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Risk Mitigation Design in the Production Process of Packaged Fruit Juice Drinks Using a Fuzzy Based House of Risk (HOR) Approach

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Abstract. Agro-industry is a sector that has quite diverse development potential, especially in the field of processing. One of them is processing fruit into fruit juice drinks. Nozy Juice is classified as an advanced MSME, but its competitive level is still lower than other agro-industry. This is because almost all of Nozy Juice's production activities are still done manually, giving rise to various risks that have an impact on decreasing the company's productivity level. To reduce this risk, a fuzzy-based House of Risk (HOR) approach is used which aims to identify the most critical risk agents. Then the risk mitigation design is carried out as an action plan. The essential risk of the 15 risk agents was a human error with an Aggregate Risk Potential (ARP) percentage of 24.275%. Furthermore, a risk mitigation design is carried out for 10 risk events. This is expected to minimize risks in the production process of packaged fruit juice drinks at Nozy Juice.

Keyword: Risk Mitigation, Agroindustry, Packaged Fruit Juice Drinks, Production Process, House of Risk (HOR), Fuzzy Logic

Abstrak. *Agroindustri merupakan salah satu sektor yang memiliki potensi pengembangan yang cukup beragam, terutama di bidang pengolahan. Salah satunya adalah pengolahan buah menjadi minuman sari buah. Nozy Juice termasuk UMKM yang tergolong maju, namun tingkat kompetitifnya masih lebih rendah dibandingkan agroindustri lainnya. Hal ini dikarenakan hampir semua aktivitas produksi Nozy Juice masih dilakukan secara manual, sehingga memunculkan berbagai risiko yang berdampak kepada penurunan tingkat produktivitas perusahaan. Untuk mengurangi resiko tersebut, digunakan pendekatan fuzzy based House of Risk (HOR) yang bertujuan untuk mengetahui agen risiko paling kritis. Kemudian dilakukan perancangan mitigasi risiko dalam bentuk action plan. Risiko kritis dari 15 agen risiko yang ditemukan adalah human error dengan persentase Agregate Risk Potential (ARP) sebesar 24,275%. Selanjutnya, dilakukan perancangan mitigasi risiko terhadap 10 kejadian risiko. Hal ini diharapkan dapat meminimasi terjadinya risiko pada proses produksi minuman sari buah berkemasan di Nozy Juice.*

Kata Kunci: Mitigasi Risiko, Agroindustri, Minuman Sari Buah Berkemasan, Proses Produksi, House of Risk (HOR), Logika Fuzzy

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1. Introduction

The potential of Indonesia's natural wealth is so large that the agricultural sector is one of the leading sectors. The abundance of natural resources requires effective and efficient management so that it can encourage high national economic growth, especially in small and medium agro-industry in the processing sector. One of the agro-industries in the processing sector that continues to increase is the fruit juice beverage sector. The sector experienced growth of 15% to 20% annually [1].

The rapid growth of the fruit juice drink market encourages increasingly competitive competition so every company must have the right strategy in increasing the company's profitability, especially those that focus on the production cycle. In general, the mechanisms run by local companies still use a manual system to reduce production costs which will certainly have an impact on the company's productivity level and are vulnerable to the emergence of risks [2]. Risk is a common thing and happens in a business. Companies should identify the causes and effects of risk through risk management. In this risk management process, it must be carried out continuously to achieve company efficiency and effectiveness through the application of risk mitigation to reduce the impact of the risks caused [3] [4].

The risk management process can be completed through several stages of various methods consisting of HOR (House of Risk) and Fuzzy Logic. Subsequent research shows that supply chain risk analysis can be carried out using the House of Risk (HOR) model [5] [6] [7] [8]. Such a representation of the work system has encouraged many studies that use a fuzzy logic approach in solving problems, including risk analysis in the production process [9] [10], risk analysis and mitigation in the supply chain [11] [12].

Nozy Juice, as one of the agro-industries in Aceh, has expanded widely by distributing its products to more than 300 outlets almost throughout Aceh and has even visited parts of North Sumatra. Production activities carried out every day in 6 working days are 100-200 bottles/day. The risks in production activities found in Nozy Juice come from labour, machines, vendors, product distribution processes, and other risks. In addition, the activities carried out by Nozy Juice are still carried out manually so they are very vulnerable to risk. Based on this information, this research aims to identifying the risks, calculating and mapping the risk agents and risk events, planning the mitigation scenario, and designing the action plan.

2. Related Work

Risk is the possibility of variations that occur naturally or the occurrence of unexpected events resulting in a threat to property and finance [13]. Risk will be disrupting the company performance. The company then will suffer losses in terms of cost, time, and quality of work. One of the risks that often occurs in a company is an operational risk [14]. Risk management is a planning and decision-making activity in dealing with risk uncertainty through effective risk management to minimize risks in the future.

HOR is a method that integrates failure modes and effect analysis (FMEA) with the House of Quality (HOQ) focuses on preventive action by measuring the priority level of the most optimal risk agent for intervention to reduce or eliminate risk with a robust system [4] [15]. The HOR method consists of two stages: HOR 1 and HOR 2. HOR 1 is used to determine risk agents that require intervention in reducing risk. One of the research projects is located at the local coffee production company. The company should treat 16 risk agents to minimise the supply chain risks [11].

Fuzzy logic is a vague logic, where the value in this logic is "true" and "false" simultaneously [16]. Both values depend on the membership weight expressed in the binary number. This research shows that there is 7,623% optimisation of the system by implementing the fuzzy-based scenario. Then, this logic indicates the extent to which a value is declared true or false. Fuzzy logic is one of the right ways to map an input space in an output space and has a sustainable value [9].

3. Methodology

There are five steps in the methodology of this research. The steps are (1) Risk Identification and Classification. In this step, it is necessary to identify the risks based on both the previous research and the real situation at the company; (2) Determination of Risk Value Using Aggregate Risk Potential (ARP). Each risk has its own characteristics; therefore, it is necessary to calculate the value of each risk; (3) Risk Evaluation. The company has limitations in treating all risks, therefore it is crucial for the company to list the priority to treat the risks. The top priority risks based on the 20:80 principle of the Pareto Diagram will then be input for risk scenario preparation steps; (4) Risk Scenario Preparation Using Mamdani's Fuzzy Logic. The results of this step will ensure that the risk scenario is valid and possible to be applied; and (5) Risk Mitigation Design.

4. Result and Discussion

4.1. Risk Identification

Risk identification is carried out to find out the risks and risk agents that have occurred in the company so far by using references based on previous research. The identification results are obtained through direct verification of the company's stakeholders. Table 1 shows the risk events while table 2 shows the risk agents. There are 15 risk events at the company. These risk events are based on the literature review and the real situation of the company. There are also 15 risk agents which influence the risk events.

Table 1 Risk Event

No	Risk Event
1	Raw materials arrive late
2	Production machine breakdown
3	Operator error in the production process

4	Production results do not meet standards
5	Packaged bottles cannot be used
6	Bottle caps cannot be used
7	Defective raw materials
8	Drink spilled during filling process
9	Labels cannot be used
10	The packaging bottle broke when it was filled
11	Semi-finished materials cannot be used
12	The specifications of the raw materials that came did not match the requirement
13	Packaging is damaged due to environmental factors in the warehouse
14	The packaging bottle has a leak
15	Product damaged in cold storage

Table 2 Risk Agent

No	Risk Agent
1	There was a problem during the delivery of raw materials
2	The packaging bottle is damaged
3	The bottle cap is damaged
4	Raw materials are damaged during storage
5	The label is damaged
6	Human error
7	Lack of control
8	Weather problems
9	Lack of Human Resources (HR)
10	Lack of coordination between members
11	Environmental conditions in the warehouse are not conducive
12	Not routine machine maintenance
13	Lack of inspection when packaging raw materials are received
14	Cold storage doesn't work when the power goes out
15	Inadequate cleaning of raw materials

4.2. Aggregate Risk Potential (ARP) Determination

The indicators for risk scoring are severity, occurrence, and correlation. We determine the value by giving questionnaires to respondents involved with the production process. Firstly, we calculate both the severity of risk events and the occurrence of risk agent score. After that, we calculate the correlation between the risk events and the risk agent. The value of three indicators is the basis for ARP calculation. Table 3 shows the ARP results. Based on the results, risk agent B6 which is Human Error ranked first out of 15 risk agents and risk agent B8 which is Weather problem ranked last.

Table 3 Risk Agent

Risk Event	***Risk Agent***															***Severity (Si)***
	B1	**B2**	**B3**	**B4**	**B5**	**B6**	**B7**	**B8**	**B9**	**B10**	**B11**	**B12**	**B13**	**B14**	**B15**	
A1	9						3	3								3
A2						3	9		1			9				8
A3						9	3		3							8
A4						3	9		1	3	3	3				6
A5		9									1		3			7
A6			9								1		3			9
A7	3			9							3					9
A8						3	1									4
A9					3	9	1									7
A10		1														5
A11				1		9	3	1							9	3

A12						9	9						3			5
A13		3	3			1	3		1	1	9					4
A14		9				1	1						3			3
A15						3	3		1	1				9		5
Oj	4	6	6	4	3	5	4	5	4	3	3	3	5	5	4	
ARP	216	642	558	336	63	1.415	1.016	60	188	81	291	270	360	225	108	
Pj	10	3	4	7	14	1	2	15	11	13	8	6	5	9	12	

Colour	Value	Description
	0	No relation
	1	Weak relation
	3	Fair relation
	9	Strong relation

4.3. Risk Evaluation

After the ARP ranking, we calculate the percentage of ARP to total ARP and cumulative percentage. The calculation is to evaluate the priority risks for mitigation. Figure 1 is a Pareto Diagram of the calculation results. The Pareto diagram systematics has the 80/20 rule. It states that for every 80% of the risk event effect is influenced by 20% of the causes. Thus, risk agents within 20% of the total value can be declared as a potential cause of risk and must be mitigated. Risk agent B6 is the only risk agent to mitigate because it meets the 20% requirement of the Pareto Diagram concept.

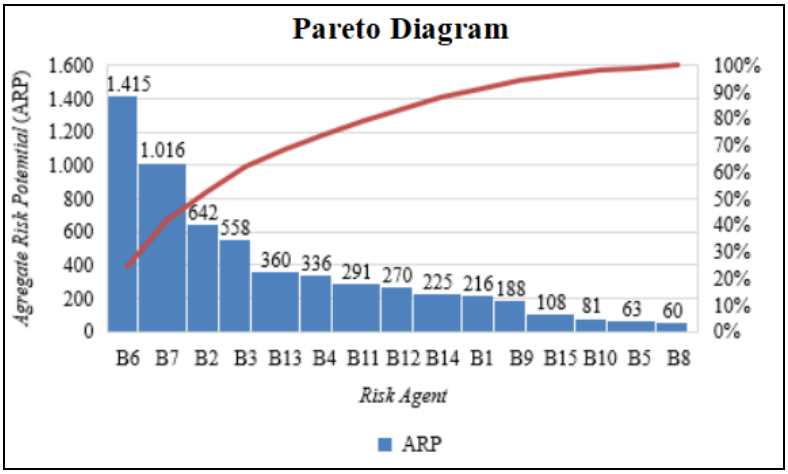

Figure 1 Pareto Diagram

4.4. Risk Scenario Preparation Using Mamdani's Fuzzy Logic

The risk preparation process uses the Fuzzy Inference System on the MATLAB fuzzy logic toolbox. In making Mamdani fuzzy logic consists of several stages. Firstly, we perform a fuzzification which forms a fuzzy set. Then, the membership function is applied by determining the membership value based on the input variable. Thirdly, we determine the composition of the rules related to the rules of the fuzzy set. The final stage is defuzzification using the centroid method which the final result is the risk status. The risk status will serve as an affirmation of whether a risk is easy or difficult to overcome. It is also to support the decision in risk mitigation. Figure 2 shows there are five selected rules based on a logical scenario. In the image defuzzification results on the input and output, there is a box called crips. The chips show fuzzy variables, fuzzy sets, and the parameters of each variable. The red line on the human error

variable (B6) is at a value of 708. This value indicates that it is possible to treat the risk of human error (B6). The membership function shows that the parameter between 0 to 708 is treatable.

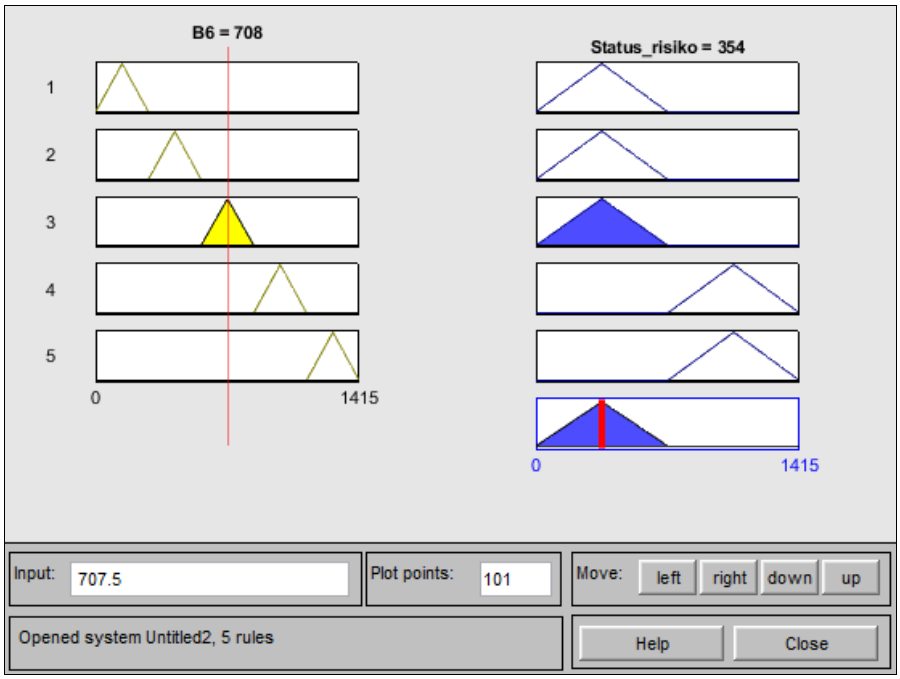

Figure 2 Defuzzification Result (Rule View)

4.5. Risk Mitigation Design

The risk mitigation is purposely designed for selected risks based on the House of Risk (HOR) method, namely Human error (B6). It has the highest value of risk agent that causes various risks in the production process of packaged fruit juice drinks. Based on the preparation of scenarios using fuzzy logic, the Human error (B6) is feasible to overcome with a risk mitigation status that is easy to solve. Table 4 shows the mitigation design.

Table 4 Action Plan for Human Error

Risk	Risk Mitigation	Data Traceability	Control Documents
Machine breakdown	Preventive maintenance	Analyze the type of damage that often occurs and consult the routine schedule of machine checks	A maintenance card is placed on each machine accompanied by the last date of maintenance and the date of the upcoming maintenance
Operator error in the production process	Create and place work instructions near workstations and kanban cards	List of operators who work at each work station, the type of product being worked on, make a checklist on the work stations that have been skipped	Types of products, tools and materials needed, work orders placed near the work station
Production results do not meet standards	Work instruction	List of operators who work at each work station, the type of product being worked on, make a checklist on the work	Types of products, tools and materials needed, work orders placed near the work station

		stations that have been skipped	
Drink spilled during filling	Make a jig to hold the packaging bottles	Make a jig according to the size of the packaging bottle	Jig placed on bottling station
Labels cannot be used	Training on labelling and important indicators on labels	Guidelines for the installation of packaging labels	Label Document
Semi-finished materials cannot be used	Carry out inspections and read work instructions	List of operators who work at each work station, the type of product being worked on, make a checklist on the work stations that have been skipped	Types of products, tools and materials needed, work orders placed near the work station
The specifications of the raw materials that came did not match what was needed	Make SOP for procurement of goods	Type of goods, specifications, quantity, and price	Agreement document in ordering goods
Packaging is damaged due to environmental factors in the warehouse	Kanban System	Provide markings on good goods to enter the warehouse, operators who distribute goods to the warehouse, warehouse capacity, storage procedures, number of goods entering the warehouse	Guidelines in warehouse management and storage instructions
The packaging bottle has a leak	Doing inspection	Checking the physical condition of the packaging bottles	If there is a leaking bottle, then immediately move it to the product section which will be returned to the vendor
Product damaged in cold storage	Create SOPs for product storage that is easy for operators to implement	Room temperature, the layout of product placement by type, and procedures for picking up products	Instructions for placing the product layout, instructions on how to take it from the refrigerator, and instructions for using storage temperatures

5. Conclusion and Future Research

Based on the identification results of 15 risk events and 15 risk agents in the production process of packaged fruit juice drinks, the highest ARP value was Human Error with a value of 24.275%. This Human Error then becomes a priority for risk mitigation. The risk status obtained based on the scenario preparation with fuzzy Mamdani found that human error can be overcome with the risk mitigation status easily overcome. The design of risk mitigation consists of 10 action plans for various risks caused by human error. In further research, the preparation of risk mitigation scenarios can use more than one method so that the comparison between the two methods, such as FMEA and HOR, can be seen to obtain more valid and concrete outputs.

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