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Biomass Energy Utilization for Enhancing the Efficiency of Cold Storage System in Banana Processing Unit

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ABSTRACT: Banana processing industries generate a large amount of organic waste such as banana peels, stems and other residues during different stages of processing. If these wastes are not properly managed, they can create disposal problems and lead to environmental pollution. Instead of allowing these materials to remain as waste, they can be collected and converted into useful biomass energy for industrial applications. At the same time, cold storage system used for preserving bananas requires significant amount of energy to maintain a sustainable temperature and storage condition increasing the overall energy demand of banana processing units. Biomass energy is considered a renewable and sustainable energy source because it can be produced from organic waste materials that are easily available in such industries. This project focuses on studying the utilization of biomass energy for improving the efficiency of cold storage system in banana processing units. The study was conducted at Tamil Nadu banana producer company limited located in Thottiyam. Currently, the company utilizes solid wood waste as biomass fuel for generating energy required for its operations. In this project, additional biomass source such as dried banana peels and powdered organic residues are proposed to enhance efficiency of the biomass system.

KEYWORDS: Banana Processing Waste Collection, Biomass Fuel Preparation, Biomass Energy Generation, Cold Storage Energy Supply, Sustainable Waste Utilization.

I. INTRODUCTION

Banana is one of the most widely grown fruit crops in India and plays an important role in the agricultural and food processing sectors. During banana processing, a considerable amount of waste materials such as peels, stems and damaged or rejected fruits are generated. In many cases, these wastes are simply discarded, which may create environmental concerns and waste management issues. At the same time, cold storage facilities are essential in banana processing units to maintain fruit quality and extend shelf life during storage. However, operating cold storage systems requires a significant amount of electrical energy, which increases the overall operational cost for processing industries. Biomass energy can provide a sustainable alternative to address this challenge. Biomass can be generated from various agricultural and organic residues. In many industries, wood-based biomass is already used as a fuel source for energy production. In addition to this, other organic materials such as banana peels and powdered processing residues also have the potential to be utilized as biomass fuel. Therefore, this project focuses on analysing the utilization of biomass resources and exploring possible methods to improve the efficiency of biomass-based energy systems in banana processing units

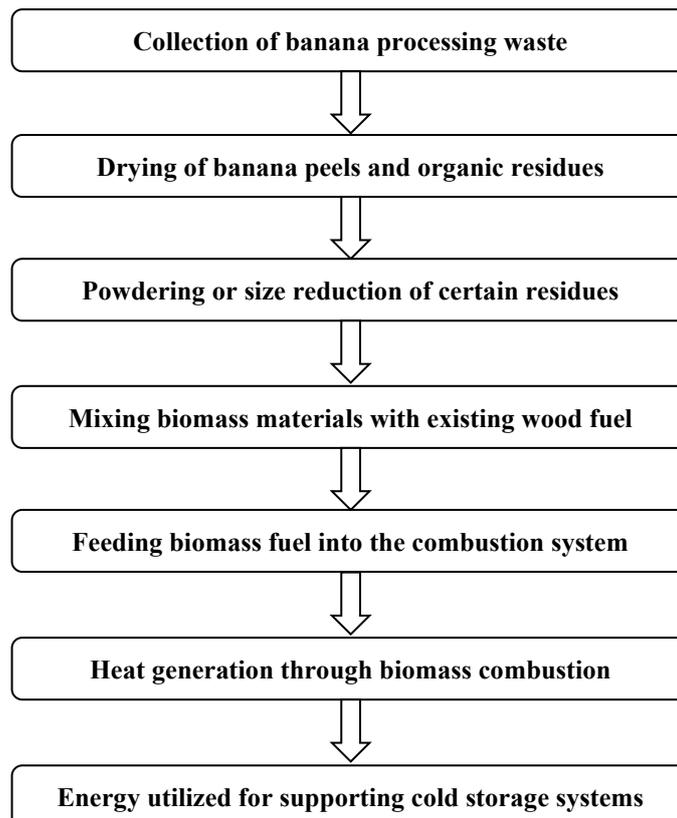
II. LITERATURE SURVEY

Many researchers have explored the effective utilization of agricultural waste and biomass resources for renewable energy and industrial applications. Banana processing residues such as peels, stems and pseudo stems have gained attention as potential biomass feedstock. Studies indicate that these wastes can be converted into useful energy forms, improving sustainability and efficiency in agro-industrial systems. Rahman et al. [1]. optimized banana peel

biomass conversion using particle swarm optimization, enhancing efficiency and reducing emissions. Wani and Dhanya [2]. highlighted the use of banana peel residues in bioenergy and value-added products, emphasizing environmental benefits. Santos et al. [3]. studied gasification and reported hydrogen-rich syngas production, suitable for energy generation. Uliyandari et al. [4]. developed briquettes from banana pseudostem and coconut pulp, showing good calorific value and fuel potential. Zhang et al. [5]. examined pyrolysis behavior, confirming biochar and energy-rich compounds production. Bishnoi et al. [6]. reviewed biomass conversion technologies and emphasized sustainable utilization. Mibulo et al. [7]. produced briquettes from fruit waste, demonstrating reliable fuel properties. Garcia et al. [8]. analyzed anaerobic digestion and confirmed high biogas yield. Patel et al. [9]. highlighted thermochemical conversion methods for sustainable energy production. Overall, banana waste serves as an effective renewable energy resource.

III. METHODOLOGY

The study collects data on energy consumption and cooling performance of the cold storage system under different conditions. Initially, the cold storage system operates using conventional energy sources. Later, biomass energy generated from banana waste and other organic residues is integrated into the system. The performance of the system is analyzed by comparing temperature stability, energy consumption and cooling efficiency. The proposed system integrates different biomass materials into the energy generation process.



The integration of multiple biomass sources improves fuel availability and increases overall system efficiency.

IV. DATA COLLECTION

The study gathers information on the cold storage system's energy usage and cooling efficiency under various circumstances. The cold storage system uses traditional energy sources at first. Afterwards, the system incorporates biomass energy produced from banana trash and other organic leftovers. Temperature stability, energy consumption and cooling efficiency are compared to evaluate the system's performance.

Parameter	Symbol	Value	Unit
Mass of banana stored	M	1000	Kg
Initial temperature	T _i	30	°C
Final storage temperature	T _f	13	°C
Temperature difference	ΔT	17	°C
Chamber volume	V	60	m ³
Density of air	ρ	1.2	kg/m ³
Specific heat of air	C _p air	1.005	kJ/kgK
Specific heat of banana	C _p banana	3.35	kJ/kgK
Biomass calorific value	CV	14 MJ/kg	
Biomass used per day	M	60	kg/day

Table No 1: Data Collection

V. WORKING PRINCIPLE

The system operates by converting banana waste into biomass energy and integrating it with a cold storage unit. Banana residues such as peels, stems and other organic waste are processed to generate usable energy through biomass conversion methods. This energy is then utilized to support the refrigeration system, either by contributing to electrical power generation or by supplying heat for absorption-based cooling systems. By supplementing the energy requirements of the cold storage unit, the system reduces dependence on conventional energy sources. As a result, overall energy efficiency is improved, operational costs may be lowered and energy utilization becomes more sustainable. Additionally, this approach promotes effective waste management by converting agricultural waste into valuable energy, thereby minimizing environmental pollution. The integration of biomass energy with cold storage not only enhances system performance but also supports eco-friendly practices and contributes to reducing the carbon footprint of agricultural and food preservation processes.

Fig. 1 illustrates the design and working components of the biomass-based cooling system. Figure (a) shows the machine design of the system and (b) represents the ammonia refrigerant unit.



(a)

(b)

VI. CALCULATION

S.No	Calculation	Formula	Given Data	Result
1	Cooling Load of Air	$Q_{\text{air}} = V \times \rho \times C_p \times \Delta T$	$V = 60 \text{ m}^3$, $\rho = 1.2 \text{ kg/m}^3$, $C_p = 1.005 \text{ kJ/kg}\cdot\text{K}$, $\Delta T = 17^\circ\text{C}$	1230.12 kJ
2	Cooling Load of Banana	$Q_{\text{banana}} = m \times C_p \times \Delta T$	$m = 1000 \text{ kg}$, $C_p = 3.35 \text{ kJ/kg}\cdot\text{K}$, $\Delta T = 17^\circ\text{C}$	56950 kJ
3	Additional Heat Load	$Q_{\text{additional}} = 5\% \times Q_{\text{banana}}$	5% of 56950	2847.5 kJ
4	Total Cooling Load	$Q_{\text{total}} = Q_{\text{air}} + Q_{\text{banana}} + Q_{\text{additional}}$	$= 1230.12 + 56950 + 2847.5$	61027.62 kJ
5	Energy from Biomass	Energy = Mass \times Calorific Value	$= 60 \text{ kg} \times 14000 \text{ kJ/kg}$	840000 kJ/day
6	System Efficiency	Efficiency = (Cooling Load / Energy Input) \times 100	$= (61027.62 / 840000) \times 100$	7.27%
7	Useful Cooling (COP)	Useful Energy = COP \times Q_{total}	$= 0.9 \times 61027.62$	54924.858 kJ
8	Final Efficiency	(Useful Cooling / Total Load) \times 100	$= (54924.858 / 61027.62) \times 100$	90%

Table No 2: Calculation

VII. RESULTS AND DISCUSSION

GRAPHICAL REPRESENTATION

Graphical representation is being used to analyse the relationship between different parameters of the system. Graphs such as temperature versus time and cooling load versus biomass input are being plotted. These visual tools help in identifying performance trends and variations. The graphical analysis makes it easier to interpret experimental data and understand system behaviour. It also supports validation of the experimental results by providing a clear representation of changes occurring within the system.

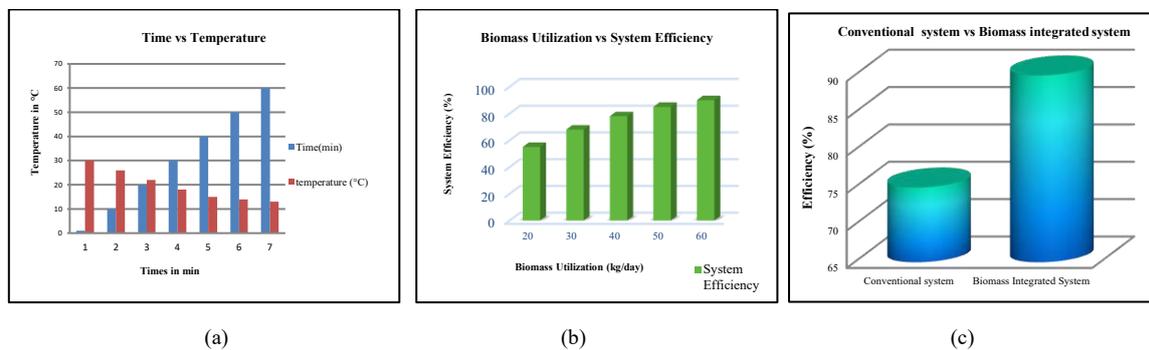
COMPARATIVE ANALYSIS (CONVENTIONAL VS PROPOSED SYSTEM)

A comparative analysis is being carried out between the conventional cooling system and the proposed biomass-based system. The conventional system depends mainly on electrical energy, whereas the proposed system utilizes renewable biomass resources. The comparison focuses on energy consumption, efficiency and environmental impact. Preliminary observations indicate that the proposed system has the potential to reduce energy usage and improve sustainability. This comparison helps in assessing the practical advantages of the developed system over existing technologies.

PERFORMANCE ANALYSIS (EFFICIENCY)

The performance of the system is being evaluated based on efficiency, cooling capacity and biomass utilization. The system is expected to achieve an efficiency of around 90% under optimized conditions. The relationship between input biomass and cooling output is being analysed to determine system effectiveness. Efforts are being made to minimize energy losses and improve overall performance. This analysis helps in understanding the feasibility and reliability of the system for real-time applications. The results obtained will support further improvements and optimization of the design.

Fig. 2 shows the system performance analysis, where (a) time vs temperature, (b) biomass utilization vs system efficiency and (c) conventional system vs biomass integrated system.



VIII. CONCLUSION

This study demonstrates that waste materials generated from banana processing can be effectively utilized as a mixed biomass energy source to support cold storage operations. Agricultural residues such as dried banana stem, dried banana peel and solid wood waste were used together as biomass fuel to produce thermal energy. The generated heat was then utilized in the refrigeration system to maintain the required temperature inside the cold storage chamber for preserving bananas. The results obtained from the analysis indicate that the use of mixed biomass provides a reliable and sustainable energy source for refrigeration applications. By utilizing these agricultural residues, the waste generated in banana processing units can be converted into useful energy instead of being discarded. This not only helps reduce waste disposal problems but also promotes efficient resource utilization within the processing unit. In addition, the integration of biomass energy with the cold storage system improves the overall performance of the system. During continuous operation with approximately 60 kg of mixed biomass feed, the system achieved an efficiency of around 90%. This improvement in efficiency highlights the potential of mixed biomass as an alternative energy source for agro-processing industries. Overall, the study shows that using mixed biomass for cold storage applications can enhance energy efficiency, reduce environmental impact and support sustainable energy utilization in banana processing industries.

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