Journal of Halal Science and Research (JHSR)
Vol. 6, No. 1, Month February, Year 2025, Page 1 – 11
doi: 10.12928/jhsr.v6i1.8816

P-ISSN: 2715-6214
E-ISSN: 2964-4909

Analyzing swelling characteristic of Nata de Coco: A Study on quality control challenges and solutions

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ABSTRACT
Nata de coco is a food product derived from fermented coconut water with the help of the bacterium *Acetobacter xylinum*. CV ABC is the company that always produces nata de coco and notices the quality of the product. The problem in this study lies in the product standard testing, which often results in deviations from the swelling capacity test and the oversized test, which do not comply with company standards, thereby reducing the quality of Nata de Coco products. This research activity aims to analyze and formulate solutions related to the factors that cause deviations in production results. The method used is quantitative, with a graphical control chart to determine the magnitude of deviations that occur in the swelling capacity test and oversize test. Fishbone diagrams determine the factors causing nata de coco to deviations from company standards. The data is in the form of documentation of the results of the swelling capacity test and the oversized test of 15 data. Data collection used a random sampling technique, which involved taking 400 grams of samples of nata de coco from each batch. The results of the 15-day analysis showed that the swelling capacity test did not meet company standards by 7 days, or 47%, and the oversized test did not meet the maximum limit by 4 days, or 27%. Factors that dominate the causes of irregularities are equipment and people. There is a need for machine standardization and employee discipline to maintain the quality of nata de coco.

Article History
Submitted: August 8, 2024
Revised: January 10, 2024
Accepted: January 19, 2025
Published: February 25, 2025

Keywords
Nata de coco, Oversize, Swelling capacity.

INTRODUCTION

The type of nata commonly found in the community is nata de coco (Sarwoko, 2020). Nata de coco (NDC) uses coconut water and *Acetobacter xylinum* bacteria. It has a chewy texture and a transparent white appearance. The failure of nata de coco production is due to bacterial growth factors, sterility of the appliance, temperature, pH, starter type, starter concentration, medium concentration, room temperature, and fermentation duration (Nurhasanah et al., 2017). Some of the media that produce nata include guava (nata de syzygium) (Wahyuni & Jumiati, 2019), tala (nata de tala) (Safitri et al.,

P-ISSN: 2715-6214
E-ISSN: 2964-4909

2018), jackfruit straw bark juice (nata de jackfruit) (Rose et al., 2018), and snake fruit (nata de salacca) (Salelatu & Rumahlatu, 2016).

The formation of nata de coco is caused by the activity of cellulose bacteria, which are shaped like capsules. These bacteria get trapped in the fibrillar mass of cellulose and turn into stacked cellulose threads. *Acetobacter xylinum* is a commonly used bacterium in producing nata de coco. It grows in carbon and nitrogen media and works in an alkaline environment. These environmental conditions produce extracellular enzymes that convert sugar into cellulose (Asri & Wisanti, 2017).

Nata de coco is a fermented coconut water product using *Acetobacter xylinum* as a growth medium containing carbon (sugar), hydrogen, nitrogen, and acid. Nata is a thick membrane containing 35-62% cellulose, cloudy white, and rubbery (Sari et al., 2017). CV ABC is a food company that produces nata de coco. The company, founded in 2003, has a lot of experience maintaining high-quality nata de coco products. One of the special concerns is related to product quality standard testing.

The main quality parameters of Nata de Coco are swelling capacity and oversized tests. These parameters indicate the absorption and retention of water in a huge amount of polymers (Saputra & Ruth, 2019). The purpose of the control test is to ensure that the quality of the nata de coco produced is by company standards so that the quality of the product is guaranteed. The swelling capacity test is a way to measure the difference in weight of nata before and after soaking (Dewi & Permatasari, 2021). The swelling capacity or expansion test is useful for knowing the nata yield. The swelling test standard the company sets is 1000 to 1100 grams or with a 1:5 ratio scale. To ensure the swelling capacity results meet the standards, yield calculations range from 5 to 5,5. Meanwhile, the oversized test is a test on particles that have a size larger than the standard has been established (Junaidi, 2019). The oversize test is used to determine how much deviation the size of the nata de coco pieces produced is against the size criteria set by the company.

As a developed company, increasing demand for nata de coco products has an impact on increasing the intensity of the nata production process, and there will be the potential for new problems related to the quality of the products produced. This problem can be found in the nata de coco product type 12 (0,3 cm), where deviations from the swelling capacity test and oversize test often occur. The swelling capacity and the cut results (oversized test) of nata de coco, which is not by the company's quality standards, affect the yield obtained. This is a concern in the production process, especially when pressing and cutting nata de coco, which companies may experience material and labor losses. A deeper analysis of how the nata de coco production process complies with company standards is needed. In this study, the causes and effects of the problems that occur during the production process can be known, and then how to solve them can be arranged so that the quality of nata according to company standards can be obtained.

RESEARCH METHOD

Materials

The materials used in this study are nata de coco type 12 from CV ABC and water. Tools used are machine cutting conveyors, press machines, digital scales (SF 400), stirrer machines, jars, spoons, and sieves (100 mesh).

Methods

1. Quantitative Method

   The quantitative method collects data in numbers that can be added to categories in order of rank and then measured in units of measurement. Data types are useful for creating graphs and tables of raw data. The principal goal of research is to answer the problem. Problems are deviations from what should be what happened (Balaka, 2022). The data that has been obtained is then analyzed by calculating how much the results of the swelling capacity test and the oversized test are appropriate and not according to company standards using a control chart. A control chart is used to monitor the stability of the standard test and determine changes in test results from time to time.

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2. Qualitative Method

   Qualitative analysis is carried out by processing or analyzing data based on observations, interviews, and documentation (Primayandi & Khairi, 2022), which aims to solve the problems that occur with the causes of discrepancies in the results of swelling capacity tests and oversized nata de coco. Qualitative data are analyzed, compared to company standards that affect product quality, and presented in a fishbone diagram. The fishbone diagram is a diagram that is used to find the causative factors of deviations (Rahman, 2021). This diagram is important to choose the right cause of the problem, organize the relationship, and determine the right solution.

RESULT AND DISCUSSION

Aeration will occur every two days of fermentation (Permata & Hidayah, 2024). *Acetobacter xylinum* can only grow optimally in aerobic conditions, at around 28ºC, and a pH range between 3.5 and 7.5 (Putri et al., 2021). Failures in the Nata de Coco production process often hinder improving product yields (Nurdin & Nurhidayah, 2023). The high yield is because, during fermentation, the ratio between carbon and nitrogen works optimally and is well controlled (Layuk et al., 2012). According to Nursiwi et al. (2018), the failure of nata de coco products is generally due to a lack of knowledge of *Acetobacter xylinum* starters. During fermentation, aeration is performed every 2 days by thorough mixing.

In addition to these technical considerations, ensuring the halal status of nata de coco is crucial for meeting consumer expectations and expanding market reach. Nata de coco's halal integrity depends on the carbon and nitrogen sources used during fermentation, typically sugar, urea, or ammonium sulfate. It is essential to verify that these ingredients and their processing aids do not originate from non-halal or impure sources. For instance, if enzymes are used in sugar refinement, their origins, whether plant, microbial, or animal, must be scrutinized to ensure compliance with halal standards. Similarly, activated carbon used in sugar bleaching should be derived from permissible sources, such as coal or plant materials, rather than bones of non-halal animals. Implementing thorough halal certification processes can help maintain product integrity and consumer trust.

Swelling capacity test

The swelling capacity or expansion test is carried out before packaging to determine whether the production process, especially pressing, has been done properly. The swelling test aims to determine the ability of the nata membrane to absorb water (Al Baani et al., 2017). The swelling test measured the difference in weight of the nata de coco membrane before and after immersion (Dewi & Permatasari, 2021).

The pressing process can affect the results of the swelling capacity test due to water absorption or yield. A swelling capacity or expansion test is carried out to determine the yield of nata de coco. The yield is obtained by weighing the final weight resulting from the comparison process with the initial weight before processing (Kemalawaty et al., 2019).

The following are the working steps for the *swelling capacity* test

1. Weigh 200 grams of nata de coco type 12 after pressing and acidification steps and put it in a measuring jar.
2. Added 2 liters of water, closed the jar using plastic, and attached it to the stirrer engine.
3. Turn on the stirrer, set the speed at 600 rpm, and wait 10 minutes.
4. Turn off the stirrer when finished. Then, open the lid of the measuring jar.
5. Pour the developed sample into the filter, wait for 10 seconds, and then pour it back into the measuring jar.
6. Weigh the nata de coco test results.
7. The resulting yield is calculated with the formula:

$$\frac{swelling\ weight\ (gr)}{sample\ weight\ (200\ gr)} \times 100\%$$

The standard set by CV ABC for development test results is a ratio of 1:5, where every 200-gram sample of solid nata that is developed will produce a range of 1000 to 1100 grams. Then, the yield of

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E-ISSN: 2964-4909

the development test results is calculated to ascertain how much the percentage of the development results is to reach the nata yield standard, where it has been determined that the tolerance or yield standard is 5 – 5.5%. If the development test results are below or above the company's standard standards, then this indicates that the pressing process is not going well according to the instructions. The results of the swelling capacity test data or development test of nata de coco type NATA DE COCO can be seen in Table 1.

Based on the calculation results in Table 1, the NATA DE COCO swelling capacity test on the conveyor cutting machine, which was carried out for 15 days on the nata de coco sample (0.3 cm), showed that the total number of tests was 16,082 grams with an average known total weight of 1,072 grams. The total percentage yield obtained from the results of the swelling capacity test was 80.44%. The average yield was 5.36%, so it can be concluded that the overall average results of the swelling capacity and yield tests have met the company standards, where the company's minimum standard is 1000 grams. The maximum standard is 1100 grams, and the standard yield ranges from 5 to 5.5%. However, there were several days when the tested nata samples had swelling capacity and yielded test results that were below or exceeded the standards set by the company.

Table 1. Swelling capacity test results and yield NATA DE COCO.

No	Date	*Swelling Capacity*				
		Sample Weight (g)	**Results**	**Standard (g)**	**Standard Maximum (g)**	**Yield (%)**
1	14/03/2023	200	955	1000	1100	4.78
2	15/03/2023	200	1262	1000	1100	6.31
3	16/03/2023	200	1158	1000	1100	5.79
4	17/03/2023	200	1008	1000	1100	5.04
5	18/03/2023	200	1058	1000	1100	5.29
6	21/03/2023	200	961	1000	1100	4.81
7	24/03/2023	200	1250	1000	1100	6.25
8	28/03/2023	200	1096	1000	1100	5.48
9	29/03/2023	200	971	1000	1100	4.86
10	30/03/2023	200	1032	1000	1100	5.16
11	31/03/2023	200	1076	1000	1100	5.38
12	03/04/2023	200	1091	1000	1100	5.46
13	04/04/2023	200	1023	1000	1100	5.12
14	05/04/2023	200	1105	1000	1100	5.53
15	06/04/2023	200	1036	1000	1100	5.18
Total		3000	16082	15000	16500	80.44
Average		200	1072.13	1000	1100	5.36

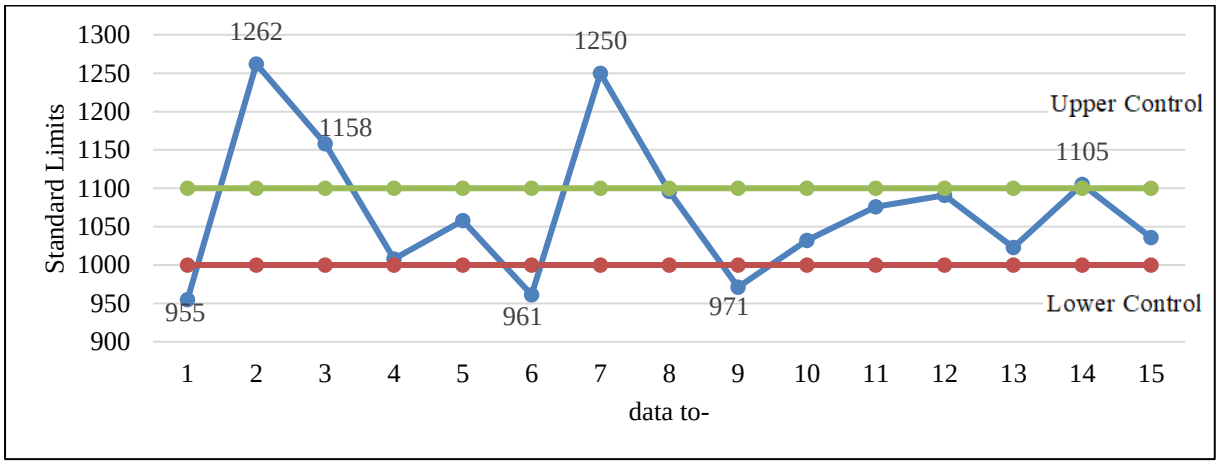

Figure 1. Control chart of swelling capacity test results.

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E-ISSN: 2964-4909

Based on Figure 1, the swelling capacity test results are known that results Tests that meet company standards are 8 days, namely on the fourth day, fifth day, eighth day, tenth day, eleventh day, twelfth day, thirteenth day, and fifteenth day. Meanwhile, the results are not based on the standard swelling capacity test, and the company's yield is 7 days on the first day, second day, third day, sixth day, seventh day, ninth day, and fourteenth day. The test results on the first day only reached 955, so the yield was only 4.78%. On the second day, the results of the swelling capacity test exceeded the company's standard, reaching 1,262 grams, which is a yield of 6.31%. On the third day, the result was 1,158 grams, so the yield was 5.79%, which exceeded the company's maximum standard. On the sixth day, it only reached 961 grams, so the yield was only 4.81%, less than the company's minimum standard. On the seventh day, the swelling capacity results exceeded the standard limit, reaching 1,250 grams, so the yield was known to be 6.25%. On the ninth day, the test results only reached 971 grams, so the yield only reached 4.86%; this did not meet the company's minimum standards. Furthermore, on the fourteenth day, the test results reached 1,105 grams, and it was known that the yield reached 5.53%, where these results exceeded the company's maximum standards.

Nata de coco that meets the standards is then subjected to a packing process, while nata de coco that does not meet company standards will be subjected to a pressing and acidification process until it meets company standards, namely with a ratio of 1:5. Test results that do not meet the standards will be detrimental to the company, it is necessary to handle or improve the production process. Factors that cause discrepancies between the swelling test results and company standards are the equipment or machines used during the production process, human factors related to employee performance, material factors related to the quality of the nata produced, and methods related to work instructions that are not followed. The following is a picture of a fishbone diagram to analyze the deviation factor that occurs in the nata de coco swallowing capacity test.

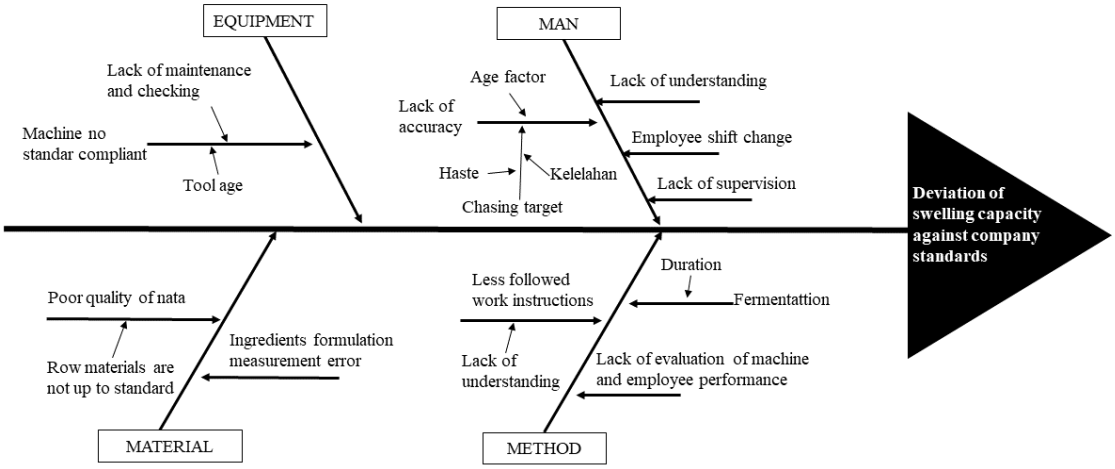

Figure 2. Fishbone diagram of the swelling capacity test.

Based on Figure 2, the deviation factors of the swallowing capacity test results are divided into four, namely equipment, people, materials, and methods. The following is an explanation of the causes of deviation in each factor:

1. Equipment Analysis

   The equipment or machine used for pressing is not up to standard, reducing the product's quality. In the press machine, due to not carrying out routine calibration or checking, the machine's strength in pressing nata is reduced; besides that, the placement of nata into the press is not quite fit, causing the result of pressing to be not optimal. Excessive or overloaded use of the machine can also affect the machine's work; the high demand for production makes the machine work intermittently continuously and does not pay attention to the maximum capacity of the machine; it can affect the machine's performance, which is not optimal. The age of the old

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and often used machine is prone to damage. Old machines whose performance is no longer optimal and less stable, thus affecting production results that are not up to standard. It is recommended that no feasible components be replaced with new components or spare parts to return to work optimally.

2. Man Analysis

   The human factor is the second factor causing deviations in the results of the swallowing capacity test. The lack of accuracy of employees in work is caused by age; employees who have entered their productive age decline cannot work properly because the performance of their sensory organs decreases. Then, due to consumers' high demand for production, employees must complete the pressing process quickly. This tends to make employees work in a hurry, so the level of accuracy decreases, and they experience fatigue more quickly. Furthermore, the employees' lack of understanding regarding the correct machine work system and lack of accuracy resulted in decreased production quality, so it did not meet company standards. Worker accuracy must be done with full concentration on the object being worked on. The workload must also be adjusted to the ability of employees and sufficient rest time.

3. Material Analysis

   The existence of material factors based on the quality of the nata produced is not good because the raw materials used are not according to standards. Selection of the right raw materials and the right dose can produce very good quality nata in terms of chemical, physical, sensory, and nutritional content. Measuring errors in the formulation of nata-making ingredients that do not pay attention to the provisions makes the nata produced not optimal. So, this affects the results of the pressing and swelling capacity test of nata de coco, which does not meet standards. There needs to be awareness for each employee, especially those involved in the cooking or fermentation processes, to be more careful and to be able to sort and select suitable nata to continue with the next production process. In addition, it needs regular supervision by the quality control team regarding all materials used for making nata that meet the criteria set by the company

4. Method Analysis

   Employees do not follow the work instructions that CV ABC has made and are not well understood, so miscommunication often occurs between one division and another, so the nata de coco production process does not go as planned. Work instructions that have been made are better understood and properly implemented to maintain product quality. In production, it is also necessary to carry out periodic evaluations regarding the performance of machines and employees so that it can be identified what deficiencies are and must be corrected to obtain quality nata and meet company standards; the lack of evaluation makes existing problems not be resolved immediately so the problem is getting worse accumulate so that the repair process will also take a long time. This disrupts production activities and hinders employee performance.

Oversized test

The next quantitative analysis is the oversized test, which determines deviations in the size of the nata de coco pieces produced against the standard or criteria for the size of the pieces the company has set. Measurement compares a quantity with a standard quantity (Junaidi, 2019). The observed nata de coco samples were 0.3 cm cut nata taken from the results of the swelling capacity test of 200 grams and came from a conveyor machine with a maximum oversize limit of 3%.

The following are the characteristics of oversized nata de coco pieces:

1. Has a size greater than 0.3cm
2. Has an indistinct shape
3. Shaped like a chain or nata, the results of the pieces are not separated, as shown in Figure 3.

The following is the procedure for oversizing nata de coco type NATA DE COCO:

1. Pour 200gr of NATA DE COCO, which has been developed for 10 minutes, into the tray.
2. Add enough water to the tray.
3. Oversized nata is taken and placed in a separate container.

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4. Weigh the total weight (grams) of the oversized nata de coco that has been collected.
5. Calculated the number of percent (%) oversize with the formula:

$$\frac{\text{oversized nata de coco } (gr)}{nata\ de\ coco\ total\ (200gr)} \times 100\%$$

Figure 3. Oversized Nata de coco cut.

The value obtained from the oversize test is used to determine the quality of the cut on the conveyor machine used. Oversize test observation data is presented in Table 2. Based on Table 2, the nata de coco oversize test on the conveyor cutting machine carried out for 15 days showed that the total number of oversize tests obtained a value of 48.8%, so the overall average is known to be 3.25%. This shows that the average cut of nata de coco has a deviation of 0.25% from the maximum oversized limit set by the company. There were 4 days of oversized test results that did not meet the company's standards: the first day, the third day, the sixth day, and the fourteenth day. The result of oversized nata de coco is shown in Figure 3.

Table 2. Nata de coco oversize test results on conveyor cutting machines.

No	Date	*Oversize* Test		
		Sample Weight	Results	Standard Limit (%)
1	14/03/2023	200	4.8	3.0
2	15/03/2023	200	2.9	3.0
3	16/03/2023	200	5.7	3.0
4	17/03/2023	200	3.0	3.0
5	18/03/2023	200	3.0	3.0
6	21/03/2023	200	4.1	3.0
7	24/03/2023	200	2.1	3.0
8	28/03/2023	200	2.4	3.0
9	29/03/2023	200	3.0	3.0
10	30/03/2023	200	2.9	3.0
11	31/03/2023	200	1.8	3.0
12	03/04/2023	200	2.0	3.0
13	04/04/2023	200	2.9	3.0
14	05/04/2023	200	5.8	3.0
15	06/04/2023	200	2.4	3.0
Total		3000	48.8	45.0
Average		200	3.25	3

The following chart compares the oversized data and company standard with samples of nata de coco for 15 days with a maximum limit of company oversized value of 3% (Figure 4).

Based on Figure 4, it is known that results that meet company standards are 11 days, and oversize test results that have exceeded company standard limits are 4 days, for which an oversize of 4.8% is obtained. This phenomenon means a deviation from the maximum oversized limit of 1.8%. On the third day, an oversize of 5.7% was obtained, meaning there was a deviation from the maximum oversize limit

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E-ISSN: 2964-4909

of 2.7%. On the sixth day, an oversize of 4.1% is obtained, the deviation from the maximum oversize limit is 1.1%, and on the fourteenth day, an oversize is obtained by 5.8%, resulting in a deviation of 2.8% from the maximum oversize limit set by the company (3%). Based on the results of the oversize test that has been carried out, deviations in size can reduce product quality so that it can reduce the level of consumer confidence in nata de coco products at CV ABC, cause losses or reduce company income and increase raw material costs seeing the many defects produced from cut nata conveyor machines, as well as the more waste generated due to defects.

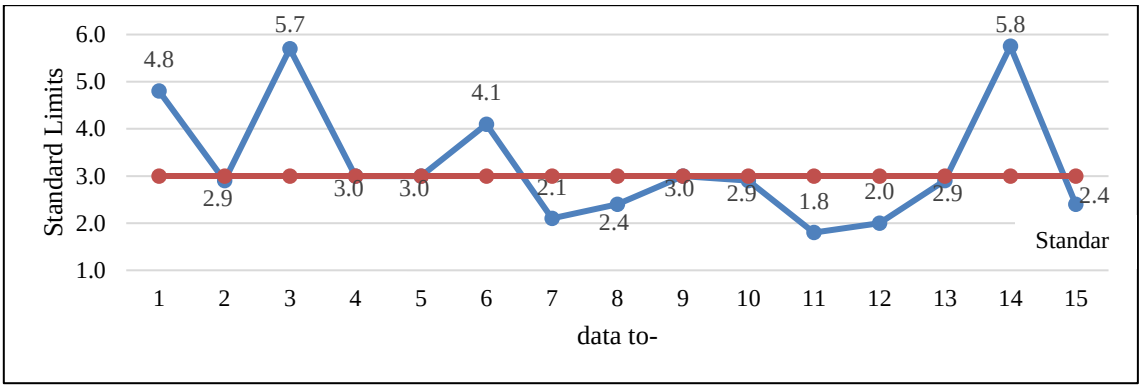

Figure 4. Comparison of standard and oversize.

The proportion of occurrences of oversized test results carried out for 15 days has been known to be by the maximum oversized limit (3%). Namely, there are 11 days, the percentage is 73%, and test results that do not match or exceed the maximum oversize limit are 4 days with a percentage of 27%. The deviations obtained are quite high, so it is necessary to analyze the causes of deviations in the results of nata de coco cuts so that nata, according to the cut standards, is obtained in the next production process.

Factors that cause deviations from the oversized test results are caused by the equipment used during the nata-cutting process that does not work optimally, the human factor related to employee performance, material factors related to the quality of the nata produced, and methods related to work instructions that are not followed. The following is a picture of a fishbone diagram to analyze the deviation factor that occurs in the nata de coco oversize test (Figure 5).

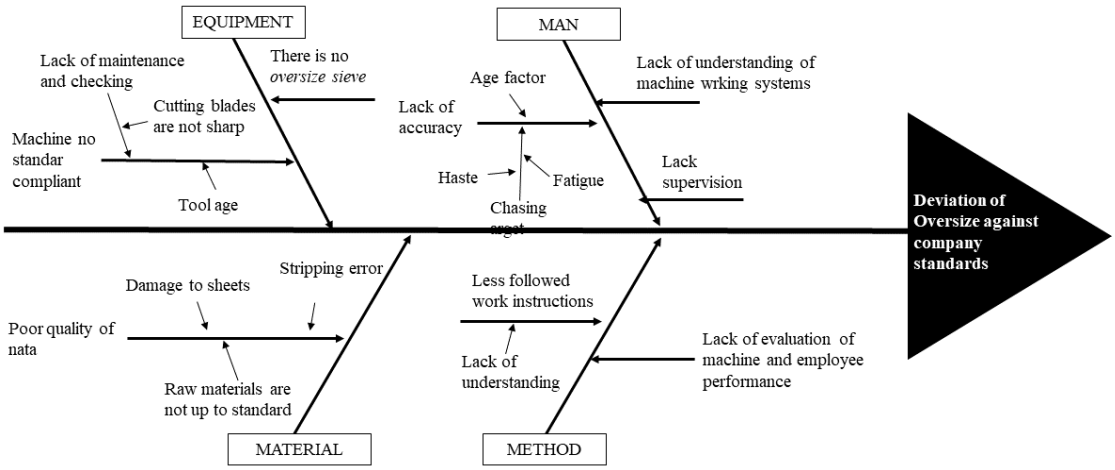

Figure 5. Oversize test fishbone diagram.

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E-ISSN: 2964-4909

Based on Figure 5 of the fishbone diagram of the oversized test, equipment is the main factor causing the deviation of cut nata de coco. Equipment or machines are the most important components in the cutting and pressing of nata de coco.

1. Equipment Analysis

   Equipment or machines used, especially in cutting conveyors, that are not up to standard reduce the quality of the nata produced. On a conveyor cutting machine, a knife that is not sharp enough causes the nata not to be cut evenly, and the improper placement of the nata on the cutting mat results in sloppy cuts, which is the cause of the high oversize value obtained. Care needs to be done both before and after use. Periodic maintenance is necessary because it significantly affects the engine components, so the engine remains stable and operates smoothly and properly.

   The age of the old and often used machine is prone to damage. Old machines no longer perform optimally and are less stable, thus affecting production results that are not up to standard. It is recommended that no feasible components be replaced with new components or spare parts to return to work optimally. There is no oversized sieve to facilitate the separation of nata pieces that exceed the size limit; the testing time is effective and efficient with an oversized sieve.

2. Human Analysis

The lack of accuracy in employees at work is caused by age; several employees have entered an age that is no longer productive, so they cannot work properly because the performance of their sensory organs decreases. Then, because of the high demand for consumer production, employees must complete the cutting process quickly. This tends to make employees work in a hurry, so the level of accuracy decreases, and they experience fatigue more quickly.

Furthermore, employees' lack of knowledge regarding the correct machine work system causes the cutting of nata to have many defects. Lack of accuracy and routine supervision resulted in the declining quality of nata de coco production and failure to meet company standards. The workload must also be adjusted to the employee's ability and adequate rest time.

3. Material Analysis

Material factors based on the analysis of the causes of deviations in pieces are due to the poor quality of the nata produced; this is because the raw materials used are not up to standard. Selection of the right raw materials and the right dose can produce quality nata. Fermenting the data for too long makes the texture of the nata tougher, so it is difficult to cut; also, when the fermentation takes place, the tray must be still or not shaken and must be tightly closed; this aims to keep the data so that it is perfectly formed.

Stripping the epidermis on the nata sheet that is not careful and thoroughly causes physical damage to the nata, such as the nata being torn apart so that the surface is uneven. This causes marks or holes on the surface so that when the sheet splits are imperfect or defective, a different thickness of nata is obtained; as a result, when cutting with a conveyor machine, many oversized nata defects are obtained. It is necessary to carry out routine supervision in the fermentation, stripping, splitting, and cutting divisions so that employees work in a disciplined manner and produce low-oversized defects. There is also a need for awareness for each employee to be more careful and to be able to sort and choose nata suitable for entering the production process.

4. Method Analysis

   The causative method factor is related to the work instructions that have been made by CV ABC, which are not followed by employees and are poorly understood, so there is often miscommunication between one division and another. Work instructions that have been made are better understood and properly implemented to maintain product quality. In production, it is necessary to regularly evaluate the performance of machines and employees to identify deficiencies that must be corrected to obtain quality nata and meet company standards.

   The skill and tenacity of the technician team in dealing with the causes of irregularities, especially in machines, is needed so that production continues to run smoothly with quality that meets standards. Then, the supervision of the production process by quality control staff 66 is expected to be more active and firmer so that all employees are more disciplined in the rules that have been set. Suppose all work components at CV ABC work together and coordinate well to

P-ISSN: 2715-6214
E-ISSN: 2964-4909

achieve the company's goals. In that case, all kinds of problems can be resolved easily so that the quality of Nata de Coco products and qualified human resources are superior.

CONCLUSION

Nata de coco swelling capacity did not comply with company standards as much as 47% of total production. Factors causing the improper swelling capacity are equipment or press machines that are not up to standard, lack of supervision by quality control staff, and work instructions that employees do not follow. Meanwhile, oversize test results do not meet company standards by 27% of total production. Factors causing the oversized test to exceed the maximum limit are equipment or cutting machines that are not optimal, the texture of nata de coco, and the lack of accuracy in checking and supervising the machine's work. Companies are advised to minimize deviations from nata de coco production to company standards by evaluating the entire production process, repairing equipment, and routine supervision.

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