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Smart fish drying: Solar-powered automatic salted fish production system

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Kata kunci:
ikan asin;
lensa cembung;
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sel surya

ABSTRAK: Karena ketidakstabilan cuaca dalam beberapa tahun terakhir, produksi ikan asin di Indonesia mengalami penurunan, sementara kualitas ikan asin yang dihasilkan tetap rendah. Untuk mengatasi tantangan ini, "*SMART FISH DRYING*" dirancang sebagai sebuah sistem pengeringan ikan otomatis berbasis rumah kaca transparan. Sistem ini menggunakan dinding akrilik dan atap lensa cembung yang memfokuskan sinar matahari. Di dalam "*SMART FISH DRYING*", ikan disusun di atas meja kawat stainless steel yang dilengkapi dengan sensor kelembaban. Meja ini akan berputar secara otomatis ketika kadar air pada satu sisi ikan mencapai 30%. Ketika kedua sisi ikan telah mencapai kadar air yang diinginkan, lampu LED dan alarm akan aktif sebagai penanda bahwa ikan asin siap dipanen. "*SMART FISH DRYING*" beroperasi menggunakan sel surya yang terhubung ke baterai, sehingga secara signifikan mengurangi konsumsi energi dan biaya operasional. Selain itu, sistem ini dilengkapi dengan mekanisme penangkap gas untuk menyerap senyawa H_2S yang dilepaskan selama proses pengeringan, yang kemudian dapat diolah menjadi pestisida. Proses ini dipantau oleh sensor gas MQ136 untuk mengukur konsentrasi senyawa berbahaya. Selain itu, "*SMART FISH DRYING*" mengoptimalkan kelembaban yang dihasilkan selama proses pengeringan melalui sistem distilasi untuk menghasilkan air murni sebagai produk sampingan. Dengan teknologi ini, produksi ikan asin dapat dipercepat hingga dua kali lipat dibandingkan metode tradisional, dengan peningkatan profitabilitas hingga empat kali lipat serta peningkatan kualitas produk sebesar 20%.

Keywords:
dried fish;
convex lens;
automatic;
solar

ABSTRACT: Due to weather instability in recent years, dried fish production in Indonesia has declined, while the quality of the produced dried fish remains low. To address this challenge, the authors introduce "SMART FISH DRYING," an automatic fish drying system based on a transparent greenhouse structure. This system uses acrylic walls and a convex lens roof that focuses sunlight. Inside "SMART FISH DRYING," fish are arranged on a stainless steel wire mesh table equipped with a humidity sensor that automatically rotates the table when the fish's moisture content on one side reaches 30%. When both sides reach the desired moisture level, an LED light and alarm activate, signaling that the dried fish is ready for harvesting. "SMART FISH DRYING" operates using solar cells connected to a battery, significantly reducing energy consumption and operational costs. Additionally, the system features a gas collection system to capture H_2S compounds released during the drying process, which can be processed into pesticides. This process is monitored by an MQ136 gas sensor to measure the concentration of harmful compounds. Moreover, "SMART FISH DRYING" optimizes the moisture from the drying process through a distillation system to produce purified water as a byproduct. With this technology, dried fish production can be accelerated by two times compared to traditional methods, with a fourfold increase in profitability and a 20% improvement in product quality.

1 INTRODUCTION

As the world's largest archipelagic country, Indonesia has an extensive marine area covering approximately 5.8 million km² [1]. Indonesia's marine resources are highly diverse, including petroleum, natural gas, fish and marine biota, and coral reef ecosystems. Fish, as a primary resource, is a protein-rich food commodity and plays a crucial role in meeting public nutritional needs [2]. Indonesia's fisheries potential is estimated to reach 23,131,525.37 tons in 2023, which can be processed into various products such as fresh fish, processed fish, and dried or salted fish [3]. The consumption of fish in Indonesia has been increasing annually in

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fresh, processed, and salted forms, as reported by the Central Bureau of Statistics (BPS) in 2021. To maintain fish quality and extend shelf life, various preservation methods are used, including salting, drying, boiling, smoking, fermentation, and refrigeration [4]. One of the popular fish preservation methods in Indonesia is drying to produce salted fish. In 2021, the consumption of salted fish in Indonesia reached 0.712 ounces per capita per week [5]. Further data indicates that from 2014 to 2021, salted fish consumption increased by 19.17% [2].

However, despite the growing demand for salted fish, domestic production remains relatively low in both quantity and quality. As a result, Indonesia had to import 300 tons of salted fish between 2017 and 2018 to meet market demands [6]. One of the primary challenges in salted fish production is the reliance on traditional drying methods, which are heavily dependent on weather conditions. During the rainy season, the drying process is hindered, reducing production output. Additionally, locally produced salted fish often struggles to compete with imported products, which have a longer shelf life and superior quality [7].

To overcome these issues, the authors propose an innovation called "SMART FISH DRYING," an automatic fish drying system utilizing a greenhouse method. By incorporating a convex lens as a roof to focus sunlight, "SMART FISH DRYING" enables efficient fish drying regardless of weather conditions. Solar energy is utilized as the primary power source, aiming to enhance both the quantity and quality of salted fish production in Indonesia.

2 METHODS

Tools, Materials, and Prototype Development Location

The prototype development was carried out in the fishing village of Lumpur, Gresik. Previously, the process of making salted fish in this area relied on simple equipment and was highly dependent on natural conditions. Salted fish producers could only carry out production during the dry season. The components used in the development of "SMART FISH DRYING" include a convex lens, stainless steel wire, acrylic, a DC motor, a moisture sensor, a solar panel, a battery, an Arduino Mega, an MQ136 sensor, a condenser tube, and several small electronic components.

Literature Study

This activity was conducted to gather supporting materials from books and other literature sources to ensure the proper design of "SMART FISH DRYING." The materials sought include information on fish, the process of making salted fish, convex lenses, the MQ136 sensor, Arduino Mega, H_2S condensation, moisture sensors, and solar panels.

Device Design

The design phase was carried out to ensure that the device met expectations and to minimize errors in its development. The design of "SMART FISH DRYING" consists of essential components, including input, output, and power, as illustrated in Figure 1.

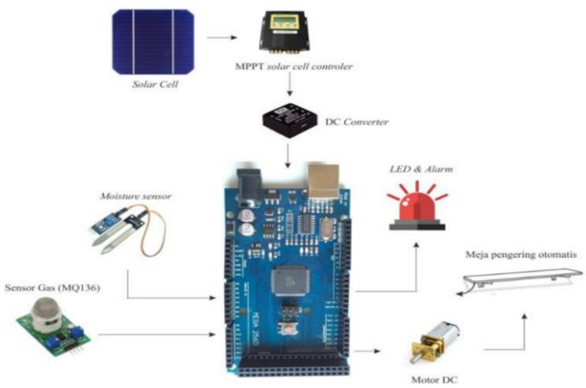

Figure 1. "SMART FISH DRYING" System Design

1. The fish drying table is made of woven stainless steel wire with a hinge on one side and latches on the other three sides to prevent fish from falling when the drying table rotates. The table is placed inside "SMART FISH DRYING" at a 15° incline facing the fan.
2. The transparent enclosure is made of four clear acrylic panels, each 5 mm thick, serving as walls. The floor is made of black plastic, while the transparent roof is made of a convex lens with a focal length of 50 cm.
3. Moisture sensors measure the moisture content of the fish from both the top and bottom of the drying table. The sensor's voltage readings are processed by the Arduino Mega. These sensors work based on humidity levels and the moisture content of the drying fish.
4. The drying table automatically rotates 180° when the fish moisture content reaches a certain level, as detected by the Arduino Mega from the moisture sensor readings.

5. An automatic harvest notification system is integrated, where an alarm sounds and an LED light turns on when the fish moisture content reaches a specific threshold, based on the Arduino Mega's moisture sensor readings.
6. A fan is placed on the north side of "SMART FISH DRYING" to direct airflow toward the condensation tube through a duct at the base of the structure. Additionally, the fan helps accelerate the fish drying process.
7. The MQ136 gas sensor is positioned inside the condensation tube to detect gas types and their concentrations. The sensor readings are displayed on an LCD screen at the top of the tube.
8. The H_2S condensation system operates inside the condensation tube, which contains an SO_2 solution.
9. The power source consists of two 200Wp solar cells as the primary energy source for "SMART FISH DRYING," along with an MPPT solar charge controller to optimize solar panel performance. The system is also equipped with a battery to store energy for nighttime use or cloudy conditions.

Device Fabrication

The fabrication of "SMART FISH DRYING" follows these steps, with a general illustration of the system shown in Figure 2.

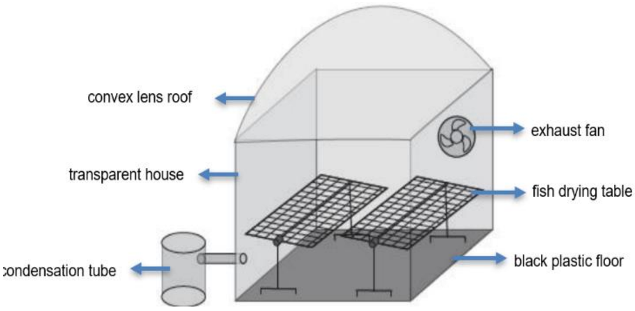

Figure 2. General Overview of "SMART FISH DRYING"

1. "SMART FISH DRYING" Dimensions: The structure is built on a square base with an area of 1 m^2 and a height of 1 meter. The prototype is located in the fishing village of Lumpur, Gresik.
2. Fish Drying Table Dimensions: The drying table has a length, width, and height of 90 cm, 45 cm, and 45 cm, respectively. The table can rotate 180°, with its axis positioned at the center. The spacing of the stainless steel wires depends on the type of fish being dried.
3. Light Focusing System: The "SMART FISH DRYING" structure is designed with transparent walls to allow sunlight to enter from various directions. The roof, made of a convex lens, focuses sunlight onto the drying table, increasing the heat received by the fish compared to traditional sun drying.
4. Automatic Table Rotation System: The drying table rotates 180° when the fish moisture content reaches 45% and 30%. This system ensures even drying and improves the quality of the salted fish.
5. Power Source: The energy for "SMART FISH DRYING" comes from solar panels connected to a battery that powers all sensors and the table rotation motor. The battery serves as a backup energy source for nighttime and cloudy conditions, ensuring uninterrupted operation.
6. Harvest Notification System: When the moisture sensor detects that the bottom layer of fish has reached 30% moisture content, the "SMART FISH DRYING" alarm will sound, and an LED light on the left side of the drying table will illuminate, indicating that the salted fish is ready for harvest.
7. H_2S Condensation System: Air inside "SMART FISH DRYING" is directed by the fan through a duct into the condensation tube. Inside the tube, gases containing H_2S react with the SO_2 solution, producing water and sulfur colloids. The sulfur colloid can be further processed for use in cosmetics, fertilizers, and pesticides.

Device Testing

This stage serves as a benchmark for the success of "SMART FISH DRYING." The device is considered to function properly if the following conditions are met:

1. The automatic table rotation system operates when the moisture sensor detects moisture levels of 45% and 30%.
2. The H_2S condensation system functions correctly and produces sulfur colloid.
3. The alarm sounds and the LED lights up when the moisture sensor detects that the bottom layer of fish has reached 30% moisture content.

If all these parameters are achieved, the "SMART FISH DRYING" design is deemed successful.

3 RESULTS AND DISCUSSION

The idea proposed by the author can be applied to salted fish production sites that still use conventional (traditional) methods, namely the drying method that relies solely on sunlight. Geographically, Indonesia has great potential for producing salted fish using drying methods since it is located on the equator and receives approximately 10 hours of sunlight daily, with a maximum intensity of 4–5 hours. However, this solar potential is not yet fully maximized, as the drying process still takes a long time—about 3 to 4 days. Additionally, fish drying produces an unpleasant odor in the surrounding environment. The conventional method of drying salted fish cannot be carried out during the rainy season because exposure to rainwater will cause the fish to spoil.

Testing the Power Source and Requirements of "SMART FISH DRYING"

The energy source for "SMART FISH DRYING" comes from solar cells, meaning the energy used is freely obtained from nature without additional costs, offering greater benefits to fish farm owners. According to data from Indonesia's Energy White Paper (2006), the estimated average solar radiation intensity received by Indonesia's surface reaches approximately 4.8 kWh per square meter per day [8].

The power generated and required by "SMART FISH DRYING" is as follows:

Solar Cells

Shinyoku Polycrystalline 200Wp solar cell with Pmax 200W, dimensions 1482×992×35 m^2, efficiency 21.7%, and an average intensity of 4.8 kWh/m^2.

$$P_{input} = I.A = 4{,}8\,\frac{\mathrm{kWh}}{\mathrm{m}^2} \times 1{,}47\ m^2 = 7{,}06\ \mathrm{kWh} \quad (1)$$

$$P_{output} = \eta . P_{input} = 21{,}7\% \times 7{,}05\ kWh = 1{,}53\ \mathrm{kWh} \quad (2)$$

With an average of 6 hours of sunlight per day, two solar panels can generate 18.35 kWh per day.

Power Requirements for "SMART FISH DRYING"

The power requirements of the SMART FISH DRYING system consist of: Arduino Mega (0.4 W), moisture sensor (0.175 W), DC motor (2 W), MQ136 sensor (0.75 W), LCD (0.2 W), and fan (100 W), totaling 103.5 W. This allows "SMART FISH DRYING" to operate for approximately 177 hours or 7.5 days. Based on power calculations from the solar cells and the system requirements, the solar cells are capable of operating the SMART FISH DRYING system for 7.5 days. With daily solar power absorption, this energy can be stored in a battery installed in the SMART FISH DRYING system, allowing it to function even on cloudy days and during the rainy season when sunlight is less intense.

Drying Process

The fish drying process using "SMART FISH DRYING" utilizes a greenhouse drying method. The transparent house, designed as shown in Figure 2, allows sunlight to enter from all directions while trapping hot air inside. The floor of the transparent house is made of black plastic, which is ideal for absorbing sunlight, making the interior temperature higher than the outside. The higher the temperature inside "SMART FISH DRYING," the faster the drying process.

The roof of "SMART FISH DRYING" is made of a convex lens with a focal length of 50 cm. A convex lens, or converging lens, is thicker in the middle than at the edges. It focuses and gathers parallel light rays [9], so this lens concentrates sunlight entering "SMART FISH DRYING," increasing the amount of sunlight received by the fish compared to other roof designs. The convex lens roof accelerates the drying process and ensures more uniform fish dryness.

Besides utilizing sunlight, "SMART FISH DRYING" also employs wind as a drying medium. A fan is installed on the northern wall of "SMART FISH DRYING" to generate airflow. "SMART FISH DRYING" is implemented in Gresik, which is located south of the equator. Throughout most of the year, the sun is positioned north of the equator. Thus, the fish drying table in "SMART FISH DRYING" is tilted at a 15° angle facing north to speed up the drying process.

Working Principle of "SMART FISH DRYING"

The fish drying table in "SMART FISH DRYING" rotates 180° automatically once the fish reaches a predetermined moisture level. A moisture sensor detects the fish's water content and sends an input signal to the Arduino Mega, which triggers the table's rotation. This rotation occurs vertically.

During the drying process until harvest time, the table rotates multiple times as the moisture level in the fish reaches the setpoint. According to Indonesian National Standards (SNI), the maximum moisture content in salted fish should be 40%, with an optimal level of 30% [10]. In this system, the fish is dried on the table until the top side reaches 45% moisture. Then, the table automatically rotates 180° to expose the underside. Once the bottom side reaches 45% moisture, the table rotates again to dry the top side further until it reaches 30%. The process repeats until both sides reach 30% moisture. When the bottom side reaches 30%, an automatic LED and alarm signal the harvest time. The design of the

"SMART FISH DRYING" drying table is shown in Figure 3.

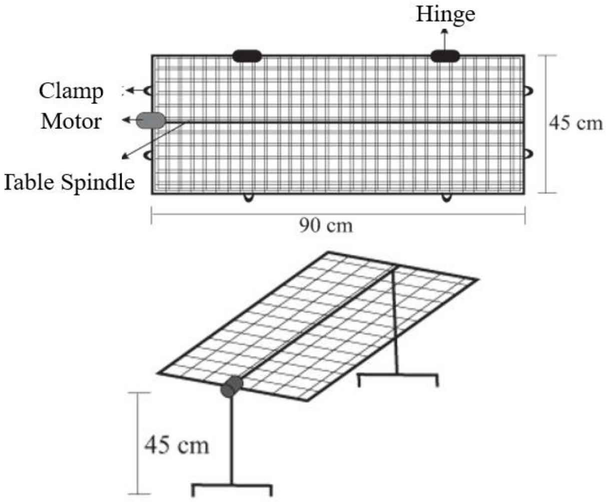

Figure 3. "SMART FISH DRYING" Drying Table Design

H_2S Condensation Process

Condensation is the process of changing gas into liquid. The conversion of H_2S gas into colloidal sulfur can be achieved through condensation by aggregating solution particles into a colloid. This reaction occurs when H_2S gas is mixed with an SO_2 solution, resulting in the following reaction:

$$2H_2S(g) + SO_2(aq) \rightarrow 3S(colloid) + 2H_2O(l) \quad (3)$$

This process produces water and sulfur, which can be used as an ingredient in cosmetics, fertilizers, and other applications [11].

During drying, fish produce an unpleasant odor due to the release of H_2S gas. In a closed space, airflow from the fan directs the gas toward a condensation tube. The H_2S concentration is displayed on an LCD attached to the tube. The average H_2S concentration during drying is 10 ppm. By using a condensation tube with a volume of 108 liters and filling one-third of it with a 0.01 mol SO_2 solution, the system can generate approximately 0.98 grams of sulfur colloid and 0.36 grams of water. Thus, the fish drying process using "SMART FISH DRYING" minimizes unpleasant odors that could pollute the surrounding environment while producing sulfur colloid and water as byproducts.

Economic Analysis

Currently, salted fish producers can only conduct production for 4–5 months per year. During the dry season, "SMART FISH DRYING" takes just one day to produce salted fish compared to conventional methods that require three days. Additionally, "SMART FISH DRYING" can be used during the rainy season, completing the drying process in about 6 hours. This significantly increases profits for salted fish producers.

1. Using "SMART FISH DRYING" With a drying area of 1 m², total salted fish produced is 1 kg/day.The market price per kg is IDR 30,000, so the annual revenue is IDR 6,000,000
2. Conventional Method With a drying area of 1 m², producers can only dry fish 50 times per year, the annual revenue is IDR 1,500,000

Thus, "SMART FISH DRYING" increases profits by approximately four times and allows business owners to recover their investment within six months. Additionally, since production is not weather-dependent, the supply of salted fish will increase, reducing Indonesia's need for imports.

Predicted Quality of Salted Fish

Salted fish produced by "SMART FISH DRYING" is of higher quality than that from traditional methods. In the "SMART FISH DRYING" design, drying takes place in an enclosed space, preventing contamination from dust, dirt, and flies. In contrast, the traditional drying method is conducted outdoors, where the fish is exposed to contaminants.

"SMART FISH DRYING" employs a greenhouse drying method, light concentration, an automatic rotating table system, and a harvest reminder, ensuring uniform dryness with a moisture content close to 30%—the optimal level for salted fish. It is estimated that the quality of fish dried using "SMART FISH DRYING" is 10% higher than that of conventional methods. However, further laboratory testing is required for precise quality assessment.

4 CONCLUSION

With "SMART FISH DRYING," salted fish producers can operate year-round, achieve better product quality, and earn up to four times more profit compared to conventional methods. The entire drying process is automated, from fish flipping to harvest alerts, using sensors and microcontrollers. "SMART FISH DRYING" relies on renewable solar energy and utilizes a convex lens to focus sunlight. Additionally, the system includes an H_2S condensation unit to reduce odors and generate sulfur colloid. This innovation ensures a stable supply of salted fish for the public and helps the government eliminate the need for salted fish imports.

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