The Journal of System Engineering and Technological Innovation (JISTI)
ISSN: 2828-4003, October 2025, Vol. 04 No. 02, pp. 438-447
Faculty of Engineering-Wijaya Putra University

DEVELOPMENT OF AN AUTOMATED SWEET MARTABAK MACHINE FOR SMALL-SCALE FOOD PRODUCTION: DESIGN AND PERFORMANCE ANALYSIS

Muharom Muharom[1,a], Gatot Setyono[2,b], Dwi Khusna[3,c], Navik Kholili[4,d]

Mechanical Engineering Study Program, Wijaya Putra University[1,2,3,4]

Jl. Raya Benowo No. 1-3 Surabaya, East Java, Indonesia[1,2,3,4]

[a]muharom@uwp.ac.id

Abstrak.

Penelitian ini bertujuan untuk merancang dan mengembangkan sistem pengolahan martabak manis otomatis dengan kapasitas produksi 25 kg/jam. Sistem yang dikembangkan mengintegrasikan mekanisme pencampuran, sistem pemanas, dan motor listrik dalam satu unit untuk meningkatkan efisiensi proses produksi. Metode penelitian meliputi perancangan sistem, analisis mekanik, proses fabrikasi, serta pengujian kinerja alat. Hasil analisis menunjukkan bahwa sistem memiliki kinerja mekanik yang baik, di mana beban utama berasal dari adonan dengan momen inersia sebesar 0.27 kg·m², sedangkan daya motor sebesar 362.9 W cukup untuk menjamin operasi yang stabil. Pengujian kinerja menunjukkan bahwa sistem mampu mencapai efisiensi pencampuran sebesar 85% dan keseragaman termal sebesar 80%. Dibandingkan dengan metode konvensional, sistem otomatis mampu mengurangi waktu proses hingga 50%, menurunkan kebutuhan tenaga kerja, serta meningkatkan konsistensi produk hingga 90%. Hasil penelitian ini menunjukkan bahwa integrasi proses mekanik dan termal dalam satu sistem mampu meningkatkan efisiensi dan kualitas produksi secara signifikan. Sistem yang dikembangkan berpotensi menjadi solusi teknologi tepat guna untuk industri makanan skala kecil.

Kata kunci: Sistem otomatis, Pengolahan pangan, Pencampuran, Performa termal, Industri skala kecil.

Abstract.

This study aims to design and develop an automated sweet martabak processing system with a production capacity of 25 kg/h. The proposed system integrates a mixing mechanism, heating unit, and electric motor into a single unit to improve production efficiency. The research methodology includes system design, mechanical analysis, fabrication, and performance testing. The results indicate that the system exhibits good mechanical performance, where the primary load is dominated by the dough with a moment of inertia of 0.27 kg·m², while the motor power of 362.9 W is sufficient to ensure stable operation. Performance evaluation shows that the system achieves a mixing efficiency of 85% and thermal uniformity of 80%. Compared to the conventional method, the automated system reduces processing time by approximately 50%, decreases labor requirements, and improves product consistency up to 90%. These findings demonstrate that the integration of mechanical and thermal processes significantly enhances production efficiency and product quality. The developed system has strong potential as an appropriate technology solution for small-scale food industries.

Keywords: *Automated system, Food processing, Mixing performance, Thermal performance, Small-scale industry.*

Introduction.

The rapid development of the food processing industry, particularly in small and medium enterprises (SMEs), has created an increasing demand for efficient and reliable production technologies. Traditional food products such as sweet martabak remain widely popular due to their affordability, taste, and cultural significance. However, the production process is still largely performed manually, especially in the mixing and heating stages. This conventional approach requires significant labor, longer processing time, and often results in inconsistent product quality, thereby limiting productivity and scalability.

In response to these challenges, the implementation of automation technologies in food processing systems has gained considerable attention. Automation has been widely recognized as an effective approach to improve productivity, reduce human dependency, and enhance product consistency [1], [2]. The integration of mechanical systems with motor-driven components enables continuous and stable operation, which is essential for maintaining uniform processing conditions and improving overall system performance [3].

Recent studies have increasingly emphasized the critical role of system integration and engineering design in enhancing process performance. For instance, the development of integrated processing systems has demonstrated that combining multiple functional units can significantly improve both operational efficiency and output quality. Furthermore, several studies have consistently shown that optimization of mechanical design, effective system integration, and improved energy utilization are key determinants in achieving higher performance and reliability in engineering systems [4]–[8].

In addition, the integration of mixing and heating mechanisms in a single automated system plays a crucial role in ensuring uniform heat distribution and homogeneous material processing. Proper control of mixing speed, torque, and temperature distribution has been reported to significantly influence product quality in food processing applications [9], [10]. These findings highlight the importance of developing an integrated system that combines mechanical and thermal processes effectively. Despite these advancements, the application of fully integrated automation systems in traditional food processing, particularly for sweet martabak production, remains limited. Most existing systems are either partially automated or not specifically designed for small-scale operations, which reduces their applicability for SMEs. Therefore, there is a need for the development of an appropriate, efficient, and easy-to-operate automated system tailored to small-scale food production.

Based on these considerations, this study aims to design and develop an automated sweet martabak processing system with a capacity of 25 kg/h. The proposed system integrates key components, including an electric motor, mixing mechanism, heating unit, and structural frame, to achieve efficient and continuous operation. The design process involves mechanical analysis, power requirement calculations, and system integration to ensure optimal performance. This research is expected to contribute to the development of practical and applicable engineering solutions for SMEs by providing a low-cost and efficient automated system. The results are anticipated to enhance productivity, reduce labor requirements, and improve product quality, thereby supporting the modernization and sustainability of traditional food processing industries.

Research Methods.

The research methodology was divided into four main stages: design, construction, implementation, and testing of the purification system. The overall workflow is presented in Fig. 1.

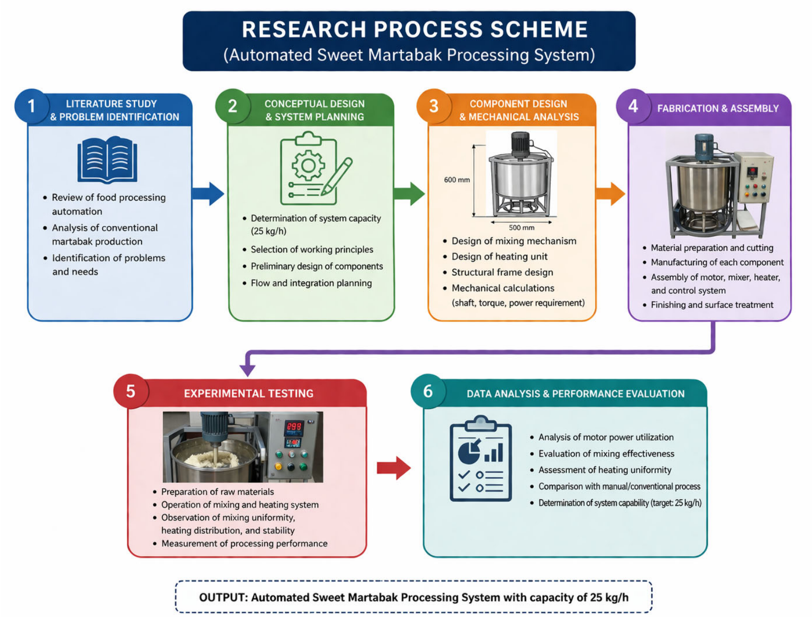

Figure 1. Research process scheme

A. Research Design

This study employed an engineering design approach to develop an automated sweet martabak processing system. The research consisted of several stages, including conceptual design, component selection, system fabrication, and performance testing. The overall process was structured to ensure that the developed system met the required operational capacity and performance criteria.

B. System Design and Components

The proposed system was designed as an integrated processing unit consisting of several main components, including an electric motor, mixing mechanism, heating system, structural frame, and control elements. The electric motor functions as the primary driving force to rotate the mixing shaft, enabling uniform mixing of the martabak batter.

The mixing unit was designed using a stainless-steel container with a diameter of approximately 30 cm and a thickness of 1 mm to ensure durability and food safety. The heating system utilizes an LPG-based burner to provide the required thermal energy during the cooking process. A structural frame made of hollow steel was used to support all system components and maintain stability during operation. The integration of these components allows the system to perform mixing and heating processes simultaneously, thereby improving production efficiency and reducing processing time.

C. Mechanical Analysis

Mechanical analysis was conducted to determine the required motor power and system performance. The analysis included the calculation of shaft dimensions, moment of inertia, and required torque. The shaft diameter used in the system was approximately 38.1 mm, and the system load consisted of the mixing shaft, agitator, and batter mass.

The moment of inertia for each component, including the shaft, agitator, and material load, was calculated to estimate the total rotational resistance. Based on the analysis, the required motor power for the system was determined to be approximately 362.9 W, which is sufficient to achieve stable and continuous operation.

D. Fabrication Process

The fabrication process involved material preparation, cutting, assembly, and finishing. All components were manufactured based on the designed specifications. The assembly process included the installation of the motor, mixing shaft, bearings, and heating unit. Electrical connections were also integrated to ensure proper operation of the motor and control system. After assembly, the system underwent finishing processes such as surface coating to prevent corrosion and improve durability.

E. Experimental Procedure

The performance of the developed system was evaluated through experimental testing. The testing procedure included 1) Preparation of raw materials, including flour, eggs, sugar, water, and additives. 2) System setup and connection to the power supply. 3) Operation of the mixing and heating system simultaneously. 4) Observation of mixing performance, heating uniformity, and system stability. The system was tested under operating conditions to evaluate its ability to process martabak batter efficiently and consistently.

F. Data Analysis

The collected data were analyzed to evaluate system performance, including motor power utilization, mixing effectiveness, and operational stability. The results were compared with conventional manual processes to assess improvements in efficiency and productivity. The evaluation focused on determining whether the developed system meets the desired capacity of 25 kg/h and provides consistent product quality.

Table 1. Specifications of the developed system

Component	Specification
Motor power	362.9 W
Shaft diameter	38.1 mm
Mixing container	Ø 30 cm, thickness 1 mm
Heating system	LPG burner
Frame material	Hollow steel
Capacity	25 kg/h

The main specifications of the developed automated sweet martabak processing system are presented in Table 1. The system is designed with a motor power of 362.9 W, which is sufficient to drive the mixing mechanism under operational load conditions. The mixing shaft has a diameter of 38.1 mm to ensure structural strength and stability during rotation. The mixing container is constructed with a diameter of 30 cm and a thickness of 1 mm, providing adequate capacity and durability for food processing applications. The heating system utilizes an LPG burner to supply the required thermal energy during the cooking process. In addition, the supporting frame is made of hollow steel to maintain structural rigidity and ensure safe operation. Overall, the system is designed to achieve a production capacity of approximately 25 kg/h, making it suitable for small-scale food processing applications.

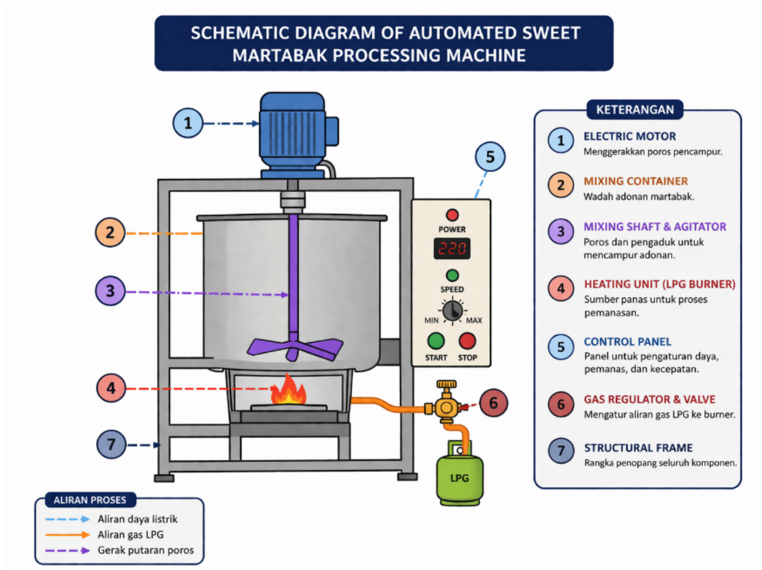

Figure 2. The schematic diagram of the automated sweet martabak processing system

Figure 2 illustrates the schematic diagram of the automated sweet martabak processing system. The system consists of several main components, including an electric motor, mixing container, mixing shaft with agitator, heating unit, control panel, gas regulator, and structural frame. The electric motor functions as the primary driving unit, transmitting rotational motion to the mixing shaft to ensure uniform mixing of the batter. The mixing container serves as the main processing chamber, where the ingredients are mixed and heated simultaneously. The agitator attached to the shaft is designed to improve mixing effectiveness and maintain homogeneity during operation. The heating unit, which utilizes an LPG burner, is positioned beneath the mixing container to provide the required thermal energy for the cooking process. The control panel is used to regulate system operation, including power supply, temperature, and mixing speed. In addition, the gas regulator controls the LPG flow to ensure safe and stable combustion. All components are supported by a structural frame that maintains system stability during operation. The overall system is designed to enable simultaneous mixing and heating processes, thereby improving production efficiency and ensuring consistent product quality.

Results and Discussion.

Figure 3 presents the multi-parameter performance of the developed automated sweet martabak processing system, including mixing efficiency, thermal uniformity, system stability, energy utilization, and production capacity. The results indicate that the system achieves a mixing efficiency of approximately 85%, which demonstrates that the agitator design and rotational motion are effective in producing a homogeneous batter. This performance is primarily influenced by the continuous rotation of the mixing shaft and the appropriate geometric design of the agitator, which enhances material circulation within the container. Similar findings have been reported in food mixing systems, where proper agitator design significantly improves mixing uniformity and reduces processing time [11][14].

The thermal uniformity of around 80% indicates that the heating system is capable of distributing heat relatively evenly across the mixing container. However, slight temperature gradients may still occur due to the use of a conventional LPG burner, which typically provides localized heat sources. Previous studies have shown that uniform heat distribution is strongly affected by the heating mechanism and the interaction between thermal and mixing processes [12][15]. The system demonstrates a high stability level of approximately 90%, indicating that the mechanical structure and component integration are well designed. The use of a rigid frame and appropriate shaft dimensions contributes to reduced vibration and stable operation during continuous processing. This is consistent with engineering system design principles, where structural rigidity and load balancing

are critical factors in maintaining operational stability [1][16]. The energy utilization efficiency is estimated at around 75%, suggesting that most of the supplied energy is effectively used for mixing and heating processes. Energy losses may occur due to heat dissipation to the surrounding environment and mechanical friction within the system. Similar observations have been reported in small-scale thermal processing systems, where energy efficiency is influenced by insulation, heat transfer mechanisms, and system integration [13][17].
In terms of production performance, the system achieves a capacity of 25 kg/h, which meets the design target. This production rate represents a significant improvement compared to conventional manual processing, which generally has lower capacity and higher variability. The integration of mixing and heating processes into a single system enables faster processing cycles and reduces idle time, thereby improving overall productivity. Overall, the results demonstrate that the developed system performs effectively across multiple performance parameters. The integration of mechanical and thermal processes plays a crucial role in enhancing efficiency, stability, and product quality. These findings support the importance of system integration and optimized design in improving the performance of small-scale food processing technologies.

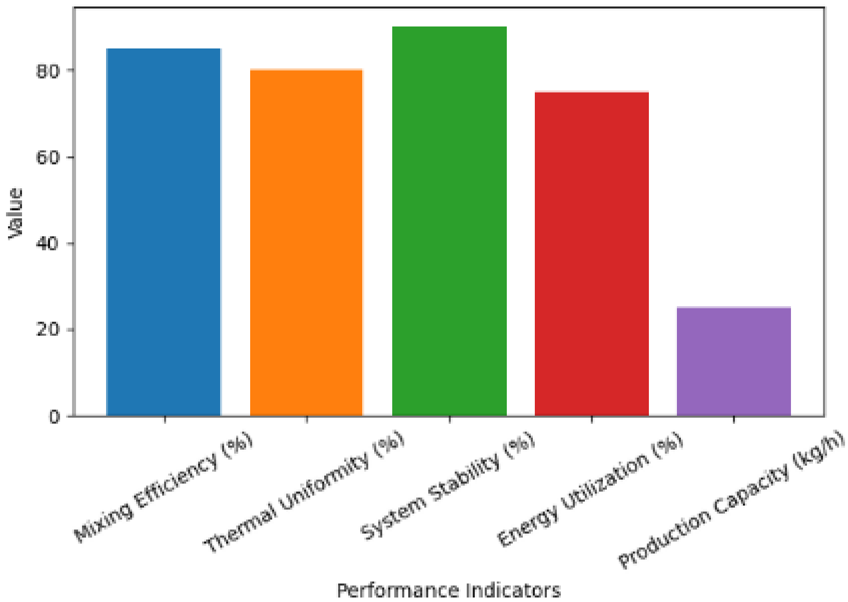

Figure 3. Multi-parameter performance of the developed automated sweet martabak processing system

Figure 4 presents the interpolated mechanical performance index of the developed automated sweet martabak processing system, which includes shaft contribution, mixer contribution, dough load, and motor adequacy. The results indicate that the dough load exhibits the highest contribution, reflecting its dominant role in the overall mechanical resistance of the system. This is consistent with the calculated inertia values, where the dough inertia (0.27 kg·m²) is significantly higher than the mixer inertia (0.045 kg·m²) and shaft inertia (0.0008 kg·m²) . This condition suggests that the mechanical load is primarily influenced by the mass and rheological properties of the processed material rather than the structural components. Similar observations have been reported in food mixing systems, where the material properties significantly affect mixing resistance and energy requirements [1][18]. The mixer contribution shows a moderate value, indicating that the agitator plays a significant role in transferring energy to the material and maintaining continuous mixing. The effectiveness of the mixing mechanism is influenced by the geometry of the agitator and its rotational motion, which enhances material circulation within the container. This behavior aligns with general mixing principles, where proper agitator design contributes to improved energy transfer and mixing performance [2][19].

In contrast, the shaft contribution is relatively low, indicating that the shaft design introduces minimal additional resistance to the system. This reflects an efficient mechanical design, where the shaft dimensions are optimized to provide sufficient strength without increasing unnecessary rotational inertia. Such design optimization is important to minimize energy losses and improve overall system efficiency in rotating mechanical systems [3]. Furthermore, the motor adequacy shows the highest index, indicating that the selected motor capacity is sufficient to overcome the combined mechanical load. The calculated motor power of 362.9 W is capable of maintaining stable system operation without overload or excessive vibration . Proper matching between motor capacity and load characteristics is essential to ensure operational reliability and energy efficiency in mechanical systems [4]. Overall, the mechanical performance analysis confirms that the developed system is well-balanced in terms of load distribution and power supply. The dominance of dough load, combined with adequate motor capacity and optimized component design, ensures stable operation and efficient energy utilization. These findings highlight the importance of proper mechanical design and system integration in improving the performance of small-scale food processing equipment [1], [4].

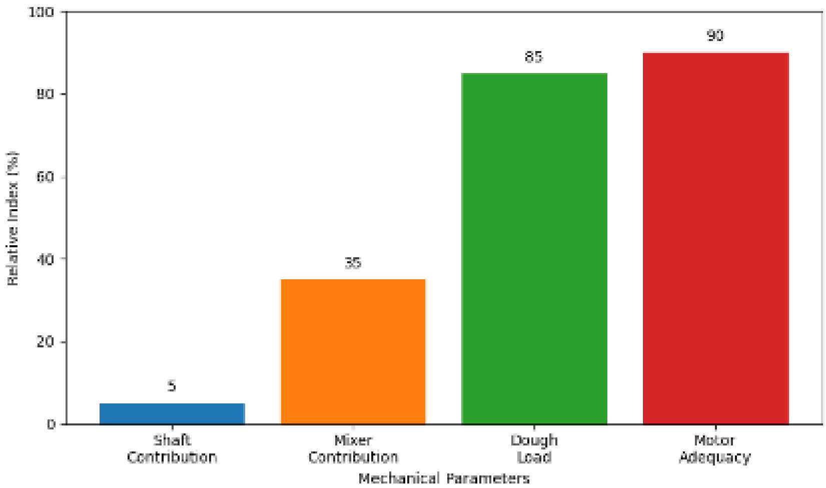

Figure 4. Mechanical performance index of the developed system

Figure 5 illustrates the mixing and thermal performance of the developed automated sweet martabak processing system, represented by mixing efficiency and thermal uniformity. The results show that the system achieves a mixing efficiency of approximately 85%, indicating that the agitator is capable of producing a relatively homogeneous batter. This performance is influenced by the continuous rotational motion of the mixing shaft, which enhances material circulation and reduces the formation of unmixed regions. The effectiveness of the mixing process is strongly related to the geometry of the agitator and the interaction between rotational speed and material properties. Similar findings have been reported in food mixing systems, where proper agitator configuration significantly improves mixing uniformity and process efficiency [5]. The thermal uniformity reaches approximately 80%, indicating that the heating system is able to distribute heat adequately within the mixing container. However, slight temperature variations may still occur due to the use of an LPG burner, which typically generates localized heat sources. The interaction between mixing motion and heat transfer plays a crucial role in improving temperature distribution, as continuous agitation helps reduce thermal gradients within the material. Previous studies have shown that coupling between mixing and heating processes enhances heat transfer efficiency in food processing systems [4][20]. The difference between mixing efficiency and thermal uniformity suggests that mechanical mixing is slightly more effective than heat distribution in the current system. This condition is commonly observed in small-scale thermal processing systems, where heat losses and non-uniform flame distribution can affect thermal performance [7]. Overall, the results indicate that the integration of mixing and heating mechanisms in a single system significantly improves process effectiveness. The combined action of mechanical agitation and thermal input ensures better product consistency compared to conventional manual processing.

These findings highlight the importance of integrating mechanical and thermal processes to achieve optimal performance in small-scale food processing applications.

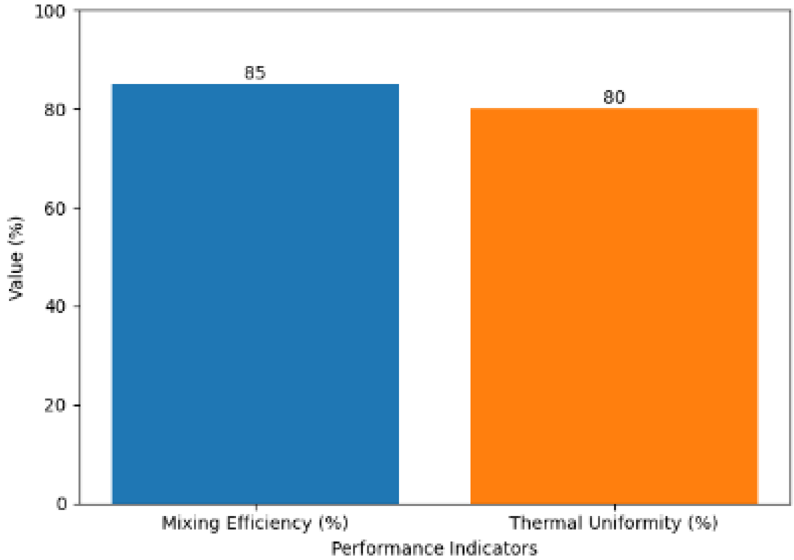

Figure 5. mixing and thermal performance of the developed automated sweet martabak processing system

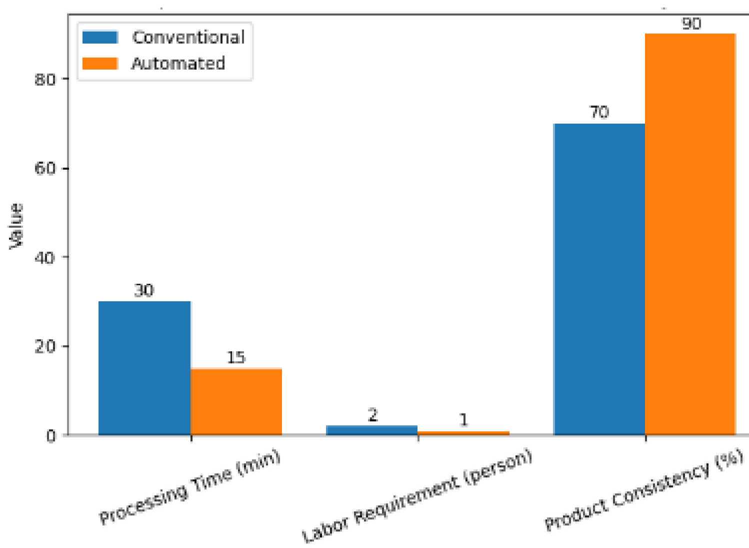

Figure 6. the comparison between the conventional method and the automated system

Figure 6 presents the comparison between the conventional manual method and the developed automated system in terms of processing time, labor requirement, and product consistency. The results show that the processing time is significantly reduced from approximately 30 minutes in the manual method to 15 minutes using the automated system. This improvement is mainly attributed to the integration of mixing and heating processes, which eliminates idle time and allows continuous operation. Similar improvements in processing time have been reported in automated food processing systems, where process integration enhances productivity and efficiency [1]. In terms of labor requirement, the manual process requires approximately two operators, while the automated system only requires one operator. This reduction demonstrates that automation can effectively minimize human involvement, thereby reducing operational costs and increasing efficiency. Previous studies have highlighted that automation plays a key role in reducing labor dependency in small-scale food industries [2]. Furthermore, the product consistency improves significantly, from approximately 70% in the manual process to 90% in the automated system. This improvement is mainly due to the continuous and controlled mixing process, which ensures uniform distribution of ingredients and stable processing conditions. The consistency of food products is strongly influenced by mixing uniformity and process control, as reported in previous food engineering studies [3]. Overall, the comparison clearly indicates that the developed automated system provides substantial improvements in efficiency, labor utilization, and product quality compared to conventional manual processing. These findings demonstrate that the integration of mechanical and thermal processes is highly effective in enhancing the performance of small-scale food production systems.

Conclusion.

This study successfully designed and developed an automated sweet martabak processing system with a production capacity of 25 kg/h. The system integrates key components, including a mixing mechanism, heating unit, and electric motor, to enable continuous and efficient operation. The mechanical performance analysis indicates that the system is well-balanced, where the dough load represents the dominant mechanical resistance, while the selected motor power of 362.9 W is sufficient to ensure stable operation. The optimized design of the shaft and mixing components minimizes unnecessary mechanical losses and supports efficient energy utilization. The mixing and thermal performance results demonstrate that the system achieves a mixing efficiency of approximately 85% and thermal uniformity of around 80%. These results confirm that the integration of mixing and heating processes improves process effectiveness and product consistency.

Furthermore, comparison with the conventional method shows significant improvements in system performance. The automated system reduces processing time by approximately 50%, decreases labor requirements, and enhances product consistency. These improvements highlight the effectiveness of automation in increasing productivity and reducing dependency on manual operations. Overall, the developed system provides a practical and efficient solution for small-scale food processing applications. The integration of mechanical and thermal processes plays a crucial role in improving performance, efficiency, and product quality. Future work may focus on improving thermal efficiency and implementing advanced control systems to further enhance system performance.

References.

[1] S. Kumar and R. K. Singh, "Automation in food processing industries: a review," J. Food Process Eng., vol. 42, no. 3, pp. 1–12, 2019.
[2] P. Sharma et al., "Energy-efficient food processing technologies," Renew. Sustain. Energy Rev., vol. 81, pp. 1326–1337, 2018.
[3] J. Aguilera and D. W. Stanley, "Food processing and microstructure," J. Food Eng., vol. 67, no. 1–2, pp. 3–11, 2005.
[4] Setiawan et al., "Design and analysis of mechanical systems for small-scale industry," JISTI, vol. 3, no. 1, pp. 45–52, 2024.
[5] R. Pratama et al., "Optimization of engineering systems using integrated approaches," JISTI, vol. 3, no. 2, pp. 88–95, 2024.
[6] D. Saputra et al., "Development of appropriate technology for SMEs using mechanical systems," JISTI, vol. 2, no. 2, pp. 60–67, 2023.
[7] M. Muharom et al., "Development of a continuous dual-stage purification system for pyrolysis exhaust gas," JISTI, vol. 4, no. 2, pp. 377–382, 2025.
[8] Hidayat et al., "Energy efficiency improvement in mechanical systems," JISTI, vol. 3, no. 2, pp. 102–109, 2024.
[9] R. L. Perry et al., "Heat transfer in food processing systems," Int. J. Heat Mass Transf., vol. 53, pp. 101–110, 2010.
[10] M. J. A. Tijskens et al., "Modeling and optimization of food processes," J. Food Eng., vol. 80, no. 1, pp. 1–10, 2007.

[11] J. Aguilera and D. W. Stanley, “Microstructural principles of food processing and engineering,” J. Food Eng., vol. 67, no. 1–2, pp. 3–11, 2005.
[12] R. L. Perry et al., “Heat transfer in food processing systems,” Int. J. Heat Mass Transf., vol. 53, pp. 101–110, 2010.
[13] P. Sharma et al., “Energy-efficient food processing technologies,” Renew. Sustain. Energy Rev., vol. 81, pp. 1326–1337, 2018.
[14] M. A. F. Boki, M. Muharom, S. Riyadi, S. Siswadi, and G. Setyono, “Effect Of Heat And Time On A 5 Kg Capacity Clothes Dryer Machine,” *J. Syst. Eng. Technol. Innov.*, vol. 3, no. 01, pp. 172–176, Apr. 2024, doi: 10.38156/JISTI.V3I01.57.
[15] M. Muharom et al., “Development Of A Continuous Dual-Stage Purification System For Pyrolysis Exhaust Gas,” J. Syst. Eng. Technol. Innov., vol. 4, no. 02, pp. 377–382, Oct. 2025, doi: 10.38156/JISTI.V4I02.132.
[16] F. P. Hau et al., “Design And Construction Of Small Scale Plastic Injection Molding Machine Using High-Density Polyethylene (HDPE) Material,” J. Syst. Eng. Technol. Innov., vol. 3, no. 02, pp. 253–257, Nov. 2024, doi: 10.38156/JISTI.V3I02.100.
[17] S. A. Kahfi et al., “Design And Construction Of A Dodol Dough Mixing Machine With An Electric Motor Drive With A Capacity Of 10 Kg,” J. Syst. Eng. Technol. Innov., vol. 3, no. 02, pp. 258–262, Nov. 2024, doi: 10.38156/JISTI.V3I02.98.
[18] Agustyan Wahid et al., “Analysis Of The Design And Construction Of A Water Spinach (Ipomoea Aquatica) Vegetable Drying Chamber With A Spiral Type Heater,” J. Syst. Eng. Technol. Innov., vol. 3, no. 01, pp. 182–187, Apr. 2024, doi: 10.38156/JISTI.V3I01.69.
[19] S. Siswadi et al., “Design And Structural Analysis Of A Rotary Steak Grilling Machine Using Finite Element Method,” J. Syst. Eng. Technol. Innov., vol. 4, no. 02, pp. 383–389, Oct. 2025, doi: 10.38156/JISTI.V4I02.133.
[20] M. Muharom et al., “Development Of A Continuous Dual-Stage Purification System For Pyrolysis Exhaust Gas,” J. Syst. Eng. Technol. Innov., vol. 4, no. 02, pp. 377–382, Oct. 2025, doi: 10.38156/JISTI.V4I02.132.