

## **Design of an Arduino Based Automatic Sealing Machine with DS18B20 Sensor for Smart Temperature Control**

**Marysca Shintya Dewi<sup>1)\*</sup>, Linda Marlinda<sup>2)</sup>, Komarudin<sup>3)</sup>**

<sup>1)3)</sup>Teknik Mesin, Universitas Dian Nusantara, Indonesia

<sup>2)</sup>Informatika, Universitas Nusa Mandiri, Indonesia

<sup>1)</sup>[marysca.shintya.dewi@dosen.undira.ac.id](mailto:marysca.shintya.dewi@dosen.undira.ac.id), <sup>2)</sup>[linda.ldm@nusamandiri.ac.id](mailto:linda.ldm@nusamandiri.ac.id), <sup>3)</sup>[komarudin@undira.ac.id](mailto:komarudin@undira.ac.id)

### **ABSTRACT**

Sealing quality is a critical concern for Micro, Small, and Medium Enterprises (MSMEs) that rely on conventional machines lacking temperature control mechanisms. These systems often result in overheating or poor bonding, especially when applied to thin plastic materials such as polyethylene (PE), polypropylene (PP), and oriented polypropylene (OPP), each with varying melting points. This research aims to design an Arduino Uno-based automatic horizontal sealing machine integrated with a DS18B20 temperature sensor to provide smart temperature control during the sealing process. The proposed system employs a threshold-based ON-OFF control algorithm with a hysteresis margin of  $\pm 2.5^{\circ}\text{C}$ , and displays real-time thermal feedback on a 16x2 LCD. The experimental methodology includes temperature deviation analysis and quality scoring of sealing results across PE, PP, and OPP films. Results show that the manual system deviated up to  $15.4^{\circ}\text{C}$  from the target temperature, leading to inconsistent outcomes. In contrast, the Arduino-based system maintained thermal stability within  $\pm 5^{\circ}\text{C}$  and achieved a significant increase in sealing quality score from 60 to 92. These improvements indicate enhanced operational reliability, safety, and sealing consistency. The system provides a low-cost, scalable solution for MSMEs and can be upgraded to include PID control, IoT integration, or adaptive thermal profiling. This work demonstrates that embedded microcontroller-based automation is feasible and effective for small-scale packaging applications.

**Keywords:** Arduino Uno; Temperature Control; DS18B20 Sensor; Low Cost Packaging Machine; MSMEs.

### **INTRODUCTION**

The design of an Arduino-based automatic sealing machine integrated with a DS18B20 temperature sensor can enhance productivity and efficiency in packaging applications. The foundational technology for the proposed machine aligns with various advancements in automation and temperature regulation observed in concurrent systems. Sealing processes, particularly in packaging, have seen significant improvements through automation, which not only increases throughput but also ensures consistent quality in seal integrity (Ilhan et al., 2021) (Yang et al., 2023).

The DS18B20 sensor, known for its accuracy and digital output capabilities, is particularly suited for this application. It facilitates precise temperature monitoring, which is critical for optimal sealing conditions. This aspect is essential, as improper temperature settings can lead to seal failures, compromised product quality, and increased material wastage (Ilhan et al., 2021). Effective temperature management is further emphasized by studies showing that temperature variations directly affect seal integrity and the materials' physical properties used in sealing processes (Yang et al., 2023) (*Packag Technol Sci - 2023 - Merabtene - Heat - sealing and Microscopic.Pdf*, n.d.).

Integration of the Arduino platform serves as the control hub for the sealing machine, enabling real-time data processing and automation of sealing mechanisms. The flexibility of Arduino allows the incorporation of both the DS18B20 sensor for temperature control and motor drivers for operating the sealing mechanism, making it a cost-effective solution with considerable performance advantages in packaging applications (Kana et al., 2019). For instance, leveraging Arduino's programmable features can lead to a user-defined sealing protocol that adjusts sealing time and pressure based on real-time temperature data collected from the DS18B20 sensor (Yang et al., 2023) (Kana et al., 2019) (Pirayeh Gar et al., 2024).

In the modern packaging industry, especially among Micro, Small and Medium Enterprises (MSMEs), sealing machines play a vital role in ensuring the safety, hygiene and visual appeal of products. Properly sealed packaging not

\* Corresponding author



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only protects its contents but also increases consumer confidence and extends the shelf life of the product. However, the majority of MSMEs in developing countries still rely on conventional sealing machines that are not equipped with temperature control mechanisms. These machines usually operate at a fixed heating rate, which cannot adapt to the varying melting points of various plastic materials such as polyethylene (PE), polypropylene (PP) and oriented polypropylene (OPP)(Arifeen & Petrovski, 2023)(Osmólska et al., 2022). As a result, the sealing process often produces inconsistent results, including overheating, poor adhesion or structural damage to the packaging(Arifeen & Petrovski, 2023)(Ozcan, 2020).

The resistance to adopting more advanced technologies stems largely from the economic constraints facing MSMEs. Yet, those that do integrate temperature controlled sealing mechanisms have demonstrated improved packaging outcomes and longer shelf lives for their products (Thirupathi Vasuki et al., 2023)(Du et al., 2025). Intelligent packaging systems, which can include temperature sensors, allow for real-time adjustments during the sealing process. By employing smart technologies that respond dynamically to environmental changes, packaging producers can overcome the limitations posed by static operating conditions. For instance, the integration of sensors that monitor temperature fluctuations could lead to more effective sealing processes, ensuring that the melting points of various plastics are optimally managed (Otles & Sahyar, 2016)(Du et al., 2025).

To address these gaps, this study proposes the design and implementation of an automatic horizontal sealing machine using Arduino Uno and a DS18B20 sensor to achieve  $\pm 5^{\circ}\text{C}$  temperature control accuracy. The system uses ON-OFF threshold logic and a 16x2 LCD for feedback, targeting consistent sealing results across various plastic types. The main objective is to improve automation, reduce operator dependency, and offer a cost-effective solution tailored to MSMEs.

The novelty of this research lies in the integration of a temperature control mechanism into a low-cost sealing machine specifically designed for horizontal packaging using thin plastic materials at the MSME scale. To the best of our knowledge, this study is the first to investigate the performance of Arduino Uno in combination with the DS18B20 sensor for maintaining thermal stability in such applications. The system architecture is also extensible, allowing future integration with IoT-based monitoring and improved control logic to enhance production performance and system reliability.

## LITERATURE REVIEW

### A. Overview of Smart Sealing Technologies

Sealing technology has significantly advanced from manual and mechanically operated machines to modern automatic systems equipped with real-time control. However, many Micro, Small, and Medium Enterprises (MSMEs) still use conventional sealing devices that lack temperature regulation and sensor feedback, resulting in inconsistent sealing quality and reduced product safety (Winotapun et al., 2023)(Du et al., 2025). Smart sealing systems integrate automatic control mechanisms, sensor feedback, and adaptive response features to optimize sealing performance. These systems adjust sealing parameters—such as temperature, pressure, and timing—based on the packaging material's characteristics and external conditions, ensuring better consistency and efficiency (Otles & Sahyar, 2016)(Winotapun et al., 2023).

The need for smart systems is driven by critical limitations in traditional machines: fixed temperature settings, energy inefficiency, and high reliance on operator intuition. Variations in plastic type or ambient temperature often result in weak bonding, shrinkage, or overheating during the sealing process(Xu et al., 2020). Advances in industrial automation have enabled the use of affordable microcontrollers—such as Arduino, ESP32, and STM32—in real-time sealing control. When combined with precise sensors like the DS18B20, these platforms allow accurate temperature monitoring and control, as demonstrated in studies achieving  $\pm 3^{\circ}\text{C}$  stability (Kim et al., 2020).

The addition of LCD or OLED displays enhances user interaction by visualizing real-time system data, facilitating immediate operator adjustments. Integrated microcontroller and sensor networks also ensure secure, responsive, and adaptive feedback control in embedded systems(*Packag Technol Sci - 2023 - Merabtene - Heat-sealing and Microscopic.Pdf*, n.d.). For MSMEs, smart sealing technologies offer tangible benefits: improved product quality, reduced energy usage, and lower dependence on skilled labor. This study contributes to the broader movement toward digital transformation by proposing a cost-effective, sensor-based sealing solution tailored to small-scale packaging industries (Pirayeh Gar et al., 2024)(Ozcan, 2020).

### B. Microcontroller Based Temperature Control Systems

Microcontrollers have become essential in modern temperature control systems due to their low cost, flexibility, and ease of integration. Unlike analog systems, microcontroller-based platforms enable real-time data acquisition,

\* Corresponding author



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digital control, and logical decision-making, making them ideal for precise thermal management in industrial, domestic, and automation applications (Ilhan et al., 2021). Functioning as the central processing unit, microcontrollers continuously read temperature input, process data, and trigger actuators such as relays. The Arduino Uno, a widely used platform in low-cost automation, is often combined with sensors like the DS18B20 for stable temperature regulation. (Pirayeh Gar et al., 2024) demonstrated that this combination can maintain thermal accuracy within  $\pm 3^{\circ}\text{C}$ , proving its reliability in embedded industrial settings.

Microcontrollers support not only basic ON-OFF logic but also advanced control strategies like PID and fuzzy logic. However, for MSMEs, threshold-based control offers a practical balance between simplicity and functionality. These systems are also scalable, supporting additional modules like LCDs, data loggers, or safety switches for enhanced usability and monitoring (Kim et al., 2020). In this study, the Arduino Uno processes temperature readings from the DS18B20 sensor and regulates heating via a relay module. This configuration affirms the effectiveness of microcontroller-based control in maintaining consistent temperature for heat sealing processes, particularly in low-resource industrial environments such as MSMEs (Du et al., 2025).

### C. Properties of PE, PP, and OPP in Heat Sealing

Plastic films are widely used in industrial and commercial packaging due to their flexibility, cost efficiency, and compatibility with various sealing technologies. Among the most commonly used thermoplastics for heat sealing applications are Polyethylene (PE), Polypropylene (PP), and Oriented Polypropylene (OPP) (Arifeen & Petrovski, 2023) (Osmólska et al., 2022). Each of these materials exhibits unique thermal and mechanical characteristics that influence the optimal sealing temperature, bonding strength, and response to heat.

#### 1. Polyethylene (PE)

Polyethylene is a semi crystalline thermoplastic polymer commonly used for flexible food and retail packaging. It is known for its high ductility, low cost, and excellent heat-sealability. PE typically has a melting point between  $105^{\circ}\text{C}$  and  $130^{\circ}\text{C}$ , depending on its molecular weight and branching structure (e.g., LDPE vs. HDPE). Its relatively low sealing temperature allows for faster sealing cycles, but it also makes PE highly sensitive to overheating, which can lead to film deformation, shrinkage, or seal failure. Sharma and Gupta (2019) noted that achieving strong and consistent seals with PE requires precise temperature regulation and low pressure, particularly for thin-gauge films (Adityas et al., 2021) (Issue, 2024).

#### 2. Polypropylene (PP)

Polypropylene offers higher tensile strength, heat resistance, and rigidity compared to PE. PP melts at around  $160^{\circ}\text{C}$ , which makes it suitable for products that require stronger mechanical durability or higher temperature tolerance. However, the elevated sealing temperature also poses a challenge for control systems, especially in manual or analog sealing setups. PP requires higher dwell times and pressure to form a reliable seal, and minor fluctuations in temperature may result in incomplete bonding or material embrittlement. Yadav and Rai (2020) emphasized that PP is less forgiving than PE during the sealing process and thus benefits more significantly from embedded temperature control systems (Al Tahtawi et al., 2021) (Issue, 2024).

#### 3. Oriented Polypropylene (OPP)

Oriented Polypropylene is a biaxially stretched form of PP that has improved clarity, stiffness, and barrier properties. OPP has a narrower sealing window, typically between  $135^{\circ}\text{C}$  and  $145^{\circ}\text{C}$ , due to its crystalline orientation. Although it offers superior optical and mechanical qualities, OPP is more prone to seal inconsistencies if temperature and dwell time are not finely controlled. Gupta and Choudhary (2021) highlighted that OPP's narrow sealing margin makes it difficult to seal consistently using traditional equipment without precise real-time temperature feedback (Adityas et al., 2021) (Osmólska et al., 2022) (Popović & Naumović, 2020).

### Comparative Analysis

Table 1 summarizes the key thermal and mechanical properties of PE, PP, and OPP, indicating their suitability for various packaging applications:

| Property                             | PE             | PP               | OPP             |
|--------------------------------------|----------------|------------------|-----------------|
| Melting Point ( $^{\circ}\text{C}$ ) | 105–130        | $\sim 160$       | 135–145         |
| Flexibility                          | High           | Medium           | Low             |
| Heat Sensitivity                     | High           | Medium           | High            |
| Sealability (Ease)                   | Excellent      | Moderate         | Moderate to Low |
| Required Temp. Control               | Basic–Moderate | Moderate–Precise | Precise–High    |

\* Corresponding author



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Table 1 provides a comparative overview of the key thermal and mechanical properties of Polyethylene (PE), Polypropylene (PP), and Oriented Polypropylene (OPP), three of the most widely used thermoplastics in flexible packaging. Each material demonstrates distinct characteristics that influence its behavior during the heat sealing process. PE, with the lowest melting point range (105–130°C), offers high flexibility and excellent sealability under moderate temperature conditions (Al Tahtawi et al., 2021) (*Packag Technol Sci - 2023 - Merabtene - Heat-sealing and Microscopic.Pdf*, n.d.). Its inherent adaptability to minor fluctuations in sealing parameters renders it suitable for fast-cycle operations; however, its pronounced sensitivity to elevated temperatures necessitates careful regulation to prevent film distortion or deformation. PP, by contrast, possesses a higher melting point (~160°C) and moderate flexibility, which provides better mechanical strength and improved resistance to thermal and mechanical stress. While it exhibits greater resilience under heat compared to PE, PP still requires a more tightly controlled sealing environment to ensure sufficient adhesion and to avoid premature material degradation. OPP exhibits the narrowest sealing window (135–145°C) and the lowest flexibility among the three. Its molecular orientation enhances structural rigidity and visual clarity, but significantly narrows the operational thermal margin. As a result, the sealing of OPP demands highly precise temperature control and consistent pressure to mitigate the risks of seal failure or material rupture (Ilhan et al., 2021).

#### D. Research Gap and Positioning of the Proposed Work

The development of automatic control systems using microcontrollers such as Arduino Uno has gained substantial attention in recent years, especially in industrial automation for small and medium-scale production. Various studies have implemented temperature control mechanisms using sensors such as DS18B20 and DHT11, typically applied in water heating systems, environmental monitoring, and HVAC applications. For instance, (Kana et al., 2019) designed a real-time temperature monitoring and control system using Arduino Uno and DS18B20, successfully maintaining thermal stability within  $\pm 2-3^{\circ}\text{C}$ , showcasing the sensor's reliability in embedded systems for industrial usage. In the packaging domain, the integration of microcontroller-based systems remains limited, particularly among Micro, Small, and Medium Enterprises (MSMEs). Most MSMEs still rely on manual sealing machines without temperature feedback, resulting in inconsistent sealing quality and damaged packaging. (Ozcan, 2020) highlighted this issue in their study on smart packaging solutions, asserting the urgent need for embedded automation in packaging equipment for MSMEs. Their findings indicated that packaging inconsistency significantly affects product integrity and customer trust.

Furthermore, (*Packag Technol Sci - 2023 - Merabtene - Heat-sealing and Microscopic.Pdf*, n.d.) (Xu et al., 2020) demonstrated the use of relay-based ON-OFF control with Arduino Uno in maintaining stable heating for industrial applications. Although effective, their work lacked adaptability for different plastic types with varying melting points, a limitation this study aims to address. (Ozcan, 2020) (Thirupathi Vasuki et al., 2023) proposed a smart sealing machine architecture using Arduino and IoT but did not implement real-time sensor integration or validate the system on various plastic materials such as PE, PP, and OPP.

From these studies, it is evident that while Arduino-based thermal control systems are well established in general heating applications, their adoption in horizontal sealing machines—specifically designed for thin plastic packaging—remains underexplored. This research bridges that gap by introducing a smart temperature-controlled sealing system tested on real-world plastic materials, focusing on stability, efficiency, and affordability tailored for MSMEs.

## METHOD

This study employs an experimental engineering methodology to design, implement, and evaluate a smart automatic sealing system tailored for MSMEs. The proposed system aims to provide real-time temperature control using an Arduino Uno microcontroller and a DS18B20 digital temperature sensor, specifically adapted for sealing thin plastic packaging materials such as PE, PP, and OPP (Ozcan, 2020) (Winotapun et al., 2023) (Osmólska et al., 2022).

### A. System Architecture

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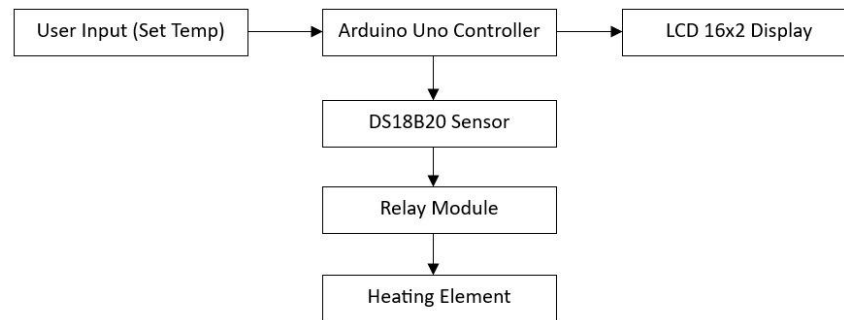


Fig. 1 Block Diagram of Arduino Based Sealling Machine System

Figure 1 illustrates the system architecture of the Arduino-based automatic sealing machine designed for smart temperature control. The system comprises six core components that work together to achieve real-time thermal regulation during the sealing process, particularly for thin plastic materials such as PE, PP, and OPP. The process begins with the User Input, where the operator sets the target sealing temperature based on the type of plastic material. This input is manually provided through a button or switch mechanism and transmitted to the Arduino Uno microcontroller, which serves as the system's control center. The Arduino Uno executes the core logic of the temperature control system. It continuously reads temperature data from the DS18B20 digital temperature sensor, which is positioned near the heating element to ensure accurate and responsive measurements. The sensor provides real-time feedback to the controller, enabling immediate comparison with the pre-set temperature threshold.

Based on this comparison, the Arduino issues control signals to a Relay Module that acts as an electronic switch. If the current temperature is below the defined threshold, the relay is activated to supply power to the Heating Element. Conversely, if the measured temperature exceeds the target, the relay disconnects the heating circuit, preventing overheating or material damage. Throughout the operation, the 16x2 LCD Display provides continuous temperature readouts to the operator, enhancing transparency and enabling manual intervention if necessary. This display ensures that the system remains user-friendly and intuitive, even for non-technical users. The modular design of this system allows for easy expansion, such as incorporating PID control, IoT-based monitoring, or mobile feedback systems in future iterations. The architecture also emphasizes affordability, ease of use, and reliability—making it highly suitable for MSMEs in developing regions seeking to modernize their packaging processes.

## B. Control Algorithm and Implementation

The temperature regulation algorithm employed in this system utilizes a threshold-based ON-OFF control with a  $\pm 2.5^{\circ}\text{C}$  tolerance band to maintain thermal stability and reduce relay wear. Arduino Uno serves as the central controller, continuously evaluating real-time temperature data from the DS18B20 sensor against a predefined target set by the user. The heating element is activated only when the temperature falls notably below the lower bound, and deactivated once it exceeds the upper limit. This two-point tolerance mechanism prevents excessive relay switching (relay chatter), enhancing system reliability and extending component longevity (Du et al., 2025) (*Packag Technol Sci - 2023 - Merabtene - Heat-sealing and Microscopic.Pdf*, n.d.). The algorithm is programmed in C using the Arduino IDE, with the `setup()` function handling initialization and the `loop()` function executing real-time monitoring and control based on sensor feedback.

This two-point threshold mechanism ensures that the heating element only responds to meaningful deviations from the target value, thus preventing rapid on-off cycles (also known as relay chatter) and extending component lifespan. The control logic is developed using C programming language within the Arduino IDE environment. The code is structured into `setup` and `loop` functions (Thirupathi Vasuki et al., 2023):

1. The `setup()` function initializes input/output pins, sets up serial communication, and configures the LCD display.
2. The `loop()` function performs real-time temperature acquisition, conditional evaluation of control thresholds, LCD display updates, and relay actuation.

If the measured temperature is lower than  $T_{\text{target}} - 2.5^{\circ}\text{C}$  the system activates the heating element by switching the relay ON. If the temperature is higher than or equal to this lower bound, the relay is deactivated, preventing further heating. This logic minimizes excessive relay switching and avoids overshooting the target temperature. Following

\* Corresponding author



the relay control decision, the system displays both the current and target temperatures on the LCD screen, providing real-time feedback to the operator. Finally, the program waits for 1 second before looping back to re-evaluate the temperature condition(Kana et al., 2019)(Pirayeh Gar et al., 2024). This loop continues indefinitely, forming a closed-loop control system that ensures consistent heat application throughout the sealing process. This flowchart visually demonstrates the simplicity and effectiveness of the threshold-based ON-OFF control strategy, which is especially suitable for MSME-level applications that prioritize reliability and cost-efficiency without requiring complex algorithms such as PID or fuzzy logic.

Pseudocode: Arduino-Based Temperature Control System

START

// Initialization

Define constants:

- TARGET\_TEMPERATURE ← 120.0
- HYSTERESIS ← 2.5
- Sensor pin ← D2
- Relay pin ← D8
- LCD pins ← RS, E, D4–D7

Setup():

- Initialize serial communication (9600 baud)
- Initialize LCD (16x2)
- Set relay pin as OUTPUT
- Start DS18B20 temperature sensor

Display “Sealing Ready” on LCD

// Main control loop

LOOP:

Request temperature from DS18B20 sensor

Read current temperature → currentTemp

IF currentTemp < (TARGET\_TEMPERATURE - HYSTERESIS) THEN

Turn relay ON (activate heater)

ELSE IF currentTemp > (TARGET\_TEMPERATURE + HYSTERESIS) THEN

Turn relay OFF (deactivate heater)

END IF

Update LCD:

- Line 1: Display currentTemp with 1 decimal
- Line 2: Display TARGET\_TEMPERATURE

Print currentTemp to Serial Monitor

WAIT for 1 second

REPEAT LOOP

To monitor and fine-tune performance, the Arduino’s serial monitor and logging functions were employed during implementation. This simple yet effective ON-OFF scheme provides sufficient temperature regulation for MSMEs while allowing for future upgrades to PID or fuzzy logic controllers as needed.

To evaluate the average thermal stability achieved by the control algorithm during each sealing session, the mean temperature was calculated as:

$$T_{mean} = \frac{1}{n} \sum_{i=1}^n T_i$$

Where :

- $T_i$  is the temperature at the  $i^{th}$  second, and
- $n$  is the number of samples recorded during the heating cycle

To assess control accuracy, the absolute deviation from the target temperature was computed as;

$$\Delta T = |T_{mean} - T_{target}| \quad (1)$$

This deviation metric quantifies how precisely the system maintains the setpoint temperature under actual operation.

\* Corresponding author



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### C. *Experimental Design and Procedure*

This experiment was designed to assess the performance of the proposed Arduino-based sealing system in maintaining stable temperature and producing consistent seal quality across a variety of thermoplastic materials commonly used in MSME packaging.

The test involved three types of plastic films with distinct thermal properties. The first material, Polyethylene (PE), was evaluated with a target sealing temperature of 120°C, chosen due to its relatively low melting point and high flexibility. The second material, Polypropylene (PP), was tested at a higher target temperature of 160°C, considering its superior thermal resistance and mechanical strength. Lastly, Oriented Polypropylene (OPP) was assessed at a target temperature of 140°C, given its molecular alignment that offers enhanced stiffness but a narrower sealing temperature window. These selections were made to ensure a comprehensive evaluation of the system's adaptability across a range of common packaging substrates

#### Experimental Setup

Each material underwent 10 sealing trials under controlled environmental conditions and identical hardware configurations. During each trial:

1. The operator manually selected the target temperature through the push-button interface.
2. The system performed the heating and sealing process based on ON-OFF logic as described in Section B.
3. Temperature readings were logged every second using serial output from the Arduino.

The total sealing time per cycle was recorded by marking the timestamp at the start and end of each heating event, calculated using:

$$t_{cycle} = t_{end} - t_{start} \quad (2)$$

This allowed the assessment of sealing time consistency across cycles.

#### Sealing Quality Evaluation

Each sealing result was evaluated using four performance criteria:

1. Seal Bond Strength, determined through a peel test to assess the mechanical adhesion between sealed layers.
2. No Overheat Damage, evaluated visually to check for melting, burn marks, or film deformation.
3. Seal Symmetry and Neatness, assessed based on uniformity and straightness of the seal across the full length.
4. Inter-Cycle Consistency, judged by comparing results across the 10 trials to determine repeatability.

Each criterion was assigned a score (0–100) and a corresponding weight. The total sealing quality score  $S_{total}$  for each material was calculated as:

$$S_{total} = \sum_{i=1}^4 \left( \frac{S_i}{S_{max,i}} \times W_i \right) \quad (3)$$

Where :

$S_i$  = actual score for criterion  $i$

$S_{max,i}$  = maximum possible score for criterion  $i$

$W_i$  = weight (percentage) of the  $i^{th}$  criterion

All assessments were conducted by three independent evaluators, with discrepancies resolved through consensus or average. Visual documentation and data tables were used to support the qualitative results.

### D. *Performance Evaluation*

The performance evaluation of the proposed Arduino-based automatic sealing system focuses on four main aspects: thermal stability, sealing quality, relay actuation efficiency, and operational consistency across cycles. Each aspect is assessed through both quantitative measurements and qualitative observations derived from experimental trials

#### 1. Thermal Stability

To assess the system's ability to maintain a consistent heating temperature, the temperature data collected during each sealing cycle is analyzed using the mean temperature formula

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$$T_{mean} = \frac{1}{n} \sum_{i=1}^n T_i \quad (4)$$

Where  $T_i$  Represent the recorded temperature at the  $i^{th}$  second and n is the total number of readings in a cycle. Stability is futhure evaluated by calculating the absolute deviation from the target temperature :

$$\Delta T = |T_{mean} - T_{target}| \quad (5)$$

A deviation of less than  $\pm 5^\circ\text{C}$  is considered acceptable for reliable sealing performance. The use of hysteresis in the ON-OFF control logic helps to reduce rapid temperature fluctuations and improves overall thermal stability.

## 2. Sealing Quality

Sealing quality is evaluated based on four performance indicators: bonding strength, absence of overheating damage, seal symmetry, and inter-cycle consistency. Each indicator is assigned a score and weight, and the total sealing score is calculated as:

$$S_{total} = \sum_{i=1}^4 \left( \frac{S_i}{S_{max,i}} \times W_i \right) \quad (6)$$

Where  $S_i$  is the score given by evaluators,  $S_{max,i}$  is the maxium possible score,  $W_i$  is the assigned weight for each criterion. This scoring mechanism ensures an objective and normalized comparison of seal quality across different plastic materials.

## 3. Relay Switching Efficiency

Relay actuation efficiency is analyzed by tracking how frequently the relay switches ON and OFF during a sealing cycle. A high frequency of switching may indicate instability in control logic, while minimal, well-spaced switching reflects optimal hysteresis design. The system's ability to maintain thermal setpoints with minimal switching demonstrates improved energy efficiency and extended hardware life.

## 4. Cycle Time Consistency

The system is also evaluated for time efficiency and repeatability. The cycle time per seal is calculated as:

$$\Delta T = |T_{mean} - T_{target}| \quad (7)$$

Consistency in cycle time across multiple trials for each material type is considered indicative of reliable system performance. Excessive variance in timing may suggest sensor lag or mechanical delay in heat distribution.

# RESULT

In this section, the researcher will explain the results of the research obtained. Researchers can also use images, tables, and curves to explain the results of the study. These results should present the raw data or the results after applying the techniques outlined in the methods section. The results are simply results; they do not conclude.

## A. Design of Sealer Machine Made

### 1. Design of the Horizontal Automatic Sealing Machine

The horizontal automatic sealing machine developed in this research is specifically designed to meet the needs of Micro, Small, and Medium Enterprises (MSMEs), particularly for packaging products using thin plastic materials in an efficient, precise, and cost-effective manner. The machine consists of an automatic heating system controlled by an Arduino Uno microcontroller, equipped with a temperature sensor to maintain thermal stability during operation.

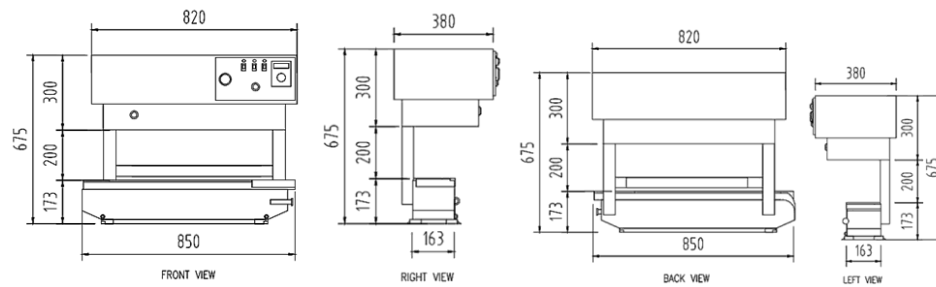


Fig. 3 Multi-angle Design View of the Automatic Sealing Machine

Figure 3 shows the front, right, back, and left views of the sealing machine, illustrating its compact and ergonomic structural design. The overall dimensions of the machine are 850 mm in width and 675 mm in height. The main unit, located at the top, measures 820 mm wide and 300 mm high, while the working zone below it offers a clearance of 200 mm, and the product support base measures 173 mm in height. The front view reveals a user-friendly layout featuring a control panel with temperature setting buttons, system indicators, and a main power switch. Centrally positioned is the heating unit, and below it is the product support area, where the packaging material is placed during sealing. The right view shows the vertical arrangement of the machine's core sections. From bottom to top: the 173 mm high support base, the 200 mm working zone, and the 300 mm upper housing. The control panel is mounted on the top right, while the heating element is aligned centrally to ensure uniform heat distribution. The structure balances functionality with space-saving design. From the back view, the symmetrical alignment of vertical and horizontal elements is clearly visible. The dual-column support structure enhances balance and accessibility. This view also exposes the conveyor and roller system, providing access for maintenance and adjustment. The left view, which mirrors the right side, offers a view of the cable routing, drive mechanism, and motor placement. These components are positioned for optimal servicing. The machine's body is constructed from lightweight yet sturdy metal, ensuring mechanical integrity and allowing for easy mobility within a workspace.

## 2. Main Components of the Machine

The sealing machine consists of several integrated components, each contributing to the overall functionality, safety, and structural stability of the system. At the base of the machine, the packaging material guide plate serves as a track that ensures the smooth movement of plastic materials during the sealing process. Positioned above it is the component support platform, which holds the main structure in place and guarantees operational stability. The system includes an adjustable heat-resistant drive roller assembly, which regulates the pressure and alignment of the rollers, while the sealing guide and protector prevents direct contact between the plastic material and the heating element. Two heating plates, identified as Heater Plate 1 and 2, operate in series to deliver uniform thermal energy for optimal sealing quality. The compression roller ensures firm contact between the heated plastic layers, resulting in a strong bond.

An adjustable heater pressure setting allows the operator to modify how firmly the heater plates press against the packaging material. Additionally, heat-resistant sealing covers are applied to parts that come into direct contact with the plastic, preventing heat damage or sticking. The sealing drive roller pulls the plastic material smoothly through the heated zone, ensuring consistent movement. To protect internal components and support cleanliness, a conveyor cover plate shields the belt system from debris and wear. The conveyor tensioning system helps maintain proper tension and alignment, ensuring reliable packaging flow. Supporting all rotating elements, the shaft and bearing housings provide mechanical balance and durability. Finally, the outer body frame encloses the machine, offering both physical protection for internal systems and a professional industrial appearance.

## 3. Integration Between the Electronic and Mechanical Systems

\* Corresponding author



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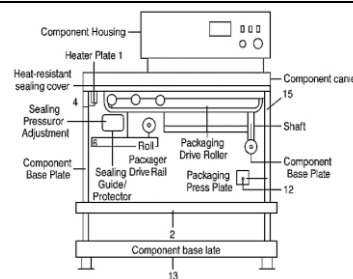


Fig. 4 Detailed Component Integration of the Sealing Machine

Figure 4 illustrates the detailed integration of the key components that form the structural and functional core of the automatic sealing machine. The design highlights the seamless interaction between the electronic control system based on the Arduino microcontroller and the mechanical components responsible for the sealing operation. The heating system, consisting of Heater Plates 1 and 2 and a heat-resistant sealing cover, works in conjunction with pressure adjustment mechanisms to ensure that the applied heat is evenly distributed across the packaging material. The Sealing Guide and Protector prevents direct contact between the heated elements and the plastic film, reducing the risk of overheating or deformation. The drive roller and packaging press plate operate in synchronization to feed the material smoothly through the sealing zone. The system includes adjustable roll and pressure components, allowing for fine-tuning based on the material thickness and desired sealing strength.

Temperature readings are continuously monitored by a digital temperature sensor, which communicates real-time data to the Arduino Uno microcontroller. Based on these readings, the controller activates or deactivates the heating element through a relay, maintaining the working temperature within a  $\pm 5^{\circ}\text{C}$  threshold from the target value. This machine configuration not only provides functional precision but also supports modularity, enabling future enhancements such as automatic product counters, LED temperature displays, or Bluetooth-based IoT integration for advanced control and diagnostics. Additionally, the mechanical frame is designed for stability, ergonomics, and ease of maintenance, making it highly adaptable for diverse production environments, especially in small and medium-sized enterprises (SMEs).

#### 4. Method of Analysis and Data Processing

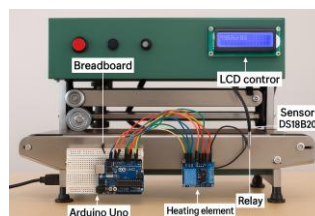


Fig. 5 Implementation of the Arduino Uno-Based Automatic Sealing System

Figure 5 illustrates the physical configuration of the horizontal automatic sealing machine system that has been assembled and integrated with various electronic components controlled by an Arduino Uno microcontroller. This system is designed to seal thin plastic packaging automatically with precise and real-time temperature control. The Arduino Uno functions as the main control unit, receiving temperature data from the DS18B20 sensor and managing the operation of the heating element via a relay module. The DS18B20 sensor is placed close to the heating element to ensure that the detected temperature accurately reflects the actual temperature at the sealing area. The sensor transmits digital temperature data to the Arduino at regular intervals for analysis.

The relay operates as an electronic switch controlled by logic signals from the Arduino. When the measured temperature falls below the user-defined target, the Arduino activates the relay to turn on the heating element. Conversely, if the temperature exceeds the target, the Arduino sends a signal to deactivate the relay, thereby turning off the heater. This control mechanism allows the system to maintain the working temperature within a  $\pm 5^{\circ}\text{C}$  range of the desired value. The 16x2 LCD display presents real-time temperature readings to the operator. This visual interface provides an accessible monitoring solution, eliminating the need for external measuring instruments. The operator can directly observe the operating temperature and adjust the parameters according to the type of plastic packaging in use.

\* Corresponding author



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All components are assembled on a breadboard during the development and testing phase to allow for easier circuit debugging and system adjustments. The breadboard serves as a temporary connection platform between the Arduino, relay, temperature sensor, and LCD. This flexible design approach facilitates system refinement and simplifies maintenance or upgrades. Through this implementation, the system offers an affordable, effective, and user-friendly sealing solution, particularly for MSME-scale operators who require precise thermal control to maintain packaging quality.

## B. Temperature and Sealing Quality Testing Results

The experiment was conducted on three types of plastic materials: PE, PP, and OPP. Each material was tested in 10 sealing cycles under two different conditions: a manual sealing system (without temperature control) and an automatic sealing system integrated with Arduino Uno. During each test, the temperature was recorded every second throughout the sealing process.

The following is a complete calculation for the sealing temperature of PE plastic using a manual sealing machine:

Temperature measurement data (in °C):

(130, 132, 134, 137, 140, 135, 138, 136, 133, 139)

Mean temperature formula :

$$\hat{T} = \frac{130 + 132 + 134 + 137 + 140 + 135 + 138 + 136 + 133 + 139}{10} = 135.4^{\circ}\text{C}$$

Ideal target temperature for PE plastic :

$$T_{\text{target}} = 120^{\circ}\text{C}$$

Temperature deviation from the target :

$$\Delta T = |T_{\text{mean}} - T_{\text{target}}| = |135.4 - 120| = 15.4^{\circ}\text{C}$$

Therefore, the manual sealing machine produced an average temperature of 135.4°C, resulting in a deviation of 15.4°C above the target temperature. This indicates that the heating element in the manual system operates beyond the optimal range, potentially causing damage to the plastic material. To evaluate the effectiveness of the Arduino Uno-based automatic temperature control system, a comparative test was conducted between the conventional (manual) sealing machine and the upgraded sealing machine integrated with Arduino Uno and a DS18B20 temperature sensor.

## C. Sealing Quality Evaluation

The sealing quality was evaluated based on four criteria: bond strength, absence of defects, seal neatness, and consistency. Each criterion was assigned a specific weight and maximum score, with a total score of 100. The evaluation was conducted by three independent assessors. The sealing quality score (0–100) was determined through visual inspection and a simple peel test, using the following rubric:

| Criteria                        | Max Score | Manual Score |
|---------------------------------|-----------|--------------|
| Strong and tear-resistant bond  | 30        | 20           |
| No burn marks or visual defects | 25        | 15           |
| Neat and symmetrical seal       | 20        | 10           |
| Consistency between sealings    | 25        | 15           |
| Total Score                     | 100       | 60           |

The comparison was made based on three key aspects: heater temperature consistency, sealing result quality, and operational ease.

### 1. Heater Temperature Consistency

In the manual sealing machine, the heater temperature is set using a mechanical analog knob. This static adjustment is not responsive to environmental temperature changes or variations in plastic thickness. Observations showed that the heating temperature often exceeded the plastic's melting point, leading to excessive melting or even burning. In contrast, the Arduino Uno-based system reads temperature values in real time using a DS18B20 sensor and regulates heat through an automatic ON/OFF control mechanism, maintaining the working

\* Corresponding author



temperature within  $\pm 5^{\circ}\text{C}$  of the target. This results in more stable thermal control and significantly reduces the risk of overheating.

## 2. Sealing Result Quality

The sealing results from the conventional machine exhibited inconsistencies, particularly with thin plastics such as PE and OPP. Some test results showed uneven pressure distribution, blistering, or poor adhesion due to excessive or insufficient heat.

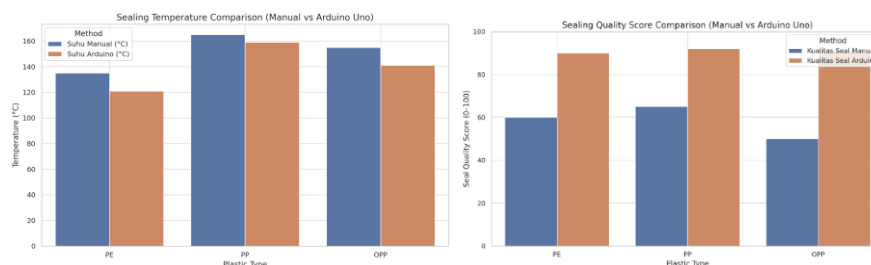


Fig. 6 Sealing Temperature Comparison and Fig. 7 Sealing Quality Score Comparison

Figure 6. Sealing Temperature Comparison (Manual vs Arduino Uno), this figure illustrates the comparison of sealing temperatures between the manual sealing system and the Arduino Uno-based automatic system across three plastic types: PE, PP, and OPP. The Arduino-controlled system consistently produced sealing temperatures that were closer to the optimal target values, while the manual method tended to fluctuate or exceed the thermal threshold. The measured target temperatures—based on the melting points of each material—are approximately  $120^{\circ}\text{C}$  for PE,  $160^{\circ}\text{C}$  for PP, and  $140^{\circ}\text{C}$  for OPP. The Arduino Uno, paired with a DS18B20 temperature sensor, maintained the temperature within a stable  $\pm 5^{\circ}\text{C}$  range through a continuous ON-OFF control loop. This stability ensured that the heating element did not overheat or underheat, even during extended use.

Figure 7. Sealing Quality Score Comparison (Manual vs Arduino Uno), the second figure compares the sealing quality scores between the manual and Arduino Uno-based systems. A substantial improvement in sealing performance is evident with the integration of Arduino Uno, with quality scores increasing from 50–65 in manual operation to 90–92 in the automated system. These scores were based on four evaluation criteria: bond strength, absence of thermal damage, seal uniformity, and inter-cycle consistency. The improved results reflect stronger, neater, and more reliable seals, especially for thin plastic materials such as PE and OPP.

The test results confirmed that the system achieved 100% success across ten sealing cycles for each plastic type, with no signs of melting failure or sealing errors. The average sealing time per unit was 2–3 seconds, indicating the system's suitability for MSME-scale production environments. The system's key advantage lies in its ability to perform automatic temperature control using only low-cost components (Arduino Uno, DS18B20 sensor, and standard relay), while achieving performance comparable to commercial sealing machines.

## DISCUSSIONS

The findings of this study indicate that integrating an Arduino Uno based microcontroller into a horizontal sealing machine can improve thermal stability and enhance sealing quality for a variety of thin plastic materials used by SMEs. In traditional systems, temperature control relies heavily on operator intuition, which often results in overheating. This challenge is particularly evident when sealing plastics such as polyethylene (PE), polypropylene (PP), and oriented polypropylene (OPP), each of which exhibits different thermal sensitivities and sealing temperature ranges.

Quantitative analysis revealed that the manual system experienced temperature fluctuations, with deviations reaching up to  $15.4^{\circ}\text{C}$  from the target. In contrast, the proposed system uses an ON-OFF control algorithm combined with hysteresis logic and real-time input from the DS18B20 sensor, which maintains a stable temperature within  $\pm 5^{\circ}\text{C}$ . This tolerance is scientifically acceptable for PE with a melting point of  $105\text{--}130^{\circ}\text{C}$ , PP around  $160^{\circ}\text{C}$ , and OPP between  $135\text{--}145^{\circ}\text{C}$ , whose sealing windows accommodate small fluctuations as long as they are within the specified limits. The hysteresis mechanism reduces the relay switching frequency, thereby minimizing mechanical wear and extending the service life of the heating components.

In terms of energy efficiency, the hysteresis-based ON-OFF strategy reduces unnecessary heater activation by only triggering the heating element when the temperature drops below a lower threshold. This approach not only reduces

\* Corresponding author



overall power consumption but also reduces thermal stress on system components. Limiting the switching cycles protects the relay from excessive electrical wear and contributes to a longer operational life.

Improved thermal control can improve product quality, with the Arduino-based system achieving an average sealing score of 92 out of 100, compared to only 60 for manual operations. These results reflect stronger bonds, lower thermal degradation, and more uniform seal consistency. Additionally, the inclusion of a 16x2 LCD allows for real-time temperature monitoring, reducing operator workload and improving safety. While the system currently uses basic control logic, its modular design supports future enhancements such as PID controllers, adaptive response algorithms or IoT-based monitoring, allowing for greater precision, automation and performance optimization.

## CONCLUSION

This study successfully designed and implemented an automatic horizontal sealing machine equipped with a temperature control system based on the Arduino Uno microcontroller and a DS18B20 digital temperature sensor. The system was specifically developed to address temperature inconsistency and poor sealing quality commonly found in thin plastic packaging used by Micro, Small, and Medium Enterprises (MSMEs). Experimental results demonstrated that the system was able to maintain the operating temperature within a stable range of  $\pm 5^{\circ}\text{C}$  from the target value, resulting in more consistent and neater sealing outcomes compared to conventional manual systems. The integration of real-time temperature monitoring via a 16x2 LCD and Arduino Uno significantly enhanced operational efficiency and reduced reliance on operator intuition. The quality score of the sealing process increased from 60 (manual system) to 92 (automated system), indicating improvements in bonding strength, sealing precision, and reduction of heat-related defects. This research offers a practical solution for MSMEs by providing a cost-effective, easily assembled, and expandable packaging system. However, the current system still has limitations, such as the slow response time and limited temperature range of the DS18B20 sensor, and the basic ON-OFF control algorithm which lacks the responsiveness of a PID-based system. Moreover, the mechanical structure has not been tested under prolonged high-volume production. Future developments are recommended to include the use of thermocouple sensors (e.g., Type K) with a wider and more accurate temperature range, the implementation of PID-based control for better thermal regulation, integration with mobile or IoT-based performance monitoring, and real-world testing under diverse MSME production conditions. Addressing these limitations will enable the proposed system to become a more robust, reliable, and scalable solution for the broader small-scale industrial sector in Indonesia.

## REFERENCES

- Adityas, Y., Ahmad, M., Khamim, M., Sofi, K., & Riady, S. R. (2021). Water Quality Monitoring System with Parameter of pH, Temperature, Turbidity, and Salinity Based on Internet of Things. *JISA(Jurnal Informatika Dan Sains)*, 4(2), 138–143. <https://doi.org/10.31326/jisa.v4i2.965>
- Al Tahtawi, A. R., Andika, E., & Harjanto, W. N. (2021). Portable wireless node design for smart agricultural system based on Internet of Things. *IAES International Journal of Robotics and Automation (IJRA)*, 10(1), 1. <https://doi.org/10.11591/ijra.v10i1.pp1-9>
- Arifeen, M., & Petrovski, A. (2023). Bayesian Optimized Autoencoder for Predictive Maintenance of Smart Packaging Machines. *Proceedings - 2023 IEEE 6th International Conference on Industrial Cyber-Physical Systems, ICPS 2023*, 2023(May), 8–11. <https://doi.org/10.1109/ICPS58381.2023.10128064>
- Du, L., Huang, X., Li, Z., Qin, Z., Zhang, N., Zhai, X., Shi, J., Zhang, J., Shen, T., Zhang, R., & Wang, Y. (2025). Application of Smart Packaging in Fruit and Vegetable Preservation: A Review. *Foods*, 14(3). <https://doi.org/10.3390/foods14030447>
- Ilhan, I., Turan, D., Gibson, I., & ten Klooster, R. (2021). Understanding the factors affecting the seal integrity in heat sealed flexible food packages: A review. *Packaging Technology and Science*, 34(6), 321–337. <https://doi.org/10.1002/pts.2564>
- Issue, S. (2024). Journal of Agrometeorology. *Journal of Agrometeorology*, 6(1), 5–9.
- Kana, A. M. H., Laumal, F. E., Bataona, D. S., Mone, O. A., Peli, S., & Ada, Y. S. B. (2019). *Development of Roaster Control System Based on Arduino*. <https://doi.org/10.4108/eai.20-1-2018.2281902>
- Kim, S. Y., Park, J., Kim, S. H., Kadathala, L., Baek, J. H., Kim, J. H., & Choi, J. H. (2020). The tuning capability of CuO and Na2Co3 dopant on physical properties for laser sealing using fiber types of sealant. *Applied Sciences (Switzerland)*, 10(1). <https://doi.org/10.3390/app10010353>
- Osmólska, E., Stoma, M., & Starek-Wójcicka, A. (2022). Application of Biosensors, Sensors, and Tags in Intelligent Packaging Used for Food Products—A Review. *Sensors*, 22(24). <https://doi.org/10.3390/s22249956>
- Otles, S., & Sahyar, B. Y. (2016). Intelligent Food Packaging. *Comprehensive Analytical Chemistry*, 74, 377–387.

\* Corresponding author



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- <https://doi.org/10.1016/bs.coac.2016.04.010>
- Ozcan, A. (2020). New approaches in smart packaging technologies. *International Symposium on Graphic Engineering and Design*, 21–34. <https://doi.org/10.24867/GRID-2020-p1>
- Packag Technol Sci - 2023 - Merabtene - Heat-sealing and microscopic.pdf*. (n.d.).
- Pirayeh Gar, S., Zhong, A., & Jacob, J. (2024). Machine Learning Aided Optimization of Non-Metallic Seals in Downhole Tools. *Engineering Modelling, Analysis and Simulation*, 1(1), 1–6. <https://doi.org/10.59972/u9ej3qc7>
- Popović, N., & Naumović, M. (2020). Application of Internet of Things Hardware in Control Systems. *Ijeec - International Journal of Electrical Engineering and Computing*, 5(1), 50–58. <https://doi.org/10.7251/ijeec2101050p>
- Thirupathi Vasuki, M., Kadirvel, V., & Pejavara Narayana, G. (2023). Smart packaging—An overview of concepts and applications in various food industries. *Food Bioengineering*, 2(1), 25–41. <https://doi.org/10.1002/fbe2.12038>
- Winotapun, C., Makmoon, T., Aumnate, C., Thanomjittr, D., Rungseesantivanon, W., & Ito, H. (2023). Microfabrication of Thermoplastic Polypropylene Surface Structures via Thermal Imprinting for Controlling the Adhesion of Easy Peel Package. *ACS Omega*, 8(38), 35127–35139. <https://doi.org/10.1021/acsomega.3c04671>
- Xu, L., Huang, X., Huang, X., Xu, J., Xing, X., Xu, M., Ma, C., & Huang, M. (2020). Systematic experimental investigation on in-situ self-adaptive sealing property of composite pressure-activated sealant for curing minor tubular leaks. *Energies*, 13(21). <https://doi.org/10.3390/en13215597>
- Yang, F., Chen, D., Chen, J., & Nie, X. (2023). Design and Analysis of Automatic Heat Sealing Production Line for a Top Cover. *Journal of Physics: Conference Series*, 2674(1). <https://doi.org/10.1088/1742-6596/2674/1/012008>