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Assessment of Electronic Fish Skinning Hand Device

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***Abstract*:-** India occupies second place in fish production in the world. Despite its importance and support to more than 14.5 million people directly or indirectly, the industry lacks good indigenous machinery for post-harvest operations. People are using ancient practices for descaling, cleaning, and other operations which is a time-consuming process and they are not confiscating fish skin due to various anthropogenic activities causing mechanical injury to the fish scales and gills. The unavailability of fish food and the blocking of the migration path is also destroying the fish breeding. The fish skinning hand device was tested at three levels of speed (5500, 6500, and 7500 rpm). The minimum skin removed 15g will take a time of 3 min 40 sec and the skin removed increased to 18g which took 4 min 12 sec were observed at the working speed of 5500 rpm, respectively. At inferior rpm, the number of stroke lengths was minimal and the skin removal was taking more time to remove skin since the amount of skin removed was reduced. The removal of fish skin was increased as the rpm was increased from 5500 to 6500. The cost and return analysis on the operation of the fish skinning hand device revealed that it will have an annual net income of RS 23,642. a payback period of 20 days, and a rate of return of 4.72. The actual cost of designing and developing the fish skinning hand device was RS 5,000/-.

Keywords – descaling, fish production, fish skin, payback, period power

1. Introduction

In India, the fisheries sector engages around 16 million people at the primary level, with an additional twice along the value chain (DAHD&F, 2019). Despite the overall decline of Indian agriculture in the national economy over the past 30 years, the fisheries sector's contribution has been steadily increasing, constituting 7.28% of the Gross Value Added (GVA) in agriculture and 1.24% of the national GVA (MoFAHD, 2020). The State of World Fisheries and Aquaculture (FAO, 2020) recognizes India's significant growth in the fisheries sector, ranking fourth globally in capture fisheries and second in inland capture fisheries, contributing 14% to the total global inland catch. Aquaculture accounts for 57% of India's total fish production, reaching 13.70 million tonnes by 2018–19, driven by mechanization, freshwater carp culture, and brackish water shrimp farming (MoFAHD, 2020). However, culture-based reservoir fisheries have not experienced the same rapid growth.

Between 1980 and 2020, the Indian fisheries sector underwent a transformation from a predominant subsistence small-scale sector to a diverse and complex multi-modal industry. This transformation included a shift from the dominance of capture fisheries, especially marine, to culture-based systems like carps and shrimp. Riverine fisheries declined significantly, while culture-based fisheries in the inland sub-sector gained importance. Similar transformations are reported in other developing Asian countries majorly exporting seafood (Watson et al., 2016; FAO, 2020). Recognizing the sector's importance, the Government of India (GOI) established a separate Ministry of Fisheries and launched a $2.7 billion special scheme for a sustainable "blue revolution" over five years (2020–24). The goal is to double the income of fishers, fish farmers, and fish workers, achieving a 9% annual growth rate to reach a target fish production of 22 million tonnes by 2025.

In the context of fish processing, manual descaling operations pose challenges, particularly for freshwater fishes prevalent in Indian markets and worldwide. Larger fishes with prominent scales, such as rohu, catla, mrigal, silver carp, and grass carp, are difficult to descale manually. The current practice of using indigenous tools in commercial plants or retailers is not safe or efficient, leading to frequent minor injuries. Manual descaling is time-consuming, comprising almost 50% of the total time required to produce beheaded and gutted fish without fins (Kowski & Dutkiewicz, 1996). To address these issues, this research paper discusses the design, development, and evaluation of fish skinning hand devices aimed at enhancing safety and reducing the labor involved in the descaling process.

Fish skin, containing significant amounts of skin mucus, plays a crucial role in fish health by providing a physical and chemical barrier against microorganisms. Skin mucus contains antimicrobial elements like proteins, lysozyme, immunoglobulin, and lectins, contributing to disease resistance. The paper emphasizes the importance of studying the antimicrobial properties of fish skin mucus, as it presents a potential source for developing new therapeutic agents and commercial applications.

Furthermore, the paper touches upon the underutilized resource of fish scales in biosorption, particularly in Asian countries like Malaysia. Fish scales, considered industrial waste, can be employed as biosorption material to remove heavy metals such as Zn and Fe ions from wastewater. The study investigates the potential biomaterial safety by examining heavy metal levels and the accumulation of potential carcinogens in the scales of two marine fishes: red tilapia (Oreochromis niloticus) and Asian sea bass (Lates calcarifer). The closed acid digestion method is employed to measure lead, zinc, copper, and cadmium levels, revealing higher concentrations in L. calcarifer scales compared to O. niloticus scales. To address these environmental challenges and utilize fish by-products efficiently, the paper introduces a creatively designed fish-skinning hand tool.

2. Materials and methods

At CIPHET (Central Institute of Post-Harvest Engineering and Technology) in Ludhiana, efforts were directed towards the development of a fish-skinning hand device. This device is designed to efficiently remove both the upper layer of the fish skin and the scales on its surface. The key components of the fish skinning device include a DC motor, a speed control electronic switch, and a variable diameter shaft crafted from stainless steel. The installation of these components was carried out using Teflon for enhanced durability and functionality. The entire assembly is enclosed in a protective casing that encompasses and secures all the elements, ensuring the safety and reliability of the device during operation.

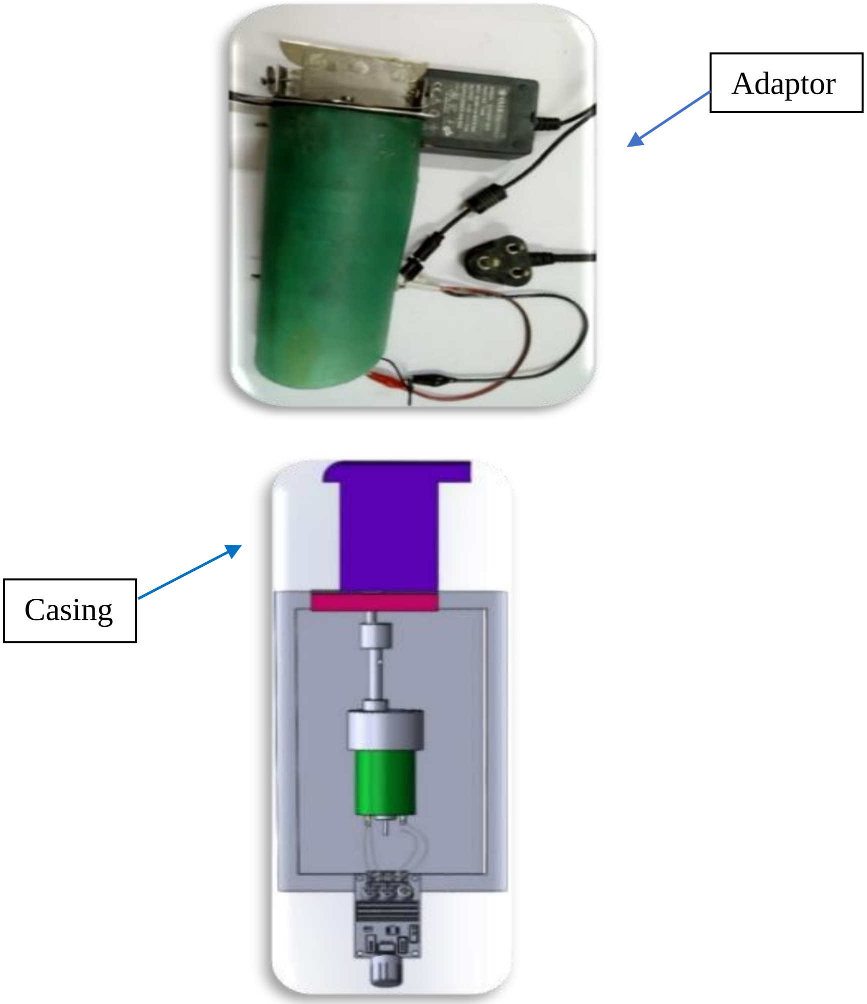


Fig.1 CAD view of fish skinning hand device

In the experimentation process at CIPHET, Ludhiana, the hand device was tested at rotational speeds of 5500, 6500, and 7500 revolutions per minute (rpms). For each trial, a fish skin weighing 50 grams was used, and the device was operated at varying speeds, ranging from 5500 rpm to 7500 rpm. This testing procedure was replicated three times for each speed setting.

To quantify the effectiveness of the fish skinning device, the skin removal process was assessed. This involved measuring the weight of the fish skin before and after the removal process. The skin removal was calculated by subtracting the initial weight of the fish skin from its final weight after removal. The resulting value represented the amount of skin removed, measured in grams. This meticulous approach allowed for a comprehensive evaluation of the device's performance at different rotational speeds and provided valuable data for further analysis refinement

Fig.2. Isometric view of fish skinning hand device

2.1 Working principle of fish skinning hand device

This is a fundamental system that converts the rotational motion of the pin into a linear movement. The initial step involves supplying power to the DC motor for connection, initiating the rotation of the shaft.

When the crank is turned counterclockwise, it results in a forward displacement of the load. The maximum displacement of the load depends on the length of the crank. As the crank completes a clockwise revolution, simultaneously, the load slides entirely forward. If there is a delay before starting the return stroke, the crank will continue turning until it returns to its initial rotational state. Consequently, the load moves backward and returns to its starting position.

Thus, with a full revolution of the crank, the load completes both forward and backward movements of the sliding component. Throughout a complete revolution of the crank, the load travels a distance equal to twice the length of the crank. The displacement of the load can be controlled by varying the length of the crank.

This mechanism effectively removes fish skin by increasing the motor speed, which, in turn, augments the number of strokes per minute, enhancing the efficiency of the fish skinning process.

Table.1. Parts of the fish skinning hand device are

1.	Crocodile connector
2.	Speed controller electronic switch
3.	Adapter (36w, +12v dc, 3.0Amps)
4.	DC motor (12V)
5.	Shaft with a 2-variable diameter
6.	Grooved “L” with a serrated blade

7.	Grooved “L” with a plane blade
8.	Blade fixture grooved “L” shaped teeth
9.	Portioning plate
10.	Fixing clip for motor
11.	Frame
12.	Supporting base
13.	Casing

2.2 Parts of fish skinning hand device

A crucial aspect of motor control involves the ability to regulate both the speed of rotation and the generated torque. While adjusting the supply voltage is a straightforward but often impractical method, a more effective and common approach is the use of Pulse Width Modulation (PWM). In PWM, the duty cycle of the signal is adjusted, modulating the width of the pulse and determining the time fraction it is "on." This modulation allows for the variation of average power, influencing the motor speed.

PWM involves rapidly switching the power to the motor on and off at high rates, minimizing the effects of switching (the output transistor is either fully on or off). This results in less wasted power as heat, enabling the use of smaller heat sinks. PWM is a widely used control technique in various applications.

In PWM, the drive signal is switched on and off within a specified period, being in the "on" state at voltage VON for a fixed fraction of the period. This "on" time is known as the "duty cycle" and is expressed as a percentage. For instance, a duty cycle of 50% indicates that the average perceived voltage of the PWM signal is 50% of the maximum voltage. The frequency of the PWM drive signal is determined by the reciprocal of the period.

Adjusting the duty cycle of a PWM signal allows for changes in the average or perceived voltage level. For example, increasing the duty cycle to 80% means that the signal is in the "on" state for 80% of the period, resulting in an increased perceived voltage of 80% of VON.

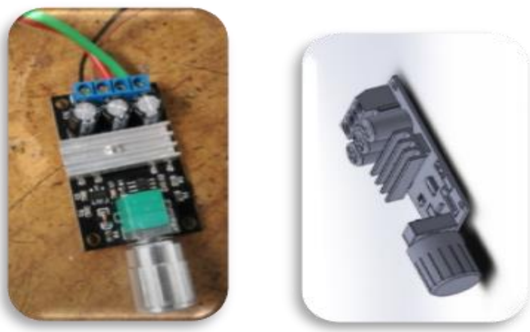


Fig.3. Potentiometer

The control switch was male-to-male attached to the motor and was used to increase or decrease the motor's speed.

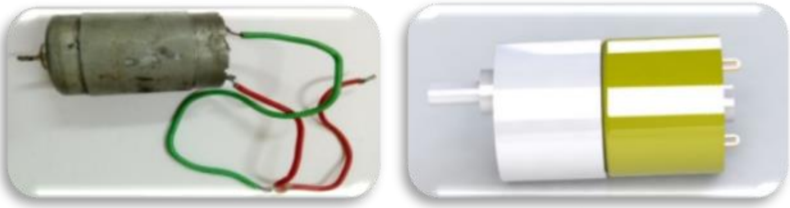


Fig.4. DC motor

The dc motor with model MXN12FB12F Without load, the motor spins at 7820 rpm and produces 594 g cm^{-1} torque. The operational voltage is 6-14 V and the normal voltage is 1.5 AMP. The motor weighs 220 gm and has a diameter of 3 mm and a length of around 10.5 mm. 37.5 mm x 75 mm in size.

Fig.5. Frame with a supporting base and partitioning plate

It is the outside frame, which is composed of stain-free steel, that provides strength to the internal parts. White substance, commonly known as Teflon, is a type of material that can minimize motor vibrations.

Fig.6. Shaft with a variable diameter

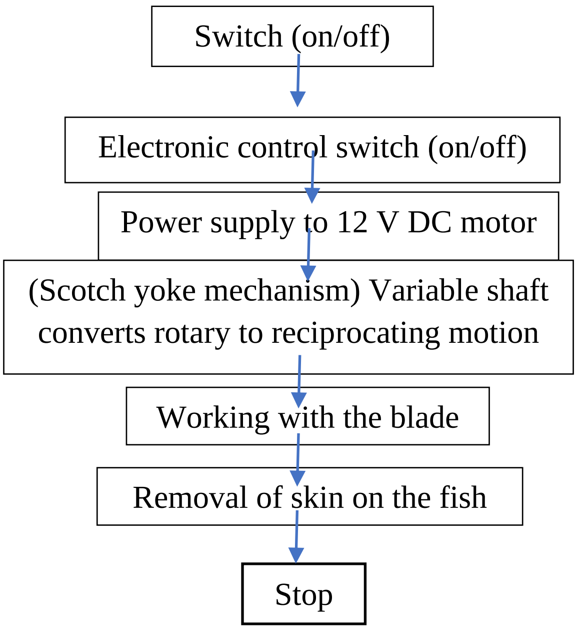
This mechanism functions similarly to a dc motor. The shaft is responsible for switching the motion from rotary to reciprocating. It is constructed of mild steel and was created using step turning on a lathe machine. The shafts perform the function of transmitting power from one rotating member to another supported by it or connected to it. Thus, they are subjected to torque due to power transmission and bending moment due to the reactions of the members that are supported by them.

Fig.7. Grooved "L" with a serrated blade

It is equipped with a serrated blade designed for efficiently removing fish skin. Operating on the scotch yoke mechanism, it transforms rotary motion into a reciprocating one. The linear impact of the blade on the fish skin is enhanced by increasing the stroke length, resulting in improved fish skinning efficiency.

Traditional methods of fish skinning involve manual tools or rubbing the fish on uneven stones, leading to challenges in effectively removing the skin. Manual skinning often requires women to adopt awkward postures, making the process tedious and time-consuming. In contrast, the fish skinning hand device operates seamlessly, effectively removing fish skin with a weight of 700g, making it easily portable from one place to another. This device proves useful for household purposes, especially for fish weighing less than half a kilogram or one kilogram. Additionally, it helps alleviate the drudgery experienced by women during the fish skinning process.

Flow chart.1. Working principle of the fish skinning device



2.3 Mechanical properties of the fish scales

In the study conducted by Bruet et al. (2008), the penetration resistance of Polypterids Senegal's ganoid scales, a small fish with a mass of approximately 200g and a length of 20 cm, revealed key principles in materials design. The scales possess multiple layers, each with distinct properties, deformation mechanisms, and a specialized approach to cracking and failure, effectively absorbing energy and safeguarding the fish. Song et al. (2011) showcased how the ganoid scale's structure contributes to toughness, penetration resistance, and the provision of non-catastrophic pathways for energy dissipation.

Ikoma et al. (2003) delved into the mechanical properties of fish scales from Pagrus major. The scale exhibited high tensile strength (around 90 MPa) due to its hierarchically ordered structure of mineralized collagen fibers. Mechanical failure was observed through lamellae sliding and the associated pulling out and fracture of collagen fibers. Conversely, demineralized scales exhibited significantly lower tensile strength (36 MPa), emphasizing the fundamental role of interactions between apatite crystals and collagen fibers in determining mechanical properties.

Arapaima Gigas scales, as reported by Lin et al. (2011), demonstrated a micro indentation hardness of 550 MPa in the external layer, considerably higher than the internal layer (200 MPa), confirming a higher percentage of calcium in the external layer. Tensile testing of the scales in dry and wet conditions revealed hydration-dependent strength and stiffness. The elastic modulus was found to be approximately 0.26, roughly ten times higher than that of bone.

2.4 Design Procedure of Fish Skinning Hand Device

Diameter of Crank = 0.6 cm.

Length of slotted bar = 9.2 cm.

Length of connecting rod = 1.6 cm.

Skin Removing Force: Assume, Power = 19.6 Watts;

Speed = 5500, 6500 and 7500 RPM

P1 = 2πNT/60= 34.54 Nm

P2 = 2πNT/60= 40.82 Nm

P3 = 2πNT/60= 47.1 Nm

Torque = Force X Radius of crank

F1 = 237.13 N

F2= 249.23 N

F3= 253.54 N

Design of Shaft:

Diameter of the shaft = 6 mm

Permissible shear stress for mild steel = 34 N/mm^2

T1 = π/16*(f s)*d1 34.54 = π/16*(f s)*0.0207

T2 = π/16*(f s)*d1 40.82 = π/16*(f s)*0.0244

T3 = π/16*(f s)*d1 47.1 = π/16*(f s)*0.0282

Fs1 = 5298751.4 N/m^2

Fs2 = 548854.6 N/m^2

Fs3 = 553425.9 N/m^2

Fs1= 5.29 N/mm^2 < Fs (permissible) =34 N/mm^2.

Fs2= 5.48 N/mm^2 < Fs (permissible) =34 N/mm^2

Fs3= 5.53 N/mm^2 < Fs (permissible) =34 N/mm^2

Therefore, the design is safe.

2.5 Scaling capacity

Scaling capacity =

$$\frac{\text{Weight of fish}}{\text{operating time}}$$

2.6 Scaling efficiency

$$\text{Scaling Efficiency} = \frac{\text{Weight of removed fish skin}}{\text{total weight}} \text{ X } 100$$

2.7 Fish skinning hand device working procedure

To initiate the operation, plug in the adaptor and turn it on. Connect the adaptor to the crocodile connector, which is further linked to an electrical switch securely attached to the platform's base using screws and bolts. The 12V DC motor affixed to the platform's base with screws and bolts, is wired to the electronic switch. Employing the scotch yoke mechanism, the rotary motion is converted into reciprocating motion through two variable-diameter shafts connected to the motor.

The motor's shaft is linked to the portioning plate, featuring an L-shaped groove allowing the passage of the blade's shaft. A blade changeable clip is fastened on the frame's base using nuts and bolts, supporting an L-shaped groove on the blade. The hand gadget's efficacy is enhanced as the stroke length and the revolutions per minute (rpm) of the shaft increase. This increase results in improved fish skin removal efficiency.


Fig.8. Removal of fish skin

2.8 Cost and Return Analysis

Using the given information and assumptions in the table below, a cost and return analysis was conducted to determine the desirability of the machine.

Table 2. Assumptions of cost and return analysis of fish skin hand device

Item	***Assumption***
The initial cost of the Fish Skin Remover	RS 5000.00
Salvage Value of the Fish Skin Remover	20% of IC
Repair and Maintenance	5% of IC
The capacity of the fish skin hand device	g/day
Useful Life of the fish skin hand device	Years
Operating Days Per Year	Days/year
Labor Cost	RS 200/day
Price of Fresh Fish	RS 180.00/kg
Price of Descaled Fresh Fish	RS 200.00/kg

The following formulas were used in the cost and benefit analysis, as follows:

2.9 Fixed Cost per Year

The fixed cost per year was computed using the depreciation

$$\text{Depreciation} = \frac{IC - S}{N}$$

Where:

D = Depreciation

IC = Initial cost of the machine

S =Salvage Value of the machine

N = Life Span of the machine (yr)

2.10 Variable cost per year

Labor Cost = Annual hours of utilization x hiring rate

2.11 Total operating cost (TOC)

TOC = FC + VC

2.12 Output capacity (OC)

$$\text{Output capacity} = \frac{\text{Mass of sample fish}}{\text{Time of skin removal}}$$

2.13 Payback period

$$\text{Payback period} = \frac{\text{Initial investment}}{\text{Average net annual benefit}}$$

2.14 Rate of return

$$\text{Rate of return(r)} = \frac{\text{Net annual profit}}{\text{capital investedt}}$$

3. Results and discussion

3.1 Scaling capacity

A minimum skin weight of 15g and a maximum weight of 18g were observed at the working speed of 5500 rpm, respectively. At lower rpm, the amount of skin removed was reduced. The loss of skin increased as the rpm was increased from 5500 to 6500. For the 6500 rpm, the lowest skin removal was 38g and the maximum was 45g. To increase the torque in the hand device to increase the fish skinning efficiency the rpm of the device was increased when the rpm at 7500 rpm. The smallest amount of skin removed was 40g, and the greatest amount was found to be 48g. The hand device removed more skin at 7500 rpm than at 5500 and 6500 rpm, but it consumed more power and it was difficult to manage the device at very high speed due to the increased vibration. Due to vibrations and high rpm the shaft size was reduced in the scotch yoke mechanism. Hence the optimum rpm found in this investigation was 6500 slightly giving less efficacy and also less effect on the variable shaft when compared to 7500 rpm.

The less skin weight of 15 g will take a time of 3 min 40 sec and the more weight of 18g it has taken a time of 4 min 12 sec were observed at the working speed of 5500 rpm, respectively. At lower rpm, the number of stroke lengths was less in this rpm and the skin removal was taking more time to remove skin since the amount of skin removed was reduced. The removal of fish skin was increased as the rpm was increased from 5500 to 6500. For the 6500 rpm, the less skin removal was 38g which consumes less time 4 min 49 sec but it removed more skin than the above-mentioned rpm, and the more fish skin removal where it consumed 5 min 11 sec the fish skin removed 45g. To increase the torque as well as in the hand device to increase the fish skinning efficiency the rpm of the device was increased to 7500 rpm. The smallest amount of skin removed was found to be 40 g which will consume 4 min 22 sec due to the number of strokes on the fish skin and the forward movement on the skin was increased, and the greatest amount consuming less time was 5 min 2 sec found to be 48 g. The hand device removed more skin at 7500 rpm than at 5500 and 6500 rpm, but it consumed more power and it was difficult to manage the device at very high speed due to the increased vibration. Due to vibrations and high rpm, the shaft size was reduced in the scotch yoke mechanism. Hence the optimum rpm found in this investigation was 6500 slightly giving less efficacy and also less effect on the variable shaft when compared to 7500 rpm.

3.2 Scaling efficiency

The scaling efficiency increases when the rpm of the motor increases. The average scaling efficiency was found 57% when operating the hand device with 5500 rpm. The optimum scaling efficiency was found to be 73% and the maximum scaling efficiency was found when operating a fish skinning hand device with 6500 rpm and the maximum scaling efficiency was 81% when the operating rpm was increased from 6500 to 7500 rpm. The rpm of the fish skin hand device has increased the efficiency of the fish skinning also increases due to the higher rpm number of strokes increased due to the rubbing action in the shaft. The diameter was reduced due to the increases in the torque for the removal of fish skin. The regression in between scaling efficiency (%) and dc motor rpm was $R^2 = 0.85$.

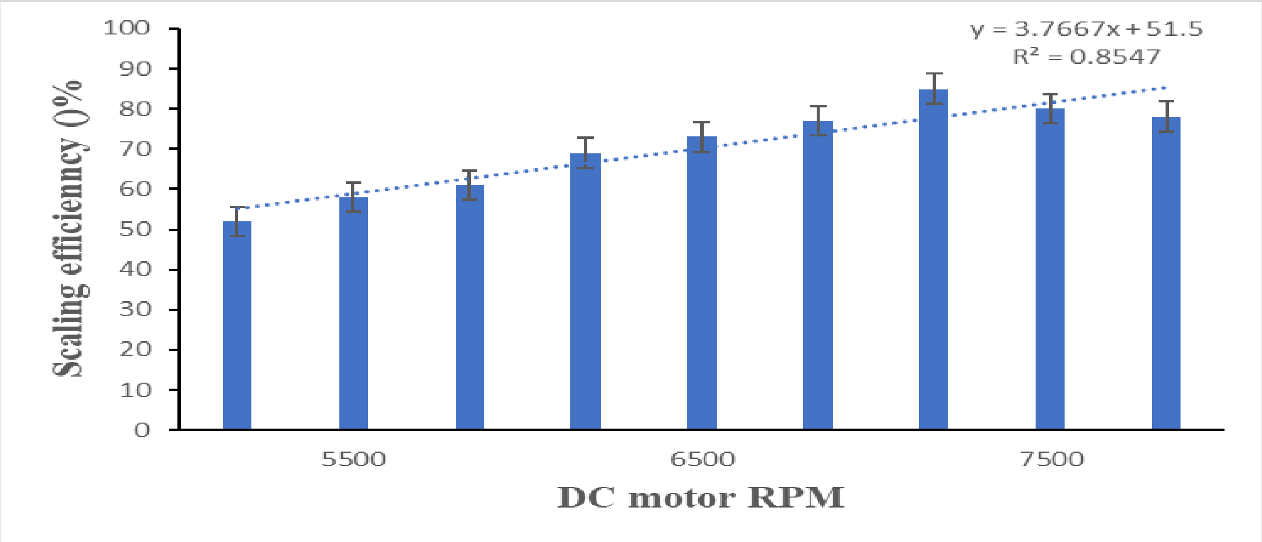


Fig.9. rotational speed vs scallig efficiecy

Table 3. Cost and return analysis of fish skin hand device

Item	Assumption
The initial cost of the Fish Skin Remover	RS 5000.00
Salvage Value of the Fish Skin Remover	20% of IC
Repair and Maintenance	5% of IC
The capacity of the fish skin hand device	g/day
Useful Life of the Fish Skin Hand Device	Years
Operating Days Per Year	ys/year
Labor Cost	RS 200/day

Price of Fresh Fish	RS 180.00/kg
Price of Descaled Fresh Fish	RS 200.00/kg

The researchers concluded that the fish skinning hand device operated fish scale remover should, at least, consist of a casing, skin remover blade, scaling board/platform, adaptor, and a DC motor as a power device with an actual cost of construction of RS 5000.00. The study has proven that the higher the speed of the fish skinning blade, the higher the scaling capacity of the fish skinning hand device, and that the bigger the scales of fish being descaled, the higher the scaling capacity of the manually-operated fish scale remover. On the scaling efficiency, the fish remover's efficiency for all the fish used in testing was highest at the medium speed setting of the scaling drum. Finally, the cost and return analysis on the operation of the fish skinning hand device revealed that it will have an annual net income of RS 23,642. a payback period of 20 days, and a rate of return of 4.72. The researchers would like to recommend that in the conduct of testing for the fish skinning hand device, the size of the fish (about 1- 2 kilograms) should be included; two or three differently designed blades drums are tested; and that the optimum scaling drum speed that will result to the highest scaling efficiency without destroying the fish skin be determined.

Conclusions

The prototype fish skinning device was designed to entirely remove the fish skin and scales, allowing us to control the speed as needed. The best operating speed for removing fish skin was found to be 6500 rpm. A fish skinning device that was developed is used to remove the skin of fish that is harmful to human health. The fish skin is removed with a scotch yoke mechanism. In addition, it is a hand-operated device, lighter in weight and more cost-effective. The cost and return analysis on the operation of the fish skinning hand device revealed that it will have an annual net income of RS 23,642. a payback period of 20 days, and a rate of return of 4.72. The actual cost of designing and developing the fish skinning hand device was RS 5,000.00

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