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Research Article

Development of a Community-Level Dried Fish Strip-Cutting Machine

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ABSTRACT

This research aimed to develop a community-scale dried fish slicing machine designed for simplicity, ease of use, and enhanced productivity for its users. The machine was engineered to produce dried fish slices with a width ranging from 3.5 to 4 centimeters, powered by a 1/3 horsepower motor driving two sets of blades in opposite directions. When dried fish is fed into the blades, it is sliced into strips. Performance testing revealed that the machine achieved an average processing capacity of 6.98±0.028 kilograms per hour with an average efficiency of 99.50±0.005%, compared to manual slicing, which averaged 0.70 kilograms per hour. This indicates that the machine operates approximately 10 times faster than manual labor. Economic analysis demonstrated that using the machine incurs a cost of 7.57 THB per kilogram, with a payback period achieved after processing 782.96 kilograms of dried fish strips, making it a cost-effective alternative to manual labor.

1. Introduction

Coastal fishing in the Gulf of Thailand is a primary occupation for the people of Songkhla, providing income and sustenance for their families. However, the seasonal environmental and weather conditions affect fishing activities, leading to inconsistent incomes. Fishermen often face challenges such as catching either too few or too many fish compared to market demand. To mitigate these challenges, fishing communities have formed occupational groups to process seafood into products that can be consumed or sold year-round. This processing not only helps stabilize income but also adds value to seafood products.

Currently, the Ban Suan Kong Coastal Resource Conservation and Restoration Group in Nathap Subdistrict, Chana District, Songkhla Province, has been processing small, low-value fish into dried fish, sun-dried fish, and fish strips. Among these, fish strips have gained significant market popularity due to high demand. However, the group struggles to meet market needs as fish strip production is labor-intensive, relying on manual cutting with scissors. This results in slow production rates and workplace accidents.

To address these issues, various slicing and cutting machines have been developed to improve efficiency, reduce accidents, and ensure consistent product quality. These machines are often tailored to specific raw materials. For

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example, the black ginger slicing machine (Yotphet, 2009) features a cylindrical centrifugal chamber with adjustable stainless steel blades for precise slicing. The fish skin cutting machine (Kongsuk, 2009) uses motor-powered circular blades with uniform spacing to ensure consistent cuts. Other examples include the cracker cutting machine, which reduces cutting time by 44% (Khunburi and Wongmanee, 2020); the semi-automatic Thai sweet cereal bar cutting machine, which improves efficiency by 68.29% (Dulyala, 2020); the sliced bamboo-shoots cutter, designed to cut bamboo shoots into sheets approximately 3 mm thick. The cutting unit consists of two blades aligned in parallel with alternating edges, rotating at a speed of 800 rpm. Performance testing using three types of bamboo shoots revealed an average processing time of 32.32 seconds per kilogram. The machine demonstrated an efficiency improvement of 78.71% compared to similar conventional models (Jairtalawanich, 2021); the sajor-caju mushroom shredding machine was designed to slice oyster mushrooms into strips with a width of 5-8 millimeters. The cutting mechanism comprises two sets of circular blades, each set consisting of 18 blades with a radius of 40 millimeters, aligned in a straight line along the shaft. The spacing between each blade is 5 millimeters. Performance testing showed that at a rotational speed of 250 rpm, the machine reduced the processing time to 6.81 minutes, compared to 25.53 minutes when performed manually representing a fourfold improvement in processing speed. The operational efficiency was comparable to manual labor, at 89% (Sumrit *et al.,* 2022); the fish double-blade filleting machine, which operates twice as fast as manual labor (Nuchangsing and Maneesaeng, 2024), was designed to slice and peel mangoes. The slicing mechanism consists of four double-edged circular stainless-steel blades, each with a diameter of 9.5 centimeters and a thickness of 0.1 centimeters, arranged in parallel with an inter-blade spacing of 1.5 centimeters. The peeling unit employs an adjustable double-edged blade, allowing for customization of both blade distance and peeling angle. Peeling is performed after slicing, with the sliced mango conveyed via a belt system. Performance testing showed that slicing alone yielded a throughput of 105.61 kg/hr, while combined slicing and peeling operations achieved 48.70 kg/hr, both at a constant rotational speed of 80 rpm (Paunrat *et al.,* 2024); the cassava cubes cutting machine was designed with two integrated cutting units: one for slicing cassava into sheets and another for dicing the sheets into cubes, connected by a conveyor belt system. The slicing unit employs a circular saw blade with pointed teeth, featuring a diameter of 10 inches and 30 teeth, operating at a rotational speed of 1,430 rpm. The dicing unit consists of 14 interlaced stainless-steel blades arranged to form square cutting grids with dimensions of 2.54 × 2.54 centimeters, operating at 1,400 rpm. Performance evaluation using two cassava cultivars yielded cubing efficiencies of 38.01 ± 2.35% and 40.23 ± 2.46%, respectively (Maichoon *et al.,* 2024) and the vegetable shredder was designed to cut vegetables into strips ranging from 2 to 5 millimeters in width. The machine is equipped with three blades and two feeding channels. Performance testing was conducted on five types of vegetables: potatoes, carrots, daikon radish, cucumbers, and onions at rotational speeds of 500, 600, 700, and 800 rpm. The results indicated that rotational speed had a significant effect on the quality of the shredded products, with each type of vegetable having an optimal cutting speed. The percentage of material loss across different operating conditions ranged from 5.28±0.84% to 19.15±1.89% (Suriwong *et al.,* 2024).

Previous research has highlighted two key considerations in the design and development of cutting machines. First, the desired shape of the cut product such as slices, cubes, or strips determines the design of the blade system. Second, the type of raw material being processed influences the selection of motor size and the rotational speed of the blades. Typically, motors of 1 horsepower (HP) or 1/2 HP are used. The rotational speed is adjusted depending on the material's properties: lower speeds are applied for materials that are easily deformed, while higher speeds are used for tougher, more rigid materials. The machine is constructed from food-grade stainless steel, and its design is tailored to meet operational requirements. This study aims to design and develop a dry fish strip cutting machine capable of producing strips with the desired width specified by the user. The machine is constructed from food-grade materials, ensuring ease of use and maintenance. Its compact design makes it portable, and it operates with low energy consumption, providing both efficiency and cost-effectiveness.

2. Materials and Methods

2.1 Study of Current Working Conditions

The research team studied the working conditions of the Conservation and Restoration of Coastal Resources Group at Ban Suang Kong, Na Thap Subdistrict, Chana District, Songkhla Province. The group consists of 12 members, most of whom are primarily fishermen but have with low income. Therefore, a group of fisherwomen came together to process low-value fish, such as greenback fish, catfish, fox fish, and garfish, into sun-dried fish, dried fish, and fish strips to increase their household income. Fish strips are sold at a higher price and are the most popular product. However, the group faces challenges when they receive high orders, as they cannot process the required amount in time.

Currently, the group processes fish strips by hand. The production process involves removing the head of fresh fish, slicing the fish without removing the bones, and sun-drying them until the moisture content is about 50%, as shown in Figure 1. The fish is then cut into strips manually with scissors, as shown in Figure 2. This cutting process is labor-intensive and time-consuming. Moreover, prolonged cutting can result in injuries to the workers, leading to a shortage of available workers for the task and the inability to meet customer demand.

Data collected indicate that a single worker can cut 0.7 kilograms of fish strips per hour. The width of the strips is inconsistent throughout their length. A sample of 100 fish strips was measured at three points: Point A (head), Point B (middle), and Point C (tail), as shown in Figure 3. The results revealed that the width at Point A ranged from a minimum of 1.5 mm to a maximum of 6.0 mm, with an average of 3.512 ± 1.135 mm; at Point B, the width ranged from a minimum of 1.0 mm to a maximum of 6.0 mm, with an average of 3.342 ± 1.127 mm; and at Point C, the width ranged from a minimum of 1.0 mm to a maximum of 7.0 mm, with an average of 3.074 ± 1.314 mm, as shown in Table 1.

The graphs in Figure 3 and Figure 4, depicting box-and-whisker plots of the width of the fish strips at each of the three points, reveal that the manual cutting process results in inconsistent strip widths across all three sections.

Figure 1 Dried fish for cutting

Figure 2 Traditional production process

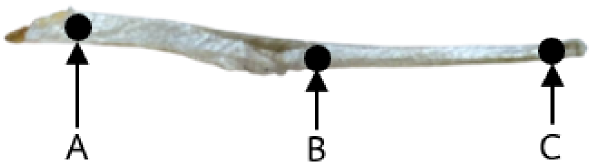

Figure 3 Measurement of the width of dried fish fillet cut into strips

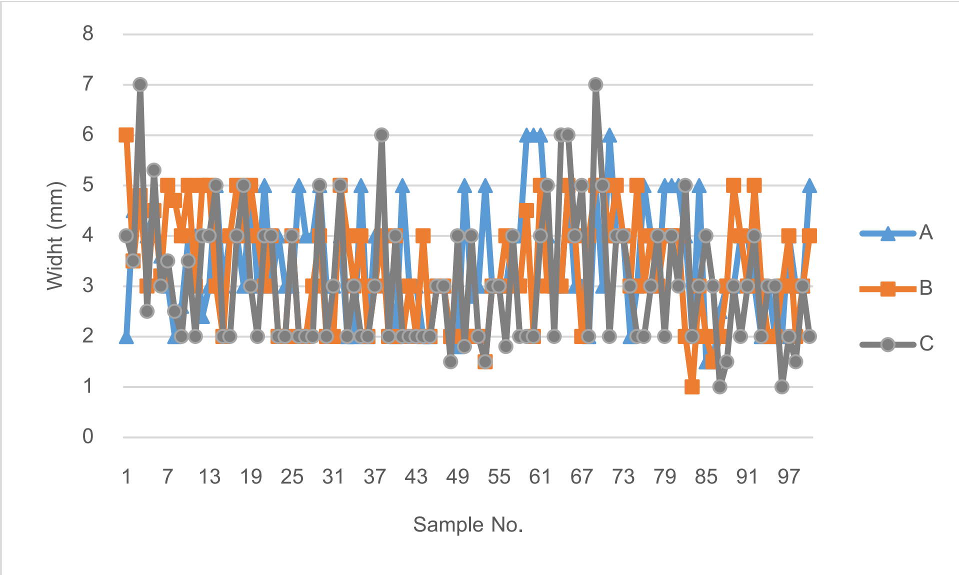

Figure 4 The line graph compares the width of dried fish strips cut by manual labor

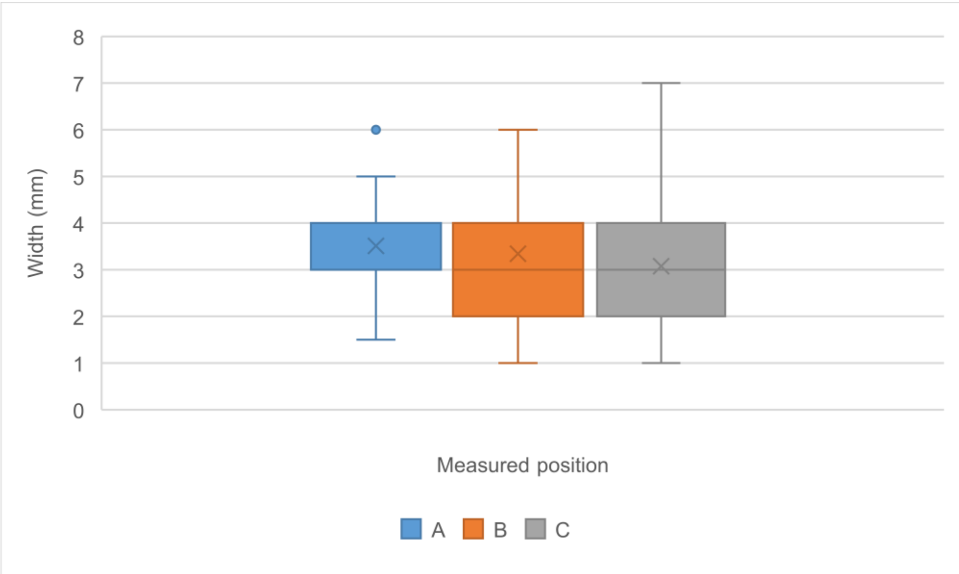

Figure 5 The box-and-whisker plot compares the average width of dried fish strips cut by manual labor

Table 1 The width of dried fish fillet cut into strips manually by human labor

Example	Width (mm)		
	A	B	C
Min	1.5	1.0	1.0
Max	6.0	6.0	7.0
Average	3.512±1.135	3.342±1.127	3.074±1.314

2.2 Design of a Machine for Cutting Dried Fish into Strips

2.2.1 Structure of a Machine for Cutting Dried Fish into Strips

Design a compact structure for a dried fish strip-cutting machine suitable for community use. The structure is constructed from food-grade stainless steel, ensuring portability and lightweight characteristics, as illustrated in Figure 6.

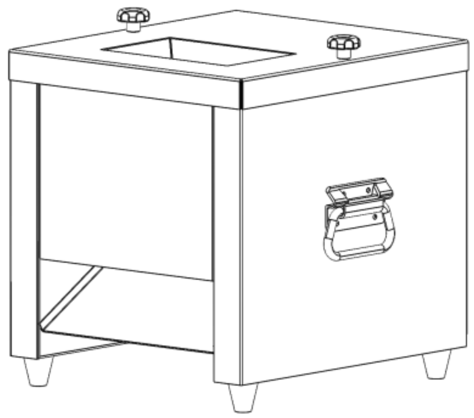

Figure 6 Structural Design of a Dried Fish Strip-Cutting Machine

2.2.2 Cutting Blade Assembly

The cutting blade assembly is designed using food-grade stainless steel to produce dried fish strips with a width (W) of approximately 3.5 millimeters, as specified by customer requirements. The term 'width' refers to the transverse dimension of the dried fish strips obtained after the cutting process (Figure 7). The blades are made from circular stainless-steel plates with a diameter of 80 millimeters and a thickness of 0.8 millimeters. These blades are alternately arranged with spacer rings of 3.5 millimeters thickness along a shaft, comprising 18 blades per set, for a total of two sets (Figure 8).

The two shafts are positioned 75 millimeters apart, with the blades of each set interleaved to achieve shearing action as the shafts rotate toward each other. The total length of the blade assembly is 100 millimeters, enabling efficient cutting of dried fish into uniform strips.

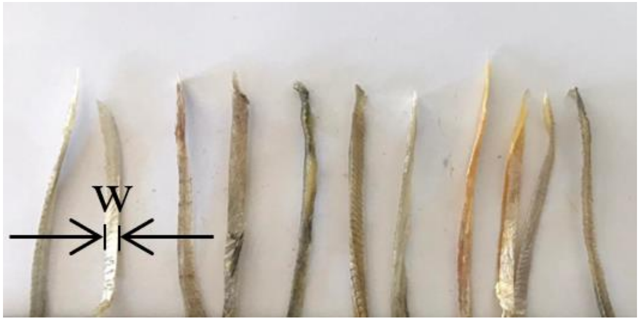

Figure 7 Measurement of the Width of Dried Fish Strips

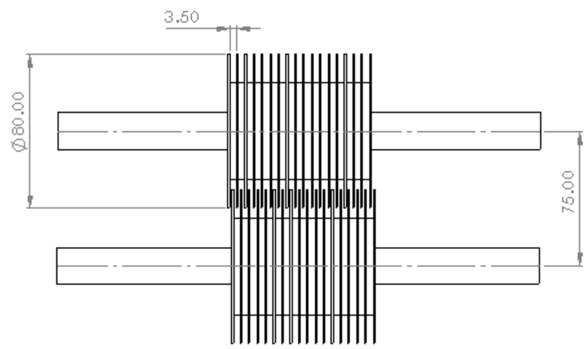

Figure 8 Cutting Blade Assembly

2.2.3 Motor and Power Transmission System

A 1/3 horsepower electric motor is selected as the primary power source. The power is transmitted to the system via a pulley mechanism. The driving pulley has a diameter of 1.5 inches, while the driven pulley has a diameter of 3 inches, connected by a belt. This configuration reduces the rotational speed from 1,450 revolutions per minute (RPM) to 725 RPM. The reduced speed ensures optimal cutting performance and minimizes the risk of jerking or uneven motion during the cutting process of dried fish strips.

2.3 Results of the Design and Construction of the Dried Fish Strip-Cutting Machine

The dried fish strip-cutting machine was designed and constructed with dimensions of 30 x 34 x 33 cm. The main components of the machine include the following:

Frame Structure (1): Designed with a compartment for loading dried fish, constructed from 1-millimeter-thick stainless steel.

Feeding Slot (2): A channel for placing the dried fish was designed with a width of 10 millimeters and a length of 150 millimeters.

Output Slot (3): The channel, where the cut strips are discharged at a 45-degree inclination, is designed to facilitate efficient material flow.

Motor (4): Provides the driving force for the machine. The motor is a 1/3 horsepower electric motor.

Pulley (5, 7): Transmits rotational power from the motor to the blade shafts. The driving pulley has a diameter of 1.5 inches, while the driven pulley has a diameter of 3 inches.

Belt (6): Transfers power between the pulleys. (V-belt)

Gears (9): Facilitate synchronization and smooth rotation of the blade assembly, including two gears with a diameter of 2.5 inches.

Blade Assembly (10): Consists of two rotating sets of blades for cutting the dried fish into strips. The blades are made from circular stainless-steel plates with a diameter of 80 millimeters and a thickness of 0.8 millimeters.

The operation of the machine, as shown in Figure 9 and Figure 10, begins with activating the switch to power the motor. Dried fish, pre-split into halves, are placed in the designated feeding slot. The fish passes through two sets of rotating blades that cut the fish into strips. The power from the motor is transmitted through the pulleys and belt system to the blade shafts. Once the dried fish is cut into strips, it falls into the output channel at the front of the machine.

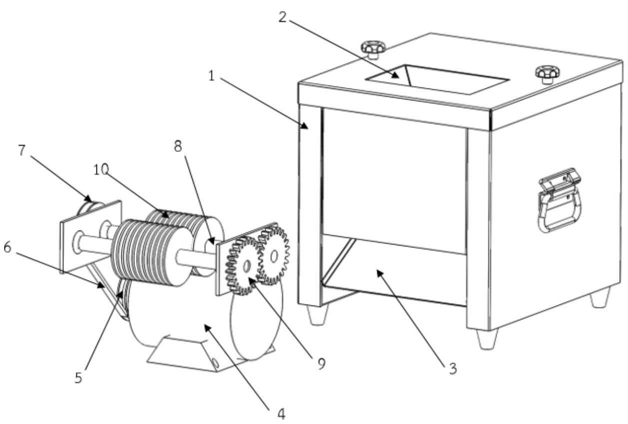

Figure 9 Components of the Dried Fish Strip-Cutting Machine

Figure 10 The Constructed Dried Fish Strip-Cutting Machine

2.4 Testing the Operation of the Machine

The performance and efficiency of the dried fish strip-cutting machine were tested following the procedure outlined below:

1. Weigh 200 grams of dried fish.
2. Place the weighed dried fish into the machine for cutting, with one operator feeding the fish. Record the time taken for the cutting process and the weight of the dried fish strips produced.
3. Repeat steps 1-2 five times and record the results.
4. Measure the width of the cut strips at three random locations: the beginning, middle, and end of the strip.
5. Calculate the capacity and efficiency of the machine using the formula provided in equation (1).

Note: In the machine operation test, dried fish were fed one at a time to facilitate comparison. Nevertheless, the machine is designed to handle multiple fish simultaneously during normal operation.

This testing procedure aims to assess the machine's cutting precision, consistency, and overall performance under typical operational conditions. (Thongkham *et al*., 2022)

$$C_c = \frac{W_1}{t} \quad (1)$$

When:

C_c = Capacity for cutting dried fish (kilograms per hour)

W_1 = Weight of the dried fish strips produced (kilograms)

t = Time taken for the operation (hours)

This equation determines the output efficiency of the machine in terms of the amount of dried fish processed per hour.

The efficiency of the machine can be calculated using the following formula (2) (Thongkham *et al*., 2022):

$$C_t = \frac{W_1}{W} \times 100 \qquad (2)$$

When:

C_t = Efficiency of the machine (%)

W_1 = Weight of the dried fish strips produced to specification (fragment excluded) (kg)

W = Total weight of the dried fish (kg)

This formula calculates the operational efficiency of the machine as the ratio of the weight of the cut fish strips to the total weight of the dried fish, expressed as a percentage.

2.5 Economic Analysis

In the economic analysis, the total cost of the dried fish slicing machine was evaluated, including fixed costs, variable costs, depreciation (Stonier,1980), electricity expenses (Beaty, 1984), and the payback period (Hunt and Wilson, 2016). The calculations were compared against the use of one laborer performing traditional manual slicing versus slicing with the developed machine.

3. Results and Disscussion

3.1 Results of the Machine's Operational Testing

The results of the operational testing of the dried fish strip-cutting machine revealed that the machine was able to cut dried fish strips at an average rate of 6.96 ± 0.043 kilograms per hour. The machine's efficiency averaged 99.40 ± 0.224 percent, as shown in Table 2.

Additionally, a random sample of 100 dried fish strips was measured, revealing the following dimensions for the width of the strips:

Head (A): The minimum width was 3.6 millimeters, the maximum width was 4.2 millimeters, and the average width was 3.965 ± 0.064 millimeters.

Middle (B): The minimum width was 3.5 millimeters, the maximum width was 4.0 millimeters, and the average width was 3.957 ± 0.077 millimeters.

Tail (C): The minimum width was 3.8 millimeters, the maximum width was 4.2 millimeters, and the average width was 3.965 ± 0.058 millimeters.

These measurements are presented in Table 3. The results indicate that the machine produces dried fish strips with consistent dimensions and high efficiency.

Figures 11 and 12 present a comparison of the average width of dried fish strips cut by the machine, using box-and-whisker plots. These plots visually represent the distribution of strip widths, including the minimum, maximum, and median values, as well as the interquartile range. The data displayed in these figures highlight the consistency and uniformity in the cutting process, demonstrating that the machine produces dried fish strips with minimal variation in width.

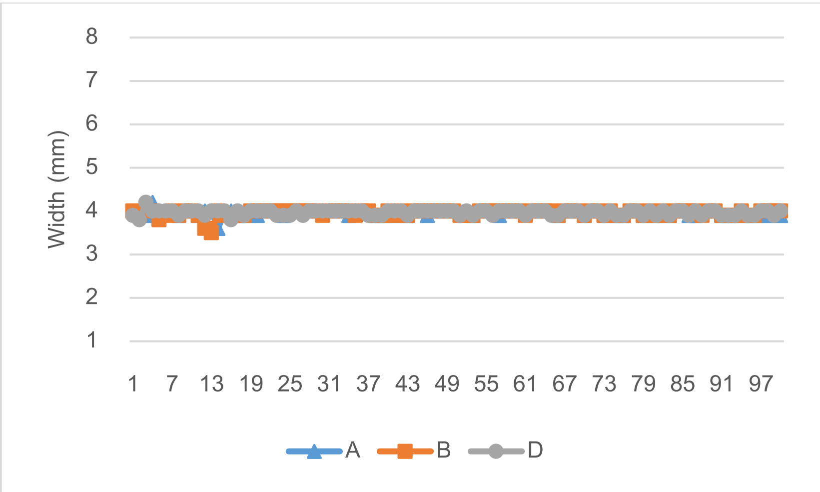

Figure 11 The line graph compares the width of dried fish strips cut by the dried fish strip-cutting machine.

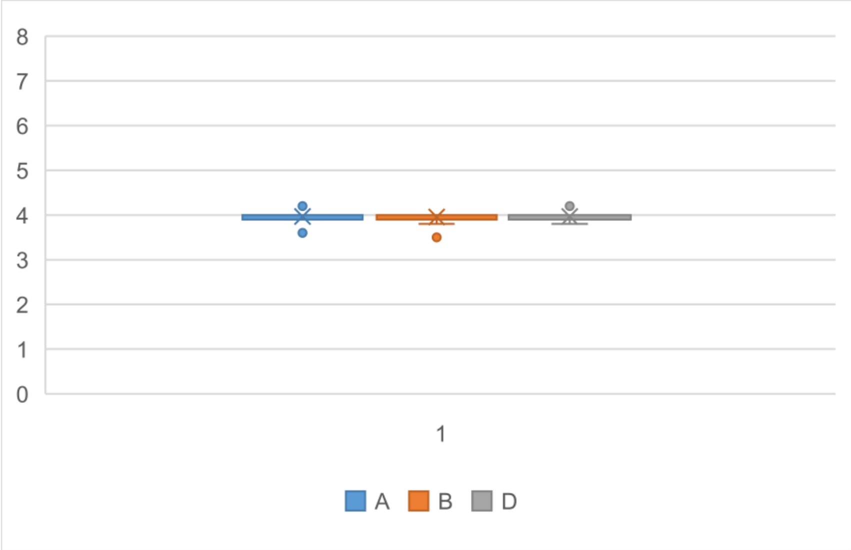

Figure 12 The box-and-whisker plot compares the average width of dried fish strips cut by the dried fish strip-cutting machine

Table 2 Performance Testing of the Dried Fish Slicing Machine

No.	W (g)	W_1 (g)	t (s)	Cc (Kg/hr)	Ct (%)
1	198	197	101	7.02	99.49
2	200	199	103	6.96	99.50
3	203	202	104	6.99	99.51
4	200	199	103	6.96	99.50
5	199	198	102	6.99	99.50
Average	200.00±1.871	198.80±1.871	102.60±1.140	6.98±0.028	99.50±0.005

Table 3 Width of the dried fish strips sliced by the machine

Example	Width (mm)		
	A	B	C
Min	3.6	3.5	3.8
Max	4.2	4.0	4.2
Average	3.965±0.064	3.957±0.077	3.965±0.058

When comparing the line graphs representing the strip width of dried fish from three sampling points (100 samples each), Figure 4 (manual cutting) demonstrated a higher degree of variation, with the majority of minimum values around 2 mm and maximum values reaching up to 5 mm. In contrast, Figure 11 (machine cutting) exhibited significantly lower variability, with widths narrowly distributed between 3.9 mm and 4 mm. These findings suggest that manual cutting introduces greater inconsistency in strip width, while machine cutting achieves more uniform results with a lower standard deviation.

A similar trend is observed in the box-and-whisker plots, which illustrate the distribution of strip widths at the three locations. In Figure 5, Point A showed most data points within the 3-4 mm range, whereas Points B and C displayed a slightly wider distribution, ranging from 2 to 4 mm. Conversely, Figure 12 revealed a much narrower distribution across all three points, with most values falling between 3.9 and 4 mm. This further supports the conclusion that machine cutting provides greater consistency and less variability in strip width compared to manual cutting.

3.2 Economic Analysis Results

Based on the economic analysis, with a prototype machine price of 50,000 THB, a service life of 10 years, and an interest rate or opportunity cost of 10%, it was found that operating the machine with one laborer incurs a total annual cost of 86,718.75 THB. This comprises a total fixed cost of 7,250 THB per year and a total variable cost of 79,468.75 THB per year. The operational cost of the dried fish slicing machine was calculated at 7.57 THB per kilogram. The net benefit is 63.86 THB per kilogram, and the payback period is achieved after processing 782.96 kilograms of dried fish, compared to manual labor. Details are presented in Table 4.

Table 4 Economic Analysis of the Dried Fish Slicing Machine

Details	Cost	Unit
Fixed cost		
Price of the Dried Fish Slicing Machine (P)	50,000	Baht
The value of the dried fish slicing machine at the end of its 10th year is estimated to be 10 percent of its initial cost. (S)	5,000	Baht
Depreciation (D) = (P-S)/L	4,500	Baht
Interest or Opportunity Cost (I) =(P+S)/2 x (10/100)	2,750	Baht
Total Fixed Cost per Year = D+I	7.250	Baht per year
Variable cost		
Maintenance cost is 10 THB per day, with 250 working days per year.	2,500	Baht per year
The average electricity consumption is 0.375 kWh, with an electricity price of 3.5 THB per unit. The machine operates 250 days per year, with 6 hours of operation per day.	1,968.75	Baht per year
The labor wage is 300 THB per day for 1 person, working 250 days per year.	75,000	Baht per year
Total Variable Cost	79,468.75	Baht per year
Total Cost	86,718.75	Baht per year
The cost per kilogram, based on 1 year of operation (1,500 hours/year), with the machine operating at a capacity of 7 kilograms per hour.	7.57	Baht per kilogram
The labor cost for manually slicing dried fish is 0.7 kilograms per hour (4.2 kilograms in 6 hours).	71.43	Baht per kilogram
Net Benefit	63.86	Baht per kilogram
Payback Period	782.96	Kilogram

The dry fish strip cutting machine shares a similar blade design with the sajor-caju mushroom shredding machine described by Sumrit *et al*. (2022), particularly in the arrangement of blades intended to produce strip-shaped cuts. However, the dry fish cutting machine utilizes a 1/3 horsepower (HP) motor operating at 725 RPM, while the sajor-caju mushroom shredding machine employs a 1/2 HP motor at 250 RPM, making the dry fish cutter more energy-efficient. In terms of performance, the dry fish cutting machine processes material ten times faster than manual labor, with an average operational efficiency of 99.40%. In comparison, the oyster mushroom slicer is only four times faster than manual slicing and has an average efficiency of 89.30%. Therefore, the dry fish strip cutting machine is a suitable replacement for manual labor, offering high consistency in strip dimensions and improved energy efficiency.

4. Conclusion

A developed dried fish slicing machine is capable of producing strips with consistent width along their entire length, operating at an average capacity of 6.98±0.028 kilograms per hour. The machine demonstrates an efficiency of 99.50±0.005 percent. In comparison, manual slicing achieves an average capacity of only 0.70 kilograms per hour, indicating that the machine operates approximately 10 times faster than manual labor. Economic analysis reveals that utilizing the dried fish slicing machine incurs a cost of 7.57 THB per kilogram, with a break-even point achieved after processing 782.96 kilograms of dried fish.

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