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Development of a Smoking Device to Enhance Quality and Production of Smoked Fish

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Abstract

This study focuses on the design and development of a smoking device aimed at enhancing the quality and production efficiency of smoked fish (Salai). The primary objective was to create a device that optimizes the smoking process, ensuring consistent product quality while increasing production capacity. The development process involved a systematic design approach, including the selection of materials and construction techniques. The smoking process utilized a combination of drying and the application of natural smoke compounds derived from the combustion of organic materials. Performance testing was conducted using catfish as the primary substrate, with measurements taken for smoking duration, moisture content, and production rate. The effectiveness of the device was evaluated based on sensory characteristics, including texture, color, and aroma. The smoking apparatus was constructed with dimensions of 126 cm x 100 cm x 180 cm and is capable of accommodating up to 32 kg of fresh fish per smoking cycle. Results indicated that the smoking device achieves a production rate of 4 kg of smoked fish per hour, yielding products with a desirable golden-brown color and distinct smoky aroma. The findings demonstrate that the device significantly improves production capacity and allows for enhanced control over smoking conditions, contributing to greater consistency in product quality.

Keywords: Production capacity, production rate, product quality, smoked fish, smoking process

INTRODUCTION

Salai is an Indonesian term that refers to the process of smoking fish or meat to preserve it and enhance its flavor. The smoking process typically involves exposing the food to smoke from burning or smoldering materials, often wood, which imparts a distinct taste and aroma while also helping to inhibit microbial growth and extend shelf life [1]. In culinary contexts, "salai" often describes both the method and the product of smoked fish, which is commonly consumed in various Indonesian dishes. The technique can vary in terms of the type of wood used, smoking duration, and the specific methods of preparation, contributing to a variety of flavors and textures in the final smoked product [2], [3].

Salai fish, as one of the processed fish-based products, has an important role in the economy of coastal communities and as a popular source of protein in various regions, especially in Indonesia [4], [5] [6]. Fish smoking has long been a traditional method used to preserve fish and extend its shelf life, while providing a

distinctive flavor [1], [4]. However, the traditional smoking process often faces various challenges, including the lack of consistency in temperature, smoking time, and the quality of the smoke used. These challenges have a direct impact on the final quality of the product, which can result in non-uniform texture, flavour and colour of salai fish [6]. In addition, the potential for microbial contamination or harmful chemicals such as carcinogenic polycyclic aromatic hydrocarbon (PAH) compounds is a concern in traditional salai fish production[7]. In response to growing public awareness of the importance of safe and high-quality food, alongside global market demands for products that meet international standards, innovation in fish smoking technology has become essential [4]. The development of this technology must address the limitations of traditional smoking methods, with an emphasis on enhancing production efficiency and ensuring consistent product quality [3].

Furthermore, the developed fish smoking device is expected to mitigate contamination risks commonly associated with traditional methods, including microbial and chemical contamination [4], [8]. As a result, the products will be safer for consumption and more competitive in both domestic and international markets. Moreover, the developed fish smoking device is expected to reduce contamination risks commonly encountered in traditional methods, including both microbial and chemical contamination [9], [7]. Consequently, the resulting products will be safer for consumption and possess higher competitiveness in both domestic and international markets [10] .

This study focuses on the design and development of an innovative fish smoking device intended for use by the Nurul Azhar Bagan Benio Islamic Boarding School. The device has been tailored to suit the specific conditions of the application site, considering both smoking capacity and fuel requirements. Additionally, this research will analyze the potential for increased production capacity through the use of this device, which is ultimately expected to make a significant contribution to enhancing the competitiveness of smoked fish products in the global market.

RESEARCH METHODS

The method used in this research is the design method of fish smoking equipment, using a stove smoking system in a smoking cabinet. After the tool is complete, testing is also carried out on the ability of the tool in the smoking process. This research was conducted to design, construct, and test a smoking device aimed at improving the quality and production of smoked fish. The approach used involves five main stages: literature review, equipment design, procurement of tools and materials, construction and installation of the device, performance testing, and result evaluation. The explanation of each stage is illustrated in the schematic diagram in **Fig. 1**

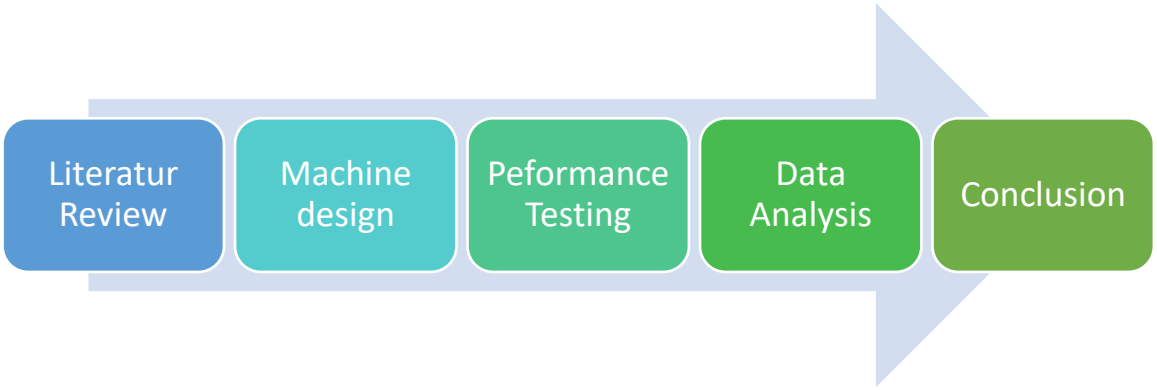


Fig. 1. Research scheme

1. Literature Review

The initial stage of this research involves gathering information from various relevant sources, such as scientific journals, books, thesis reports, and online articles discussing the fish smoking process. The literature review aims to understand the working principles of existing smoking devices, including identifying their advantages and limitations. This information is utilized to determine the design requirements, ensuring that the proposed device operates more efficiently, effectively, and meets the desired quality standards.

In addition, field observations are conducted to directly observe traditional fish smoking practices. These observations help in understanding the current processes, challenges encountered, and specific needs of users or business operators. The combination of data from the literature review and field observations forms a crucial foundation for planning and developing a more advanced and improved fish smoking device.

2. Equipment Design

Once the necessary information has been gathered, the next step is to design a tool aimed at improving the quality and efficiency of the smoked fish production process. This design is developed based on data obtained from the literature review and field observations, ensuring that it meets both technical and operational requirements effectively.

3. Equipment Performance Testing

The smoking process begins with preparing the heat source by burning coconut shells or wood to produce charcoal. This step is crucial as the charcoal serves as the primary source of both heat and smoke, which are essential for the smoking process. The burning of coconut shells or wood is carefully monitored to ensure the charcoal is properly ignited without excessive flames, creating a stable and consistent smoke output.

The equipment performance testing stage is essential to ensure that the equipment operates as intended, according to the design specifications. This phase involves several key activities, starting with operational trials to evaluate the efficiency of the smoking process, the stability of the temperature, and the overall quality of the smoked fish produced. These tests help assess the effectiveness of the equipment in achieving consistent results under real-world conditions.

Following the operational trials, a detailed analysis of the test results is conducted to verify that the equipment meets the established quality standards and is capable of supporting the optimal production of smoked fish. This analysis ensures that the equipment not only performs its intended functions but also contributes to maintaining the high quality of the final product.

If any potential issues are identified during the testing phase, corrective actions are promptly taken to address the problems and improve the equipment's performance. These improvements may include adjustments to the design, operation, or maintenance of the equipment to ensure its long-term effectiveness and reliability.

An example of the performance evaluation includes calculating the moisture content of the smoked fish. This is done by determining the percentage of water weight remaining in the fish after the smoking process, using the formula provided in Equation 1. This measurement is critical for assessing the quality and texture of the smoked fish, ensuring it meets the desired standards for both moisture levels and overall product quality.

$$\text{Moisture Content} = \frac{BeraInitial\ Weight - Final\ Weight}{Initial\ Weight} \text{ x } 100\% \quad (1)$$

The formula for calculating moisture content is used to determine the percentage of water present in a material based on the weight change before and after the drying process. The calculation involves subtracting the final weight (after drying) from the initial weight (before drying). The result of this subtraction is then divided by the initial weight and multiplied by 100% to express the value as a percentage. This formula is essential for measuring how much water has been lost from the material during the drying process and is widely applied in various fields, such as food processing and product quality control.

Additionally, to assess the capacity of the smoking equipment for improving the quality and production of smoked fish, we use the formula in Equation 2. This equation measures the equipment's ability to produce smoked fish efficiently, considering factors like smoking duration and product yield.

$$\text{Capacity} = \frac{Final\ Weight}{Smoking\ Time} \quad (2)$$

The capacity formula is used to calculate the ability of a tool or system to process materials over a specific period. Capacity is determined by dividing the final weight of the material produced after the smoking process by the total smoking time. This calculation provides an indicator of how much material the equipment can process per unit of time, typically expressed in weight per hour (such as kilograms per hour). This formula is valuable for evaluating the efficiency of the smoking equipment and determining whether the tool can meet production demands effectively and consistently.

In addition, to assess the reduction in fish weight, the yield or "rendemen" is calculated using Equation 3. This measure helps in understanding how much weight is lost during the smoking process, reflecting the effectiveness of the drying and smoking stages in terms of moisture reduction.

$$\text{Yield} = \frac{Final\ Weight}{Initial\ Weight} \text{ x } 100\% \quad (3)$$

The formula for calculating yield is used to determine the percentage of the final product compared to the initial raw material. Yield is calculated by dividing the final weight of the product by the initial weight of the raw material, then multiplying the result by 100% to express it as a percentage. This formula is essential for evaluating the efficiency of a production process, such as in food processing or raw material conversion, and for measuring how much of the material is effectively transformed into the final product. A higher yield indicates a more efficient process with minimal material loss during production, which is desirable in manufacturing, as it helps optimize resource utilization and reduce waste.

4. Results

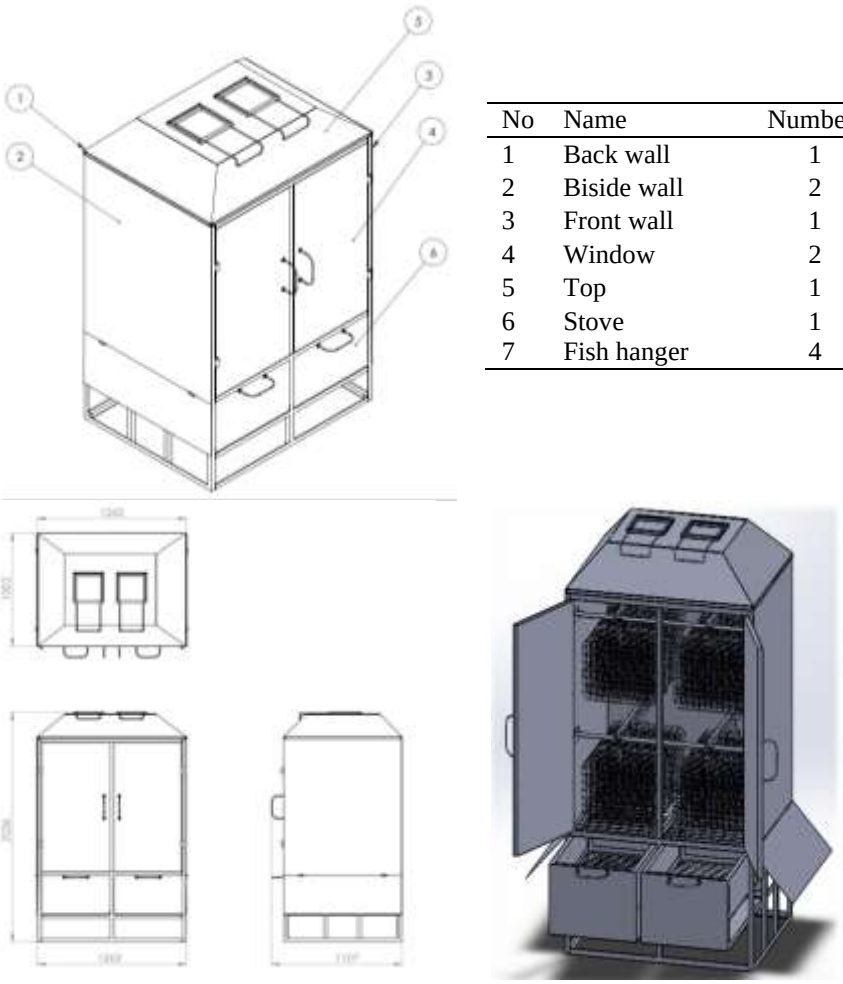
The design outcomes reveal that the smoking device had a significant impact on the quality and production efficiency of smoked fish. In particular, its precise temperature control ensured improved texture and flavor profiles compared to traditional methods.

RESULT AND DISCUSSION

Based on these findings, it is essential to further explore the factors influencing the performance of the smoking device. The results indicate that consistent temperature control plays a pivotal role in enhancing the quality of smoked fish, particularly in terms of texture and flavor. This highlights the need to examine the implications of the device's design on both production efficiency and product consistency. Therefore, the following discussion focuses on analyzing these aspects in greater depth, providing insights into the practical and technical significance of the developed smoking device.

To ensure the accuracy of the design, mechanical design software can be utilized to create a more detailed and precise visualization of the equipment. At this stage, technical specifications are also determined, including the dimensions of the equipment, the type of materials to be used, and the working mechanism that aligns with the tool's intended function and purpose. A well-prepared design at this stage aims to produce equipment that is not only efficient but also meets quality standards and user requirements comprehensively.The construction and detail of the geometry of the smoke

There are no sources in the current document. [1]d fish machine is presented in **Fig. 2.**



No	Name	Number
1	Back wall	1
2	Biside wall	2
3	Front wall	1
4	Window	2
5	Top	1
6	Stove	1
7	Fish hanger	4

Fig. 2. Construction and detail of geometry machine

Test Result

The equipment testing was conducted using catfish, with the following test results in **Table 1**.

Table 1. The test result of pre-smoking and post smoking of catfish

Parameter	Pre-Smoking	Post-Smoking
Weight	4 kg	1 kg
Color	Pink	Brownish
Texture	Soft	Firm
Aroma	Fresh	Smoky

The smoking duration was measured by timing how long it took to smoke the fish using a stopwatch. In this test, the smoking process was completed in 2 hours. Additionally, the moisture content of the smoked fish was determined by calculating the percentage of water weight remaining in the fish after smoking. This calculation was performed using a specific formula to assess the effectiveness of the smoking process in reducing moisture levels.

$$Moisture\ Content\ =\ (Initial\ Weight\ -\ Final\ Weight)\ /\ (Initial\ Weight)\ x\ 100\%$$

$$=\ (4\ kg\ -\ 1\ kg)\ /\ (4\ kg)\ x\ 100\%\ =\ 75\%$$

The capacity of the equipment, which is defined by its ability to produce smoked fish, is calculated using a specific formula. This formula helps determine the production efficiency of the device, providing a clear understanding of how much fish can be processed within a given time frame.

$$Capacity\ =\ \frac{Final\ Weight}{Smoking\ Duration}\ =\ \frac{1\ kg}{2\ hours}\ =\ 0.5\ kg/hour$$

Yield represents the weight reduction ratio of the fish and is calculated using a specific formula. This ratio helps assess the effectiveness of the smoking process by measuring how much weight is lost during smoking, providing valuable insight into the moisture loss and overall quality of the smoked fish.

$$Yield\ =\ \frac{Final\ Wight}{Initial\ Weight}\ \times\ 100\%\ =\ \frac{1\ kg}{4\ kg}\ \times\ 100\%\ =\ 25\%$$

The calculation of total equipment capacity was conducted during testing with catfish. An initial weight of 4 kg required 5 clamps, and given that the equipment has a total of 40 clamps, the maximum weight of fresh fish the equipment can hold was calculated accordingly.

$$Fresh\ Fish\ Capacity\ =\ \frac{Total\ Clamps}{Clamps\ Used}\ \times\ Initial\ Weight\ =\ \frac{40}{5}\ \times\ 4\ kg\ =\ 32\ kg$$

The first step involves gutting the fish by removing the internal organs and thoroughly cleaning it to eliminate any impurities. This step is crucial to ensure the fish is properly prepared for the smoking process and meets hygiene standards. Once cleaned, the fish is arranged on a drying rack in a well-ventilated area and left to air dry for approximately 30 minutes. This drying stage is essential to reduce excess moisture from the fish, allowing the smoking process to be more effective and improving the overall texture of the final product.

After the drying period, the fish is carefully placed on the grilling clamps. These clamps are designed to hold the fish securely during the smoking process, ensuring even exposure to heat and smoke. Proper placement of the fish on the clamps is important to prevent uneven smoking and to maintain the structural integrity of the fish. With these preparations complete, the equipment is ready to undergo performance testing to evaluate its effectiveness in producing high-quality smoked fish. For example, see **Fig. 3**

Fig. 3. Arrange the fish on the hanger

The total capacity of the equipment is determined by calculating the final weight of smoked fish, which is based on the initial weight and the moisture content. This calculation helps assess the effectiveness of the smoking process in reducing moisture and provides a clear measure of the equipment's capacity to process fish.

$$Final\ Weight\ =\ Initial\ weight\ -\ (Initial\ Weight\ \times\ Moisture\ Content)$$

$$=\ 32\ kg\ -\ (32\ kg\ \times\ 0.75)\ =\ 8\ kg$$

The doneness of the fish is evaluated by observing specific characteristics that indicate proper smoking. Fully smoked fish typically exhibit a smooth, glossy texture, a light golden-brown color, and a distinctive smoked aroma. These attributes reflect the successful absorption of heat and smoke during the process, ensuring the fish is evenly cooked, flavorful, and visually appealing. For example, see **Fig. 6**

Fig. 6. Hang fish

The equipment's capacity to produce smoked fish is calculated based on specific parameters, which help determine its efficiency in processing fish. This calculation takes into account various factors such as the number of clamps, weight of the fish, and smoking duration, providing an accurate measure of the equipment's overall performance.

$$Capacity\ =\ \frac{Final\ Weight}{Smoking\ Duration}\ =\ \frac{8\ kg}{2\ hours}\ =\ 4\ kg/hour$$

Therefore, this equipment can produce smoked fish at a rate of 4 kg per hour.
Based on the testing results, when compared to traditional methods without the designed device, the smoking time is reduced by 2 hours for the same capacity of 4 kg of fish.

After the smoked fish is fully cooked, it should be carefully removed from the smoking cabinet and placed on a cooling rack. This step allows the fish to cool evenly at room temperature, helping to stabilize its texture and preserve its smoky aroma and flavor. Proper cooling also prevents condensation, which could affect the quality and shelf life of the smoked fish. For example, see **Fig. 7**

Fig. 7. Results after fish smoking

After completing the smoking process, ensure that the remaining charcoal in the stove is fully extinguished and no active flames remain. Next, clean the smoked fish thoroughly to remove any dust or residues before storing it in designated storage boxes in preparation for packaging. Once all smoking activities are concluded, clean and store the equipment properly to maintain its functionality and longevity, and organize the workspace to ensure it is neat and ready for future use.

The research conducted by [11] demonstrated a significant improvement in production efficiency, reducing the processing time from 4 hours to just 1 hour for 5 kilograms of fish per cycle. In comparison, the newly developed equipment showcased its capability to smoke fish at a rate of 4 kilograms per hour, with a total capacity of up to 32 kilograms of fresh fish. While the first approach emphasizes time efficiency for smaller batches, the latter highlights scalability and the ability to handle larger volumes, making each innovation uniquely suited to different production needs and operational scales.

CONCLUSIONS

The construction of the fish smoking equipment led to the following conclusions: Smoking, as a method of food processing and preservation, combines drying with the introduction of natural chemical compounds produced during the combustion of organic fuel sources. A functional and efficient smoking apparatus was successfully developed to improve both the quality and quantity of smoked fish production. With dimensions of 126 cm x 100 cm x 180 cm and a capacity to process up to 32 kg of fresh fish, this equipment can smoke fish at a rate of 4 kg per hour. The affordable and efficient nature of this smoking device presents a valuable opportunity for small-scale fish processors, enabling them to produce higher-quality smoked fish. This advancement in processing technology not only enhances product quality but also democratizes access to better equipment, thereby fostering growth and innovation within the fish processing industry across various scales.

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