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Design, Development and Performance Evaluation of Fish Descaling Machine

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Abstract

In fish post-harvest processing, one of the unit operations involved is removal of fish scales which is traditionally carried out by knife. The process is time consuming and cumbersome. This may also lead to injury to the person descaling the fishes. In this context, a hand held fish descaling machine has been designed and developed to increase the speed of descaling process, reduce the drudgery and improve the safety of operation. The fish descaling machine has important components such as descaling head, flexible shaft, safety shield, 1 hp motor, AC drive and a stand for fixing motor and A.C. drive. Four different types of innovative designs of descaling heads namely, diamond shaped, inverted V shaped, 13 slots and 26 slots were tested at different speeds for the capacity, efficiency, energy consumption and injuries inflicted. Performance of the machine was tested for two fish species using four descaling heads at 1440, 2000 and 2800 rpm. The diamond shaped descaling head with its unique design showed maximum descaling rate at 2800 rpm. The fish descaling machine reduced drudgery in descaling operation and also reduced the time required in descaling from 120 to 40 s for average 500 g fish vis a vis traditional hand tool in practice. There were no incidence of injuries reported to person descaling the fishes and also no skin damages to fishes while descaling. Average energy requirement was 0.25 kwh for the machine and an unskilled labour was required for operation. The machine is suitable for descaling of catla and silver carp fish species.

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Introduction

India is the second largest producer of fish in the world contributing 5.43% of global fish production. India is also a major producer of fish through aquaculture and ranks second in the world after China. The total fish production during 2015-16 is 10.79 million metric tonnes (DADF 2016-17). The primary processing of fish in organized processing industry involves processes like fish washing/ cleaning, cutting of fins, descaling, beheading, evisceration, deskinning, filleting, slicing of whole fish into pieces etc. Contrary to this, the unorganized fish marketing and processing chain is prevalent in India and other developing countries. The retailers carry out washing/cleaning, descaling, cutting of fins, and beheading operations with their indigenous tools just prior to sale.

Typically fish body surface is covered with thin scales that overlap each other like the shingles of a roof. They are prominent outgrowths of skin, or epidermis, with numerous mucus glands. The freshwater fishes prevalent in the Indian fish markets such as rohu, catla, mrigal, silver carp and grass carp have prominent scales and their manual descaling is very difficult. Similarly, fresh water fishes found worldwide such as perch, bream, pike-perch and carp are particularly difficult to descale manually. Descaling can be done by keeping in boiling water (blanching) and then scaling by hand with motions perpendicular to the long body axis (Kowski & Dutkiewicz, 1996). But, process of blanching requires heating of water which is time consuming and energy intensive.

The operation of descaling in the commercial plants or at retailers is carried out predominantly by indigenous tools which are neither safe nor efficient for descaling operations. In fish processing industry, the workers use small sharp knife and their hands come in contact with different sharp body parts of fishes. Use of small hand tools during manual descaling often exposes workers to frequent minor injuries which in long term may be harmful (Saha et al., 2006). It was estimated that manual descaling of larger fishes requires almost 50% of the total time necessary to produce beheaded and gutted fish without fins (Kowski & Dutkiewicz, 1996). Thus, the present scenario of fish descaling operation requires an efficient and safe descaling tool. The present research paper discusses the design, development and evaluation of fish descaling machine for increasing safety of the person descaling the fishes, reduce drudgery involved in process and improve the speed of descaling operation.

Material and Methods

Fifty fish retailers in the markets of Punjab and Delhi, India were surveyed to understand the existing practice of fish descaling, tools used and problems faced by them during descaling process. The tools used for descaling at all markets were almost similar with nonstandard design. The fish retailers were using the wooden tool (Fig. 1) which had mild steel nails of 12 to 25 mm length fixed on wooden surface. The process of descaling was cumbersome as it required person to move hand tool over fish body with force. The sharp edge of the nails led to injuries on fish skin and also to the fingers of person carrying out descaling operation.

Fig. 1. Fish descaling tool used presently by fish retailers

The design considerations involved are reduction in drudgery, higher rate of descaling (number of scales removed per unit time), operational safety (reduction in injury to worker), improved descaling efficiency, reduction in injury inflicted to fishes, and use of readily available fabrication material

The Indian major carp like catla (*Catla catla*) and silver carp (*Hypophthalmichthys molitrix)* were considered for the development and evaluation of fish descaling machine. The fishes were harvested from the ponds of College of Fisheries, Guru Angad Dev Veterinary and Animal Sciences University (GADVASU), Ludhiana, India. The fishes were stored at 2±1°C in stainless trays before performance evaluation of machine.

Morphometric characteristics of the fishes such as total length, standard length, weight, lateral line scale count, body depth scale count and body width at the center which are relevant for the design of descaling machine were measured (Munshi & Srivastava, 1988).

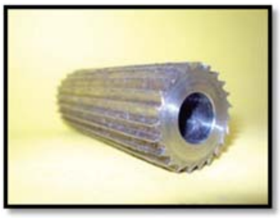
The major components of developed machine were descaling head, flexible shaft, prime mover, AC drive and stand for housing prime mover and AC drive.

The descaling head, was made up of food grade stainless steel (SS 304) material. The average width at the middle section or abdomen of catla and silver carp were found out to be 12.12 and 11.32 cm, respectively. In order to make descaling operation easier it was decided to cover the typical curvilinear shape of fish was covered in two stretches. To keep 60 mm surface of descaling head in touch with the curvilinear fish body, total length of the descaling head had to be 70 mm in length. Descaling head was attached to the flexible shaft from one end. The four types of descaling heads (Fig. 2) were developed with different geometries over surface. The descaling head with 13 slots has 5 mm depth of teeth and pitch while descaling head with 26 teeth has depth and pitch of 2.5 mm. The interior angles of 13 slots and 26 slots descaling head were 40and 100° respectively from base of teeth. The inverted v shaped type of head has teeth with both depth and pitch of 2.5 mm. The diamond shaped teeth has depth of 2.5 mm and pitch of 10 mm.

The shield was provided for safeguarding the fingers of the person carrying out descaling operations and it also minimised the scattering of scales. Safety shield (Fig. 3) was made up of stainless steel sheet with a length of 80 mm. The clearance between descaling head and shield was kept 10 mm. The shield was fixed on hand piece of flexible shaft.

The flexible shaft was connected to the motor shaft at one end and other end to the descaling head. In

1. Thirteen slots descaling head



2. Twenty six slots descaling head

3. Inverted 'v' shaped descaling head

4. Diamond shaped descaling head

Fig. 2. Types of descaling heads

Fig. 3. Safety shield

order to carry out the descaling operation for longer time without fatigue the height of ground is crucial. Gupta et al. (1983) carried out a survey of anthropometric data of Indian persons and reported that average height of person in northern region is 168.5 cm. Roebuck et al. (1975) reported that the elbow height from ground is 0.63 times the total height of the person. So, it was concluded that average elbow height of a North Indian population is 106 cm from ground (Ahmad et al., 2016). The standard height of table for working in standing position for long duration without any fatigue should be 15 cm below the elbow height (Helander, 1995). Based on this information, the height of center of motor shaft from ground was fixed at 91 cm.

A flexible shaft was used for the transmission of rotary motion from motor and to provide flexibility in the operation. Total length of flexible shaft was 1.7 m and the diameter of power transmission shaft was 18 mm. Flexible shaft was coated with a metal protective covering of aluminium. A.C motor (1 hp and three phase) with maximum rated speed of 2800 rpm of kirloskar make was used. AC drive (Kirloskar TG 600 series) was used to provide variable speed at motor shaft. The speed variation was achieved by varying the frequency input to motor. The Fig. 4 shows the final prototype and perspective view of fish descaling machine. All dimensions mentioned are in cm.

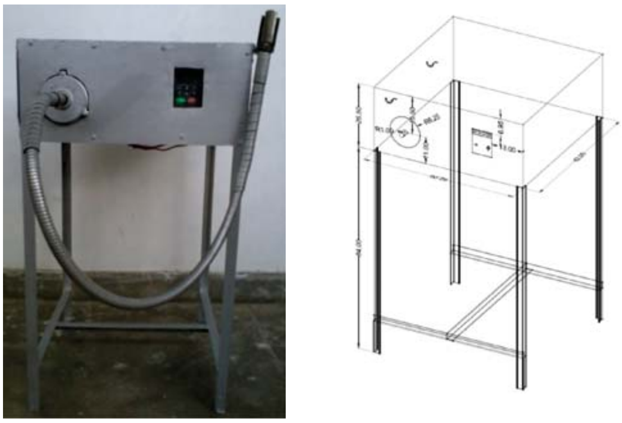


Fig. 4. Fish descaling machine prototype and drawing in perspective view

The performance of fish descaling machine was evaluated with two fish species namely catla and silver carp, at three different rotation speeds 1440, 2000, 2800 rpm and for four different types of descaling heads. Before testing, machine was installed on a levelled ground and operated at no load to ensure that each component was working properly. Three replications were conducted for each treatment combination of variables. For each test, fish descaling machine was run for 30 min. The total numbers of scales on the fishes before descaling and the number of scales remained after descaling were counted. The number of scales removed per second was determined by dividing total number scales with time required for descaling in seconds, energy consumed in kwh was measured using energy meter. The descaling efficiency was calculated by the following formula.

$$\% \text{ Descaling efficiency } (\eta) = \frac{Nt-N}{Nt} \times 100$$

Where,

η : Per cent efficiency

N_t : Total number of scales before descaling

N_r : Total number of scales remained after descaling

The fishes were removed from refrigerator few minutes prior to descaling. The head of the fish was firmly held with the hand. The descaling was carried with different descaling heads from tail end of fish to the head end in two stretches for each side. The scales remained on belly side of fish were removed in a single stretch.

On the basis of performance evaluation studies, the combination of type of descaling head and the speed were chosen for catla species. The selected optimum parameter combination is used for the final performance evaluation. The descaling was carried out for an hour in three replicates. The descaling was carried out for an hour in three replications.

The performance evaluation experiments were laid down in factorial CRD and data was analyzed using OPSTAT online software of Chaudhary Charan Singh Haryana Agricultural University, Hisar.

Results and Discussion

The morphometric characteristics relevant to descaling of common prevalent species were determined and presented in Table 1. The average width at the middle section or abdomen for species catla and silver carp was found to be 12.12 and 11.32 cm respectively. Average body weight of catla and silver carp was 573.73 and 504.87 g.

Rate of descaling was determined as number of scales removed per second. Table 2 shows the effect of descaling head and speed on descaling rate for catla and silver carp species. The operating parameters of the machine *viz.* speed of operation (rpm) and type of descaling head used as well as the fish species under study affected the rate of scale removal significantly ($p<0.01$) as shown in Table 2 and 3. The rate of descaling was increased significantly with increase in the speed of the descaling head. The diamond shaped head and rotational speed of 2800 rpm was found to be best suited for the catla with descaling rate of 32 scales s^{-1}. The combination required only 38 s to descale the fish of average weight of 500 g. The next best descaling head for catla species was inverted 'v' shaped followed by the 13 slots and 26 slots. The speed of 2800 rpm and the 26 slots descaling head was found best suited for the silver carp species with removal of 208 scales s^{-1}. The combination required only 40 second to descale the fish of average 500 g weight. The next best descaling head was inverted 'v' shaped followed by the diamond shaped and 26 slots.

As catla species has larger size of scales, the descaling rate was found to be higher with diamond shaped descaling head due to larger spacing (10 mm) between two diamond shaped protrusions. The silver carp species had very small sized scales which required smaller pitch and depth of descaling head. Thus, in descaling of silver carp, the descaling head with 26 slots having pitch and depth of 2.5 mm was found to be best among the all descaling heads.

Effect of individual factors on descaling efficiency was significant whereas all interaction effects were non-significant except the interaction between species (A) and type of descaling tool (C). The average descaling efficiency achieved was more than 98% for all types of descaling heads and different speeds of descaling. At higher speed of 2800 rpm the descaling efficiency was highest and was reduced with decrease in speed.

The Table 4 shows effect of descaling head and speed on average energy consumption. It was clear that with increase in speed the energy requirement is increased.

Table 1. Morphological characteristics of fish species used for performance evaluation

Fish Species	Length (cm)		Average width (cm)			Weight(g)	Scale Count	
	Total	Standard	Head	Middle	Tail		Lateral Line	Body Depth
Catla	33.96	27.37	11.05	12.12	4.33	573.73	41.93	15.73
Silver carp	34.27	26.20	7.56	11.32	3.95	504.87	84.80	47.47

Table 2. Performance evaluation of fish descaling machine

Species (A)	Speed (B) (rpm)	Descaling head type (C)	Time	Descaling rate (no. of scales removed/second)	Descaling efficiency (%)
Catla	1440	26 slots	82	16	98.93
		13 slots	69	18	98.37
		Inverted ‘v’ shape	68	20	99.03
		Diamond Shape	50	24	99.00
	2000	26 slots	75	17	99.38
		13 slots	63	21	99.47
		Inverted ‘v’ shape	62	25	99.55
		Diamond Shape	42	28	99.32
	2800	26 slots	70	20	99.65
		13 slots	53	25	99.62
		Inverted ‘v’shape	50	27	99.55
		Diamond Shape	38	32	99.58
Silver carp	1440	26 slots	55	148	98.84
		13 slots	78	103	96.45
		Inverted ‘v’ shape	59	140	99.10
		Diamond Shape	70	119	96.13
	2000	26 slots	43	192	99.13
		13 slots	61	133	97.12
		Inverted ‘v’ shape	47	174	99.43
		Diamond Shape	57	146	97.36
	2800	26 slots	40	208	99.56
		13 slots	54	151	98.00
		Inverted ‘v’ shape	44	188	99.70
		Diamond Shape	50	163	97.55

Speed of 2800 rpm and the diamond shaped descaling head found best suited for the catla species as this combination has shown higher rate of descaling, higher efficiency. In case of silver carp species descaling head with 26 slots and speed of 2800 rpm was found to be the best suitable combination.

The cost of fabrication of fish descaling machine is Rs. 20000/- . An unskilled person can also operate the fish descaling machine where the flexible shaft handle has to be hold and moved over fish placed on table. The machine can descale 47.36 and 45 kg h^{-1} fishes of catla and silver carp respectively. The energy cost required for operating the machine will be Rs. 2.5/- h^{-1}.

Table 3. Statistical analysis for performance evaluation of fish descaling machine

Factors	Critical difference (P<0.01)		
	Descaling Time	Descaling Rate	Descaling Efficiency
Factor (A)	0.948	0.216	0.219
Factor (B)	1.161	0.264	0.268
Interaction (A X B)	1.642	0.373	N/A
Factor (C)	1.341	0.305	0.309
Interaction (A X C)	1.896	0.431	0.438
Interaction (B X C)	2.322	0.528	N/A
Interaction (A X B X C)	3.28	0.747	N/A

Table 4. Effect of descaling head and speed on energy consumption

Fish species	Descaling Head	Mean energy consumed (kwh) Speed (rpm) 1440 rpm	2000 rpm	2800 rpm
Catla	26 slots	0.15	0.22	0.25
	13 slots	0.14	0.22	0.25
	Inverted v shape	0.15	0.22	0.25
	Diamond Shape	0.15	0.22	0.25
Silver Carp	26 slots	0.14	0.20	0.23
	13 slots	0.13	0.19	0.24
	Inverted v shape	0.14	0.20	0.25
	Diamond Shape	0.14	0.20	0.24
	Energy consumption at no Load			
	No Load	0.10	0.15	0.175

Table 5. Final performance evaluation of the fish descaling machine as compared to traditional hand tool

Descaling method	Descaling Machine		Traditional Hand tool	
Fish species	Catla	Silver Carp	Catla	Silver Carp
Average descaling time (s)	38	40	120	128
Average Efficiency (%)	99	99.50	92	90
Average Energy Requirement (kwh)	0.25	0.24	Nil	Nil

The final performance evaluation of fish descaling machine and traditional hand tool was carried out and presented (Table 5). The results revealed that descaling time was 38 and 40 s, descaling efficiency 99 and 99.5% and energy requirement 0.25 and 0.24 kwh, respectively for descaling of average 500 g fish of catla and silver carp species with descaling machine.

The traditional hand tool required 120 and 128 s for descaling with descaling efficiency of 92 and 90% for catla and silver carp species respectively.

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