DISSERTATION

OPTIMIZATION OF SUGARCANE PROCESS PRODUCTION USING RESPONSE SURFACE METHODOLOGY (RSM) AND ARTIFICIAL NEURAL NETWORKS (ANNs)

Submitted to fulfill the requirements for the Doctor of Engineering Degree
in the field of Mechanical Engineering

DEVIE OKTARINI
STUDENT ID. 03043681722008

ENGINEERING SCIENCE STUDY PROGRAM
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ENDORSEMENT PAGE

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I confirm that this dissertation, supervised by my Supervisor and Co-Supervisors, is authentic and plagiarism-free. I am willing to accept any academic consequences as per Sriwijaya University's regulations if any plagiarism cases are found in this dissertation.

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PREFACE

Alhamdulillah, I praise and thank Allah SWT for this mercy and grace, the owner of life and death on this earth, so that I can finish writing this dissertation report entitled **"Optimization of Sugarcane Process Production Using Response Surface Methodology (RSM) and Artificial Neural Networks (ANNs)"**.

The dissertation report is a prerequisite for achieving a Doctoral degree in the Engineering Science Study Program at the Faculty of Engineering, Sriwijaya University. The selected title underscores my unwavering commitment to our nation and state, particularly in the sugar industry. I am firmly convinced that upon completion of this report, the advancement of sugar production will substantially bolster state revenue in the plantation sector and sugar industry, ultimately contributing to self-sufficiency.

The completion of this report was delayed due to the Covid-19 pandemic. However, with the unwavering support of my parents and children, valuable advice from my friends, and guidance from my supervisor, I was able to regain my enthusiasm and confidence, ultimately enabling me to finish this report.

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15. The extended family of H. Bastari bin Ishak and KH. Abunawar bin H. Bakri
16. All parties that I cannot mention individually have helped me from the beginning of the research until the completion of this dissertation.

Palembang, July 19th, 2024

Writer

SUMMARY

OPTIMIZATION OF SUGARCANE PROCESS PRODUCTION USING RESPONSE SURFACE METHODOLOGY (RSM) AND ARTIFICIAL NEURAL NETWORKS (ANNs)

DISSERTATION

Devie Oktarinim, supervised by Prof. Dipl-Ing. Ir. Amrifan Saladin Mohruni, Ph.D., Prof. Ts. Dr. Safian Sharif, and Dr. Muhammad Yanis, S.T., M.T

xi + 108 pages, 36 figures, 29 tables

The sugarcane industry is crucial for Indonesia's industrial sector but has been declining, leading to increased sugar imports due to insufficient domestic supply. Factors contributing to this decline include the milling process and setup of sugarcane milling machines. Research on sugarcane milling stations' parameters has been conducted multiple times. However, research on clearance that has been carried out only discusses clearance between rollers. Even though the sugarcane that will enter the milling machine also has a clearance. The clearance of sugarcane is thought to influence the production of the amount of sugarcane juice. The first purpose of this study is to determine the effect of clearance of sugarcane, clearance of roller, and speed of roller on the optimization of the sugarcane production process. The second is to determine the optimum settings for the three parameters, and the last determine the optimal amount of sugarcane juice. The approaches used in this research are RSM with the CCD technique and ANNs with the backpropagation algorithm to predict and evaluate the optimum conditions. The results are best model based on the results of the RSM analysis for the mass of sugarcane juice is the quadratic model, the optimum conditions resulting from the prediction and evaluation using RSM are *n* is 12 rpm, *cs* are 2.4 cm, and c_2 is 1.74 cm with the resulting number of *mj* is 0.358 kg, then ANNs are *n* is 12.0 rpm, *cs* is 2.8 cm, and c_2 is 1.74 cm with the quantity of *mj* produced is 0.360 kg. Top roll rotation (1.60%) is the most significant influence on the mass of sugarcane juice. Followed by the clearance of sugarcane (1.51%). Then, rear clearance (1.06%). The sugarcane process production will be optimal with the condition top roll rotation is lower at *n* of 12 rpm, the clearance of sugarcane is higher at *cs* of 2.8 cm, and the rear clearance is lower at c_2 of 1.74 cm. The best method for optimization of sugarcane process production is ANNs by the MSE value was 0.000075 and mean % error value was 0.5704.

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CHAPTER 1
INTRODUCTION

1.1 Overview

This study was initiated by analyzing the independent variables that affect the production process of sugarcane juice, the primary material for sugar production. To ensure significant results, a prototype milling machine was developed based on the Cintamanis sugar factory's machine. Before the design phase, the first step involved determining the milling machine dimensions using dimensionless analysis. The subsequent step was to create an experimental design. The experiment's outcomes will be optimized and forecasted using the Response Surface Methodology (RSM) with the Central Composite Design (CCD) technique combined with Artificial Neural Networks (ANNs) through the Backpropagation technique.

1.2 Background of the Problem

The sugarcane industry is a strategic sector because this industrial commodity plays a crucial role in meeting people’s needs and serves as a raw material for various industrial sectors. This underscores the strategic value of the sugar industry for national food security and the enhancement of community economic growth, (Khairani *et al.*, 2023). In the sugarcane production process, the main ingredient used is the sugarcane plant (*Saccharum Officinarum*) for the cane sugar production. (Wani *et al.*, 2023). This plant is seasonal and thrives in tropical and subtropical regions. (Cheavegatti-Gianotto *et al.*, 2011).

According to data from the Ministry of Agriculture in 2023 (Kementrian Pertanian Republik Indonesia, 2024), that is national sugarcane

production only reached 2,610,658 tons. With a population of 279 million people total sugar consumption reaches 6,598,743 tons in the same year. The sugar cane industry is still the main industrial sector in Indonesia. The development of this industry has great potential to increase state income. It could have the greatest potential to become a source of state income. However, in recent years the industry has experienced a decline. Based on observations from various online news media sources, national sugar cane production only reached 2.3 tons with a population of 279 million people. Meanwhile, total sugar consumption reached 3.4 tons. So, the Indonesian government implemented a policy of importing raw sugars in the same year.

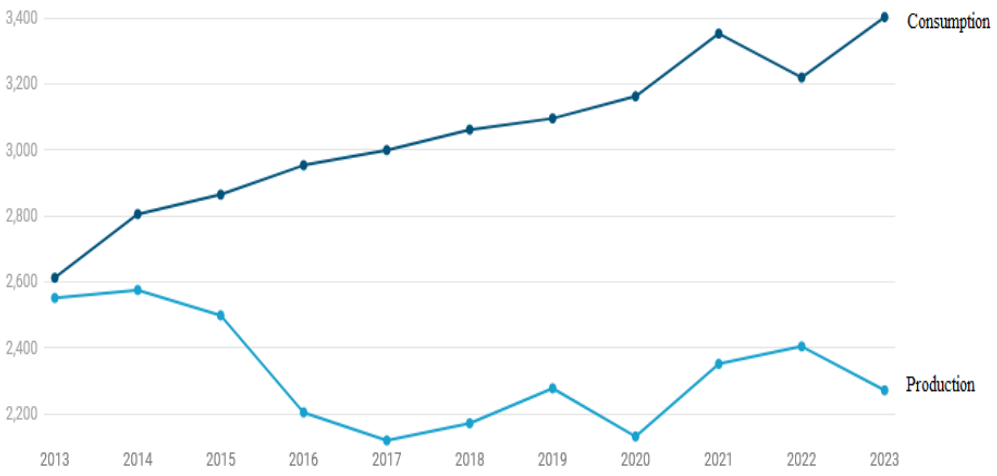

Figure 1.1 Comparison of Sugar Production and Consumption

In Figure 1.1, it can be concluded that sugar production is far behind sugar consumption. Low production means the sugar supply is insufficient to meet domestic needs; ultimately, the industry has to import. Until the end of 2022, according to sugarcane statistical data reported by the Indonesian Central Bureau of Statistics, the country will import up to 6 million tons. Based on supplier origin, 17 countries export sugar to Indonesia, of which Thailand

occupies the top position, with a share reaching 40.26%. Then followed India, Brazil, and Australia.

In 2023, the United States Department of Agriculture (USDA) stated that the global volume of raw sugar imports reached 57.4 million metric tons in the 2022–2023 trading season. In that season, Indonesia became the largest importer of raw sugar with a volume of 5.8 million metric tons, equivalent to 10.11% of total global imports. (CNBC Indonesia, 2024), see Figure 1.2.

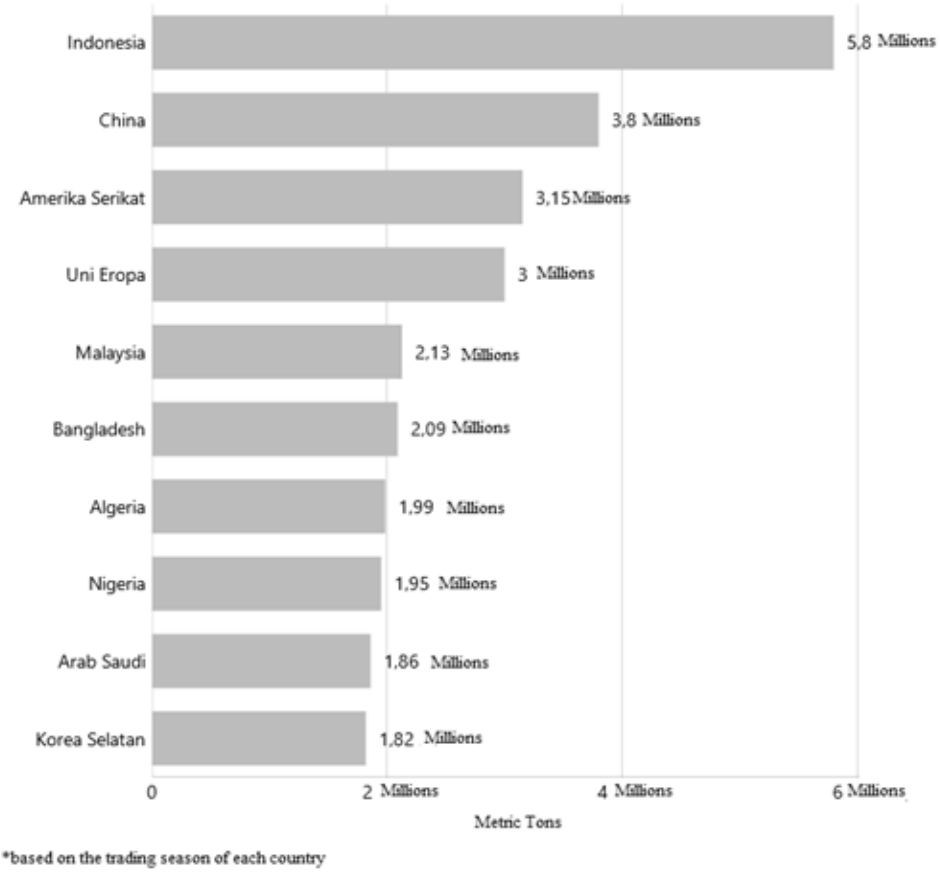

Figure 1.2 Raw Sugar Importing Countries

Several factors influence the decline in sugar production. The first factor is the process of milling sugarcane into sugarcane juice. Some analysts conclude that

the length of the milling process causes a decrease in production results. This condition occurs because most of the mills operated with inadequate milling capacity and were derived from the Dutch colonial era. (Iryani *et al.*, 2012; Prabowo, 2019). The capacity for milling sugarcane into sugarcane juice depends on the milling machine. In general, sugarcane mills in Indonesia use a milling machine consisting of three rollers: feed rollers, top rollers, and bagasse rollers. Each roller has a different function.

The second factor is the setting of the sugarcane milling machine. Besides inadequate milling capacity and originating from the Dutch colonial era, poor milling machine settings can also be a source of low sugarcane juice production because the current parameter settings of milling stations are based on worker experience. So, the result of this setup is low production of sugarcane juice (Oktarini *et al.*, 2019).

Research on a parameter of sugarcane milling stations has been carried out several times. Such as research conducted by Hegel and Dekker (1958), in (Yazdi and Khorram, 2010), suggested that the distance between the center diameters of the rollers affects the milling performance. Research by (Yang *et al.*, 2011), states that using larger diameter rolls can help reduce properties such as shear stress, effective stress, and effective strain. However, it is important to note that increasing the roller diameter can also increase the rolling force.

According to (Murthy *et al.*, 2016), that analyzed the impact of roller diameter on steel material AISI-1055. The results show that increasing roller diameter leads to a decrease in von Mises stresses, enabling the roll to handle heavier loads. In (Zhou *et al.*, 2020) research, states the roller conveying mechanism is provided with extrusion pressure by a spring, and the compression amount of the spring can be changed by adjusting the clearance between the driving roller and the driven roller, to control the pressure of the roller on sugarcane. This means that the clearance between rollers can affect the roller pressure setting on the sugar cane.

Based on the research (Srichaipanya and Chuan-udom, 2020), the speed and distance between these rollers are crucial factors affecting the amount of

sugarcane juice produced. Apart from the roll diameter, speed of roll, distance between rollers, and roll material, research on sugarcane milling parameters also studies clearance.

From several studies that have been carried out, it is known that the largest output capacity is at the smallest clearance and highest speed. This was stated by (Oriola *et al.*, 2017), where the results of their research show that the largest output capacity is 148.20 kg/h. when clearance at 4.5 mm and speed at 30 rpm by number of rolls is 3 and efficiency 67.44%. This shows that the output capacity will be maximum if the clearance is small while the speed is high, stating that it's important to choose the clearance between the top roller and the two rollers that allow entry for crushing.

According to (Helal *et al.*, 2020) that adjusting the correct setting and clearance in mills helps to increase the pressure on the fiber layer or bagasse, which helps to increase the extraction rate. Meanwhile, (Ugye and Kolade, 2019) stated that the efficiency of the machine depends on the clearance feeding rate and speed of rotation when feeding is more. However, research on clearance that has been carried out only discusses clearance between rollers. Even though the sugarcane that will enter the milling machine also has a clearance. The clearance of sugarcane is thought to influence the production of the amount of sugarcane juice.

To overcome this problem, it is necessary to research the clearance of sugarcane with the clearance of rollers and speed of roll to optimize the sugarcane production process, especially to increase the production of sugarcane juice. In this research, the Response Surface Methodology (RSM) method was used with the Central Composite Design (CCD) technique and Artificial Neural Networks (ANNs) with the backpropagation model.

1.3 Statement of the Problems

Based on the background of the problem explained in the previous sub-chapter, the problems faced are:

a. How much influence does clearance of sugarcane, clearance of roller, and speed of roller have on the optimization of the sugarcane production process?
b. What are the optimum settings for the three parameters of the sugarcane milling machine?
c. What is the optimal amount of sugarcane juice from the optimum settings of the three parameters of the sugarcane milling machine?

1.4 Objective of the Study

The objectives of this study are as follows:

a. Determine the effect of clearance of sugarcane, clearance of roller, and speed of roller on the optimization of the sugarcane production process.
b. Determine the optimum settings for the three parameters of the sugarcane milling machine.
c. Determine the optimal amount of sugarcane juice from the optimum settings of the three parameters of the sugarcane milling machine.

1.5 Significance of Study

The significance of the study lies in its specific research objectives, which can be classified as scientific, aiming to advance science or theoretical applications, and practical, focused on solving and preventing problems in the subject under study. This research focuses on optimizing the sugarcane production process, with the potential to contribute to scientific development, particularly in production engineering and manufacturing systems. The study aims to enhance the performance of milling machines in optimizing the sugarcane production process, particularly focusing on the influence of parameters on the performance of milled rollers. This study is crucial due to the lack of research on setting up rollers at a sugar factory's milling station. One of the setups involves optimizing the distance of the three rollers to increase the milling machine's production capacity. There are also no existing studies on parameters affecting the performance of sugarcane rollers. This research can potentially support the government's commitment to boosting the national sugar industry's growth, as set out by the Ministry of Industry in 2019, by increasing sugar production capacity and providing incentives for new sugar factories (Kementrian Perindustrian Republik Indonesia, 2019).

1.6 Scope of Study

This research uses data obtained from PTPN VII Cintamanis Sugar Factory and direct interviews with workers at the mill station. In this research, the sugar production process studied and analyzed is the process of milling cane sugar from chopped sugar cane into the milling machine until it comes out of the milling machine. The output calculated in the research is sugarcane juice. The location of the object of this research is Ketiau Village, Lubuk Keliat District, Ogan Ilir Regency, South Sumatra. The focus of the research is to observe the parameters that influence the quantity of sugarcane sap production. Response

Surface Methodology (RSM) with Central Composite Design (CCD) techniques and Artificial Neural Networks (ANNs) with Backpropagation models are used to determine the independent variables that influence sugarcane juice production.

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