besuki Na-Oogst tobacco is known as cigar tobacco for dekblad. Dekblad is a cigar wrapper leaf which is the outermost part of a cigar. The use of dekblad as a cigar wrapper demands excellent quality and high economic value (Supriyadi *et al*., 2021).

Besuki Na-Oogst tobacco is tobacco planted at the end of the dry season and harvested during the rainy season (Djajadi, 2015). Tobacco plants require intensive care from planting preparation to post-harvest (Putri *et al*., 2015). Besuki Na-Oogst tobacco is a quality product that requires intensive care, such as the use of seeds, fertilizers, and pesticides that are not excessive. It involves caution in handling at harvest (Arifandi *et al*., 2018).

Post-harvest handling is also a critical stage that determines tobacco production, whose quality is acceptable to consumers. Post-harvest handling of Besuki Na-Oogst tobacco leaves has a considerable effect on the quality of dekblad. Post-harvest handling includes transportation of harvested tobacco leaves to the drying warehouse, sorting, curing, fermentation, and storage (Disbun Jatim, 2011). Damage to the dry Besuki Na-Oogst tobacco leaves will have an impact on decreasing the selling price.

Poor post-harvest handling of Besuki Na-Oogst tobacco will create risks. The term risk refers to the uncertainty of outcome (Chapman and Ward, 2003). Risk means the probability of losing all or part of the profit or the principal (Asadi, 2015). It focuses exclusively on the occurrence of bad things (Khorwatt, 2015). The risk of poor post-harvest handling can lead to bad things and losses. Post-harvest handlings such as harvesting, curing, fermentation, storage, and sorting pose a risk to Besuki Na Oogst tobacco leaves (Nisa *et al*., 2017). Improper post-harvest handling can damage the tobacco leaves produced, such as perforated, folded, oily, and moldy leaves and the appearance of white and blue spots on the leaves. Proper risk handling is expected to minimize the negative impacts that may occur. It is intended to be a preventive action process and reduce or sometimes eliminate causes of failures and potential failures. The decision-making in handling the risk of tobacco leaf damage is very important for the tobacco processing industry. We need a method to identify the associated risk with that option in the industrial system and implementation phases. The method that is considered appropriate to use is *Failure Mode and Effect Analysis* (FMEA).

FMEA is an analytical methodology used to ensure that potential problems have been considered and addressed throughout the product and process development process (Chrysler *et al*., 2008). FMEAs are an integral part of managing risk and supporting continual improvement (Widianti and Firdaus, 2017). FMEA is focused on identifying and preventing system, product, and process problems before they occur. It reduces costs by identifying system, product, and process improvements early in the development cycle. It prioritizes actions that decrease the risk of failure (Rakesh *et al*., 2013). FMEA is applied to potential shortcomings in product design and manufacturing processes where the benefits are clear and potentially significant (Doshi and Desai, 2017).

The FMEA method aims to determine the potential risk or the most critical level of risk by paying attention to risks that have a high probability of occurrence, have significant negative consequences or impacts, as well as opportunities to improve by detecting failure modes before an adverse impact occurs, which is indicated by the Risk Priority Number (RPN) value. RPN is calculated as the multiplication of likelihood of occurrence, severity, and detection rank (Chrysler *et al*., 2008). The analysis of the risk of damage to Besuki Na-Oogst tobacco leaves is based on RPN's calculation and its critical value.

The FMEA method can be applied to the processing industry to handle post-harvest risks that may occur. This study took one of the Besuki Na Oogst tobacco processing industries in the Jember Regency. This study aimed to apply the FMEA as a method to identify the risks of damage to Besuki Na-Oogst tobacco leaves, analyze the risk level of Besuki Na-Oogst tobacco leaf damage, and provide recommendations for risk control of Besuki Na-Oogst tobacco leaves damage.

RESEARCH METHODS

Research Method

This study used a case study method. The case study method is a method that aims to study and investigate an empirical event or phenomenon related to the object of research in-depth and in detail (Yin, 2009). The case study was conducted in one of the processing tobacco industries of Besuki Na-Oogstin Jember Regency, which was selected purposively. The scope of the research includes risk identification, risk assessment, and risk control of tobacco leaf damage in post-harvest processing of Besuki Na-Oogst tobacco.

Data Collection Method

This study used primary and secondary data. Primary data was obtained through field observations, interviews, and questionnaires. The key informants involved in the research were workers, warehouse heads, and land coordinators. The information needed includes the post-harvest handling process of Besuki Na-Oogst tobacco leaves, types of damage, causes of damage, and ways to deal with the damage caused. Secondary data were obtained from various related references, statistical data (BPS), and company documents. This study also used tobacco leaves as sample material to study the risk of damaging tobacco leaves in post-harvest processing.

Data Analysis Method

The risk analysis for post-harvest handling of Besuki Na-Oogst tobacco leaves used the Failure Mode and Effect Analysis (FMEA) method. Data processing using the FMEA method is carried out through several standard stages (Ora *et al*., 2017). The detailed steps for processing and analyzing data using FMEA in this study are as follows:

1. Identify potential failure modes and their effects to obtain a severity rating. Severity is carried out to analyze risk by calculating how big or the event's intensity affects the process output (de Souza and Carpinetti, 2014). Severity rating parameters can be seen in Table 1.
2. Identifying potential failure causes to see the failure rate (occurrence) on the assembly line.

Occurrence is the frequency of specific failure causes of a project that occur and produce a failure (Rakesh *et al*., 2013). Occurrence rating parameters can be seen in Table 2.

3. Identify controls that the company has carried out to determine the level of detection that exists (Ookalkar *et al*., 2009). Detection is an assessment of the probability that the current process control will specifically detect the root cause of failure (Rakesh *et al*., 2013). Detection rating parameters can be seen in Table 3.
4. Determine the value of severity (S), Occurrence (O), and detection (D) using a score range of 1-5 (Rakesh *et al*., 2013). An assessment of each mode of failure was obtained through field studies and discussions with related parties.
5. Calculate the Risk Priority Number (RPN) score. The RPN score is obtained from the multiplication of severity, occurrence, and detection values (Chrysler *et al*., 2008). RPN is an indicator to measure the risk of failure mode and determine the level of priority scale for improvements that must be done first (Kang *et al*., 2017).

$$\text{RPN} = (\text{Severity}) \times (\text{Occurrence}) \times (\text{Detection}) \qquad (1)$$

6. Assess the risk level based on two perspectives, namely the level of likelihood (tendency) and the level of impact (impact or risk) (Sutrisno and Lee, 2012). Risk can be categorized as a critical risk when the RPN value is above the required value.

$$\text{RPN critical value} = \frac{\text{Total RPN}}{\text{Total Risk}} \qquad (2)$$

7. Determine the causes of tobacco leaf damage's risk based on the critical RPN value to recommend improvement strategies in dealing with risks.

RESULTS AND DISCUSSION

Identification of Leaf Damage

Besuki Na-Oogst tobacco leaf damage is a risk that may occur during post-harvest handling. Tobacco leaf damage can occur during the harvesting, curing, fermentation, storage, and sorting processes. Damage to Besuki Na-Oogst tobacco leaves can affect the quality of tobacco leaves produced.

Table 1. Severity rating parameters

Scale	Parameter	Information
1	Negligible damage	Customers may not notice defects or damage
2	Minor damage	Customers will not feel a decrease in quality
3	Moderate damage	Customers will feel a decrease, but still within tolerance limits
4	High effect damage	Customers will feel a decrease in quality that is beyond tolerance limits
5	Very high effect damage	The effect is very influential on other qualities, and the customer will not accept it

Table 2. Occurrence rating parameters

Scale	Parameter	Information
1	Remote	For damage that is in an unusual condition and has never occurred
2	Low	For low-frequency damage
3	Moderate	For moderate frequency damage
4	High	For high-frequency damage
5	Very high	For very high-frequency damage

Table 3. Detection rating parameters

Scale	Parameter	Information
1	Certainly	For damage that has a very high chance of control
2	Easy	For damage that has a high chance of control
3	Quite difficult	For damage that has a moderate chance of control
4	Difficult	For damage that has a very low chance of control
5	Very difficult	For damage that has an uncertain chance of control

Based on the observations and interviews, several types of damage were found in the industry that became the research case study. The types of tobacco leaf damage include torn leaves, perforated leaves, folded leaves, white-spotted leaves, blue-spotted leaves, oily leaves, and moldy leaves. An illustration of the appearance of dried Besuki Na-Oogst tobacco leaves damaged can be seen in Fig. 1.

The torn leaf is damage to tobacco leaves torn on the leaf surface (see Fig. 1a/1b). Torn leaves are caused by mechanical influences such as piles and shaking and the sorting process that is not carried out carefully (Kementan, 2012; Titosastro and Musholaeni, 2015). The improper sorting process also has the potential to cause the leaves to fold. Several tobacco leaves are tied into bundles in the sorting process, and one bundle contains ten tobacco leaves. The tying process with raffia rope is prone to causing damage to the tobacco leaves to become folded (Muksin and Widianto, 2017).

Perforated leaves are damage that occurs to tobacco leaves during storage in warehouses. The damage was caused by pests or cigarette beetles (*Lasioderma serricorne*) that live and breed in the storage warehouse (see Fig. 1g). *L. serricorne* is the insect considered to cause the most damage to tobacco, especially cured tobacco leaves (Kathirvel

et al., 2019). *L. serricorne* damages tobacco by excavating tunnels and holes (Kim *et al*., 2020). Another tobacco leaf damage that occurs during storage in the warehouse is oily tobacco leaves (see Fig. 1e). Oily leaves represent damage to dry tobacco leaves during storage which is characterized by a dark color change. The color change is caused by intense pressure on the tobacco leaf pile from the pressure machine or excessive leaf pile, causing the dried tobacco leaves to stick together and release oil.

During storage in warehouses, tobacco leaves are also prone to mold growth (see Fig. 1h). Mold growth is a fairly common problem that occurs during extended periods of high humidity. The most common types of mold found in nature are the genera *Cladosporium*, *Penicillium*, *Alternaria*, *Aspergillus*, and *Mucor*. Tobacco hanging in a curing barn during extended periods of high humidity can provide an ideal environment for mold growth (Bailey, 2009). Mold problems can often be traced to poor ventilation within the curing barn. Poor ventilation that promotes mold growth can be caused by placing tobacco too closely on the tier rails, lack of suitable ventilators to allow adequate airflow or poor management of ventilation systems.

(a) Torn leaves (R1)   (b) Torn leaves (R2)   (c) Blue-spotted leaves

(d) Whited-spotted leaves   (e) Oily leaves   (f) Folded leaves

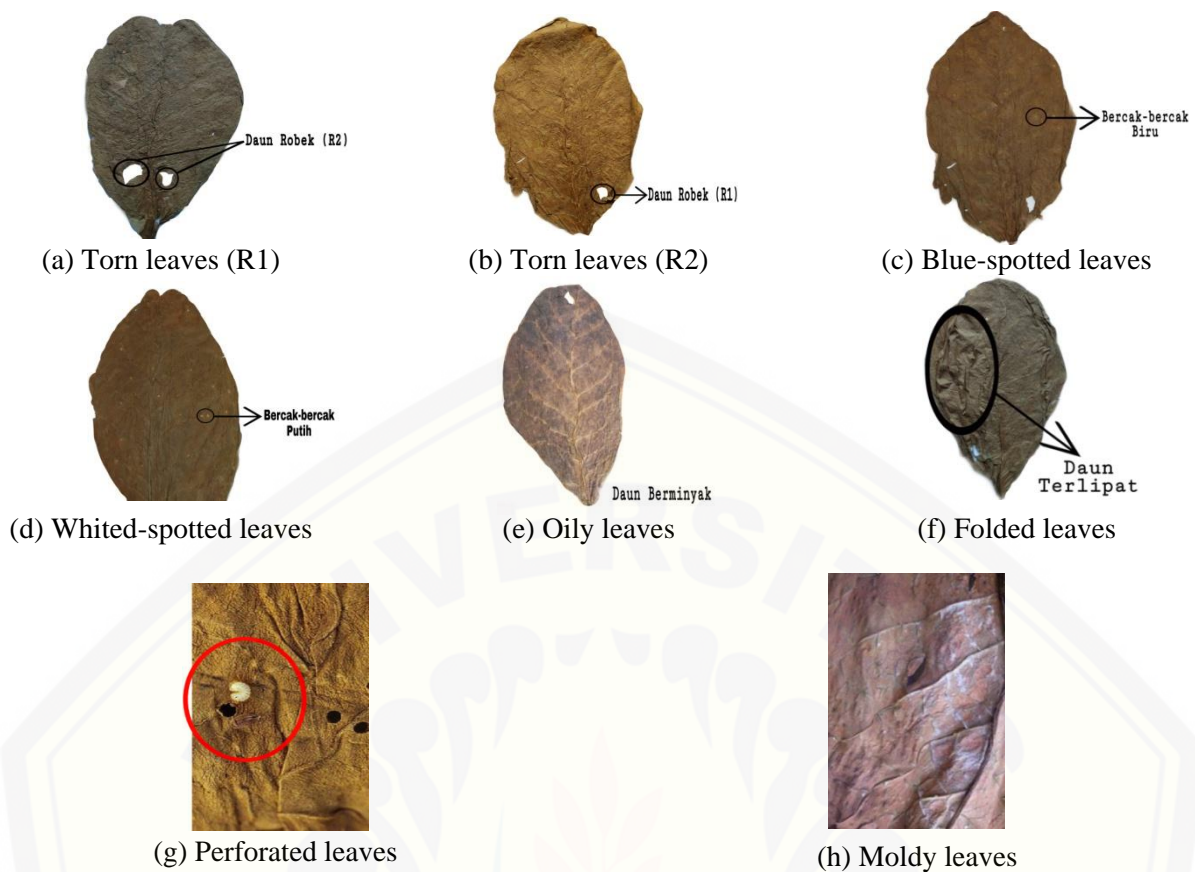(g) Perforated leaves   (h) Moldy leaves

Figure 1. The appearance of tobacco leaf damage

Blue spots are damage to tobacco leaves that occurs during the harvesting process (see Fig. 1d). Blue spots on tobacco leaves are caused by the short time between picking and fertilization. With inadequate irrigation, the vitamins contained in fertilizers cannot spread entirely to the entire surface of the tobacco leaves, resulting in blue clumps. In addition, the spots on the tobacco leaves are not only blue, but there are also white spots. White-spotted leaves or spikes are dry tobacco leaf damage during the curing process (see Fig. 1e). This damage is caused by the surface of the tobacco leaves being contaminated with water droplets around the drying warehouse and dew in the morning that enters through the drying warehouse window.

The damages that occur to Besuki Na Oogst tobacco leaves can have a negative impact on the resulting product. Damage to tobacco leaves results from changing the function of dekblad as a cigar wrapper into a cigar filler. Damaged tobacco leaves will also affect the taste and appearance of the resulting cigar. This causes consumers to dislike the product and lower the price. The impacts of tobacco leaf damage on the product are shown in Table 4.

Risk Analysis

The analysis of the risk of damage to Besuki Na-Oogst tobacco leaves is based on RPN's calculation and its critical value. Risk assessment aims to determine the potential risk or the most crucial risk level, taking into account risks that have a high probability of occurrence and have enormous negative consequences or impacts and opportunities for improvement by detecting the failure mode before an adverse effect occurs.

The results of calculating the RPN value of each type of damage to Besuki Na-Oogst tobacco leaves can be seen in Table 5. The risk of damage to tobacco leaves with the highest severity is white spots on tobacco leaves, as shown in Table 5. This damage will affect the quality of the cigars produced, especially the bland taste and pungent aroma. If this risk occurs, the negative impact is significant because the taste and aroma are quality attributes that greatly determine consumer acceptance of cigar products (Da Ré *et al*., 2018).

Table 4. Impact of tobacco leaf damage on products

No.	Type of Damage	Impact on Product
1.	Torn leaves (R1)	It can only be used on one side of the leaf for a cigar wrapper, while the other side of the leaf is used as a cigar filler.
2.	Torn leaves (R2)	- The leaves cannot be used for cigars because both sides are torn. - The impact on reducing the benefits of dry tobacco leaves is that the leaves are rubbed into chunks, which can only be used as a cigar filler.
3.	Perforated leaves	- The cigar's impact when it is burned and smoked is that a lot of oxygen enters through the hole, causing tightness of the suction. - If there are too many holes, the leaves are used as a filler or cigar filler. - The leaves appearance is less attractive
4.	Folded leaves	- Cannot tidy up when rolling the cigar pad - The leaves appearance is less attractive
5.	Whited spotted leaves	- The taste is bland - When used as a cigar bandage, the cigar looks less attractive - When used as a cigar filler, the aroma is robust
6.	Blue speckled leaves	- The taste is bland - When used as a cigar bandage, the cigar looks less attractive
7.	Oily leaves	The taste of the cigar is getting stronger, which causes a sore throat and coughing
8.	Moldy leaves	When used as a cigar bandage, the taste you get is that it can cause itching on the lips and mouth

Table 5. Calculation results of RPN

No	Type of Damage	The Severity of Average Rating	The Occurrence of Average Rating	The Detection of Average Rating	RPN
1.	Torn leaves (R1)	1,68	2,52	1,80	7,62
2.	Torn leaves (R2)	2,00	2,68	1,68	9,00
3.	Perforated leaves	3,04	2,32	2,68	18,9
4.	Folded leaves	2,04	2,36	2,20	10,59
5.	Whited spotted leaves	3,56	3,16	2,44	27,44
6.	Blue speckled leaves	2,92	2,76	2,52	20,30
7.	Oily leaves	2,88	3,68	2,40	25,43
8.	Moldy leaves	3,21	3,12	2,50	25,03
				Total RPN	144,31

Noted: The greater the severity rating, the more severe the impact of the risk; The greater the occurrence rating, the more often the risk frequency may occur; The greater the detection rating, the more difficult the risk can be detected by the system; The larger the RPN value indicates the priority of risk handling that needs to be done

Another unpleasant taste is an itchy feeling in the lips and mouth when consuming cigars. This taste occurs because cigars use dekblad derived from moldy tobacco leaves. These risks that have a high severity level need preventive actions so that these risks can be avoided.

The most common type of damage to tobacco leaves is oily leaves, indicated by the highest occurrence value (see Table 5). The oil that comes out of the tobacco leaves is caused by excessive pressure on the tobacco leaf pile. Oily leaf damage is one of the critical failures because it affects the cigar's taste to be very strong. Cigars with this taste are not liked by consumers so that they can lower the selling price. This damage often occurs, so appropriate and systematic action is needed so that when this damage occurs, it can be handled quickly.

The risks of damage to tobacco leaves are essentially easy to detect by the system. This can be seen from the reasonably low detection value, as shown in Table 5. The highest detection value is

perforated leaf damage. Among the other tobacco leaf damages, the perforated leaf damage is more difficult to detect by the system. Perforated leaf damage is caused by shedding pests (cigarette beetles). Damage to hollow leaves will be more challenging to detect if the condition of the storage warehouse is not clean, the warehouse is humid, the warehouse temperature is more than 55ºC, and the warehouse pest catcher or lasio trap is not adequate.

As a guide to finding out what risks need serious attention from the company, each risk that has been identified in the previous stage needs to be determined whether the risk is classified as critical or not. The determination of the critical risk value is based on the critical value of the RPN. Risk can be categorized as a critical risk when the RPN value is greater than the critical value. The critical value is obtained by dividing the total RPN by the entire risk of damage (see eq. 2). Based on the calculation, the resulting RPN value is 18.04.

Table 6. The critical value of RPN on each type of tobacco leaf damage

No.	Type of Damage	RPN	Critical value	Information
1.	Torn leaves (R1)	7,62		Not critical
2.	Torn leaves (R2)	9,00		Not critical
3.	Perforated leaves	18,90		Critical
4.	Leaves folded	10,59	18,04	Not critical
5.	Whited spotted leaves	27,44		Critical
6.	Blue spotted leaves	20,30		Critical
7.	Oily leaves	25,43		Critical
8.	Moldy leaves	25,03		Critical

Table 7. Risk control for tobacco leaves damage

No.	Type of Damage	Cause of Damage	Risk Control
1.	Perforated leaves	Barn pests or lasio *Lasioderma serricorne* F. beetles	- Discipline warehouse workers by holding a briefing once a week - Provides *Light Trap* or lasio cleaner
		Rice fields pests	- The window of the warehouse is given a net so that insects in the rice fields cannot enter directly, and air circulation is maintained properly - Repair the warehouse door with a rolling door so that the door is not always open
		Unclean warehouse	- Repair warehouse floors using ceramics so they don't get dirty and damp easily - Perform warehouse maintenance by scheduling pickets every three days to clean the warehouse
2.	Oily leaves	Too strong pressing pressure	Provide a barrier using a ruler made of iron so that it does not break easily along 30 cm
		Excessive stacking	Schedule workers once a week to move the bottom pile to the top pile
3.	Whited spotted leaves	Exposed to water droplets from around the drying warehouse	- Inspect and maintain the drying warehouse so that there are no holes - Check the drying shed windows during cloudy weather and early morning
4.	Blue speckled leaves	Picking time is too short and lacks watering	Give a sign using bamboo, which will be embedded in the ground and contains the date of the fertilization process and the irrigation process for the first and second time

The critical value of RPN for each type of damage to the leaves of dried tobacco leaves with Na-Oogst can be seen in Table 6. Table 6 shows that some tobacco leaf damage is considered a critical risk, and another damage is not a critical risk. Tobacco leaf damage which includes critical risks, are white spots on leaves, oily leaves, moldy leaves, and perforated leaves. These results indicate that the company should focus more on handling and preventive measures so that these risks do not have a negative impact on the company.

Risk Control

Risk control is the last stage the company must do after knowing the risks to be faced and analyzing these risks. The term risk control refers to ways to achieve its purpose in dealing with risk (Hollnagel, 2008). The risk control functions are the "what" needed to assure or increase safety, and the risk control systems are the "how" to implement the risk control functions (de Dianous and Fiévez, 2006). The verbs "prevent", "scontrol", and "mitigate" are also frequently used in describing the function of risk control (Roelen *et al.*, 2018).

Risk control is the set of ways by which companies evaluate potential losses and take action to reduce or eliminate such damages of tobacco leaves. Risk control is focused on the critical risk of damage to tobacco leaves based on the critical value of the RPN. The critical risk control for tobacco leaf damage is presented in Table 7.

CONCLUSIONS

1. There were several risks of damage identified in post-harvest handling of Besuki Na-Ooogst tobacco leaves, including torn leaves, perforated leaves, folded leaves, white-spotted leaves, blue-spotted leaves, oily leaves, and moldy leaves.
2. The risk assessment results indicate that the critical risks of damaging tobacco leaves include white spots on leaves, oily, mouldy, and perforated leaves. These risks need to be considered and handled appropriately.
3. The risk controls for tobacco leaf damage are based on risk factors. The risk control provided is in the form of improvement suggestions that the company can follow up.

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