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Performance Testing and Damage Evaluation of Nile Tilapia (*Oreochromis niloticus*) Screw Conveyor

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Abstract - Nile tilapia farming is an important economic aquaculture in Thailand, with the fish both sold domestically and exported to world markets. Nile tilapia aquaculture needs a large area, requires a high number of workers, and takes much time for harvesting. At present, Thailand does not have any machines suitable for elevating fish from ponds onto the land. To address this need, the Nile tilapia elevator machine has been developed. The fish elevator works like Archimedes' screw. It can rotate by itself. The objective of this study is to test the performance of this fish elevator and to evaluate any external or internal fish damage by comparing dead (instead of swooned fish) and live fish. The test method involves elevating three sizes of live fish, such as small (0.3-0.4 kg), medium (0.5-0.6 kg), and large (0.7-1.3 kg) and large-sized dead fish (0.7-1.3 kg). The tested rotational speeds of the screw conveyor are 100, 125, and 150 rpm. Fifteen fish are conveyed at each speed. The fish are then assessed for external damage in the form of tears and holes in the skin. The aspartate aminotransferase (AST) and lactate dehydrogenase (LDH) are assessed before the test and immediately afterwards, and then again at 1 and 2 days after the test to check for internal damage compared with fish conveyed by nets. The results showed that the large-sized dead fish elevated by the screw conveyor at 150 rpm suffered just 1.26% damage while producing the most productive rate of 7,020 kg/h, whereas, for the small, medium, and large-sized live fish, the most productive rates were 402, 224, and 210 kg/h respectively. The average external and internal damage was not significantly different from using conventional nets.

Keywords - Fish, Nile tilapia, Screw conveyor

INTRODUCTION

I. Tilapia harvesting in Thailand

Harvesting is one of the most important parts of the Tilapia farming process. There are basically two methods of Tilapia harvesting in Thailand: 1) Before being harvested, the fish are swooned by using a) clove oil mixed with ice, which is suitable for small fish, but it has a limitation in that frequent use will create a lot of fish slime; and b) RESICO 2-Phenoxy Ethanol, which it is suitable for large fish, with the appropriate ratio of RESICO 2-Phenoxy Ethanol to water depends on the size and number of fish and the volume of water which can swoon the fish for about 15 minutes. 2) The fish are harvested alive without being swooned. Harvesting is done by draining then, herding, confining, and throwing the fish with dipnets onto the land (Figure 1). In Thailand, this activity is used because there is a lack of specialist equipment, machinery, and technology. As a result, harvesting pond-raised fish can be the most labor-intensive aquacultural activity.

FIGURE 1
FISH HARVESTING IN THAILAND

Some studies have been carried out on Tilapia harvesting machines. Sengrodrat and Sayasoonthorn [1] evaluated the damage to tilapia after they passed through a fish screw conveyor. Large dead tilapias (instead of swooned tilapia) with an average weight of 0.78-1.3 kg/fish were used as the testing sample. The test involved varying the rotation speed of the screw conveyor between 2 settings: 100 and 150 rpm. A total of 30 fish were passed through the screw at each speed. Scale loss was determined by comparing the average descaled area before and after the test. The results showed that 100 rpm was the appropriate speed for transporting tilapia using a fish elevator. The average scale loss at this speed was 0.75%.

When fish pass through machines, it can result in immediate or delayed mortality resulting from mechanical damage, rapid changes in water velocity and pressure, and high shear stresses [2]. Several researchers have investigated fish damage caused by passing through various machines, such as a turbine pump, conveyor, and dipnet. The observed types of injuries were consistent with damage from mechanical causes, and the results identified two types of damage: 1) The first type was external fish damage, such as skin abrasions, epidermal erosion, punctures, lacerations, hemorrhages, split fins, and broken fin spines [3]. Immediate survival rates of fish, descaling, body injury, and delayed mortality at 24-h intervals for 96 h. [4]. Fish survival and weight gain [5]. Scale-loss by grading photographs of individual fish for scale-loss before and after the tests [2]. 2) The second type was internal fish damage, such as AST serum (aspartate aminotransferase) and LDH (lactate dehydrogenase) [5]-[7]. Physiological stress responses: plasma levels of cortisol, glucose, and chloride [8]-[9].

The potential for external and internal damage to Nile tilapia (*Oreochromis niloticus*) from passing through an Archimedean screw turbine has been investigated to improve fishermen's harvesting methods from the conventional method of using machinery technology. The objective of this study is to test the performance of a fish elevator and to evaluate external and internal fish damage, and compare the findings between dead and live fish.

MATERIALS AND METHODS

I. Fish elevator

Nowadays, machinery is playing an important role in aquaculture in Thailand. One research team has designed a fish elevator to enhance the quality of work-life for those employed in fisheries. The design of the fish elevator is based on the Archimedean screw theory. There are four factors that affect the number of fish and the volume of water that can pass through an Archimedean screw. The manner in which each of these variables affects is as follows:

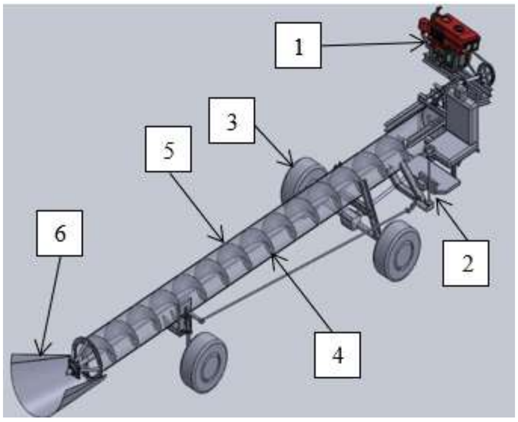
1. Diameter: All other factors are equal. The larger the screw, the larger the volume of water that can pass through the machine and the greater the quantity of energy that it can generate.
2. Rotational speed: All other factors are equal. A screw turning at a higher rpm will have a larger volume of fish and water passing through it (per unit time).
3. Number of blades: All other factors are equal. A screw with more blades can handle a greater volume of fish and water.
4. Pitch: This is the axial spacing between the blades on the screw and is equal to the diameter of the screw divided by the number of blades.

The fish elevator was designed to elevate fish from fish ponds or fish cages. The fish elevator consists of 1) a 9.5 hp diesel power engine unit which is used for driving the drive unit and screw, 2) a steering unit, 3) a drive unit, 4) a 38 cm-diameter constant pitch 15-blade Archimedean screw, 5) a 38 cm-diameter and 7 m-long screw housing, and 6) a fish feed tray. The fish elevator can move by itself without external power from an engine or towing.

II. Sample

The test was conducted by using 3 sizes of live tilapia: small (0.3-0.4 kg/fish), medium (0.5-0.6 kg/fish), and large (0.7-1.3 kg/fish). Fifteen fish of each size were used. The fish were allowed to rest for one day before being transported, and then the fish without any injury/wound were taken from a pond at the Department of Fisheries Science, Faculty of Agricultural Technology and the Agro-Industry Rajamangala University of Technology Suvarnabhumi, Phra Nakhon Si Ayutthaya Province to the Department of Farm Mechanics, Faculty of Agriculture, Kasetsart University, Bangkok (around 100 km). The fish were transported in plastic tubs: 130 x 130 x 130 cm (wide x long x high), and oxygen was given while the fish were being transported.

The fish were fed in a plastic canvas tub: 130 x 150 x 65 cm (wide x long x high) (Figure 3). The water level was set at 40 cm, and the volume of water was 780 liters/pond. The number of fish/pond was 20. The fish were fed for about 3-4 days until they could eat their food normally (1 kg/pond/time, twice a day), and oxygen was given to fish all the time throughout. Before testing, each live fish was photographed and measured for its total length, standard length, thickness, and weight.



A) FISH ELEVATOR

B) PREPARING FOR FISH ELEVATING

FIGURE 2

THE FISH ELEVATOR CONSISTS OF 1) A POWER ENGINE UNIT, 2) A STEERING UNIT, 3) A DRIVE UNIT, 4) A CONSTANT PITCH SCREW, 5) SCREW HOUSING AND 6) A FISH FEED TRAY

FIGURE 3

A POND WAS USED TO REST A FISH BEFORE TESTING AND OBSERVE THE FISH AFTER THEY WERE CONVEYED

A dead tilapia sample was taken from a wholesale market in Pathum Thani. It was fresh and without any injury/wound. Before the testing, the dead tilapia's details were recorded in the same way as the live tilapia, i.e., photographed and measured to determine its total length, standard length, thickness, and weight by Vernier calipers [1].

III. Test methods

For the live fish, the test was conducted on three sizes of fish and at three rotation speeds for the screw conveyor: 100, 125, and 150 rpm. Fifteen fish were used per speed, while the dead fish was tested at two conveyor rotation speeds of 100 and 150 rpm. Then thirty fish were used per speed. Both methods were compared to a conventional method (dipnet). After the test, the fish were checked for external and internal damage.

IV. Evaluating external fish damage

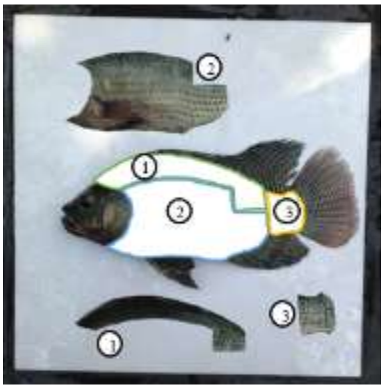
The observed stress responses were similar among the different harvesting techniques, which suggests that the method of choice could be based on other factors, such as the cost of available facilities [10].

Damage to the fish can be assessed from abrasions, holes, and tears on the skin [7]. For this purpose, photos taken from digital cameras and computer programs can be used to calculate the area of damage [11]. Before the testing, the fish were placed on white acrylic sheets (40 x 40 cm.) and photographed on both sides with a digital camera. The fish body area was calculated from (1):

$$\textit{Fish area } (cm.^2) = [\textit{Area of acrelic plate } (cm.^2) \times \textit{Area of fish (pixel)}]/\textit{Area of acrelic plate (pixel)} \quad)1($$

The process was repeated after the testing, with the fish again placed on a white acrylic sheet (40 x 40 cm.) and photographed on both sides again. The damage inflicted during the testing was divided into three areas: 1) dorsal zone, 2) abdominal zone, and 3) caudal zone (Figure 4A). The external damage area was calculated from (2):

$$\%\ \textit{external damage area} = [\textit{Damage area } (cm.^2) \times 100]/\textit{All of fish area } (cm.^2) \quad (2)$$



A) EXTERNAL DAMAGE EVALUATION: 1) DORSAL ZONE, 2) ABDOMINAL ZONE AND 3) CAUDAL ZONE

B) INTERNAL DAMAGE EVALUATION

FIGURE 4
EXTERNAL AND INTERNAL DAMAGE EVALUATION

V. Internal damage evaluation

Fish blood samples were collected at the following times: 1) before the test, 2) immediately after the test, 3) one day after the test, and 4) two days after the test. This system was applied for testing of every test speed on two fish per test speed. The results were then compared with those collected from fish removed from the pond by dipnet. Two experiments were conducted to measure survival for seven days.
The internal damage evaluation method involved analyzing the aspartate aminotransferase (AST) and lactate dehydrogenase (LDH). Approximately 2-3 ml of fish blood was collected from the caudal vein zone (Figure 4B). The blood samples were then centrifuged with a Microcentrifuge (Model Spectrafuge 16M) at 5,000 rpm for 10 minutes. Then the AST and LST were analyzed with the test kits using Sigma-Aldrich AST Activity Assay (No. MAK055) and Sigma-Aldrich LDH Activity Assay (No. MAK066), respectively.

VI. Performance evaluation

The fish elevator was evaluated by calculating the conveying rate per hour. The recording period started when the first fish was taken into the fish elevator until the last fish exited from the fish elevator. The performance was calculated for both live and dead fish at all rotation speeds.

RESULTS

I. Previous work (Dead fish) [1]

The percentages of external damage to the dead tilapia after they were transported from the pond at 100 rpm were 0.89%, 0.41%, and 3.09% in the dorsal zone, abdominal zone, and caudal zone, respectively, while at 150 rpm, they were 2.96%, 2.73%, and 0% in the dorsal zone, abdominal zone, and caudal zone, respectively. The average external damage was 0.76 and 2.54% for 100 and 150 rpm, respectively (Figure 5).

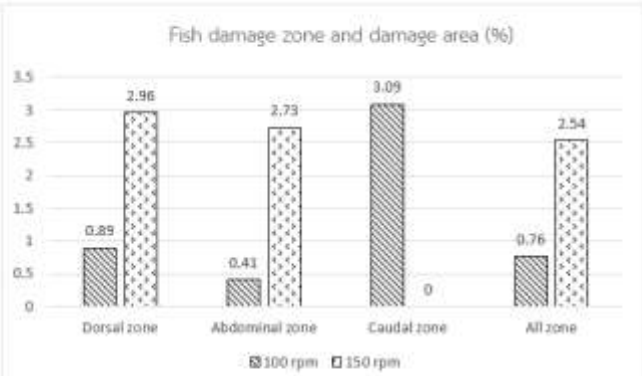


FIGURE 5
DAMAGE ZONE AND AVERAGE EXTERNAL DAMAGE AREA (%) OF DEAD FISH

TABLE I
EXTERNAL DAMAGE AREA OF FISH FIN TAIL AT VARIOUS SPEEDS

Speed of screw)rpm(	Amount of fish fin tail damages)%(		
	slight)1-3 cm^2(	moderate)4-6 cm^2(	severe)7-11 cm^2(
100	26.67	6.67	3.33
150	10.00	0.00	10.00

Table I shows the external damage area of fish fin tail at various speeds. The amount of fish fin tail damage was 26.67% (slight), 6.67% (moderate), and 3.33% (severe) at 100 rpm and 10.00% (slight), 0% (moderate) and 10.00% (severe) at 150 rpm.

II. Recent works (Live fish)

TABLE II
EXTERNAL AVERAGE DAMAGE AREA OF FISH (%) AT VARIOUS SIZES AND SPEEDS

Size	Speed of screw)rpm(			conventional method
	100	125	150	
Small	1.72%ab	1.93%ab	3.57%b	0.68%a
Medium	1.19%a	1.24%ab	2.04%ab	0.62%a
Large	1.08%a	1.15%a	1.71%ab	0.57%a
Large)Dead fish(*	0.76%a	-	2.54%ab	-

*[1]

From Table II, the average damage percentage to three sizes of tilapia, for both live and dead fish, and at three different rotation speeds are compared with damage incurred using the dipnet. The results show no significant differences under all test conditions except for small tilapia at 150 rpm speed, which had the highest damage area of 3.57%.

TABLE III
PERFORMANCE OF FISH ELEVATOR AT VARIOUS SPEEDS

Size	Speed of screw)rpm(			conventional method
	100	125	150	
Small	150 kg/h	276 kg/h	402 kg/h	600 kg/h*
Medium	109 kg/h	158 kg/h	224 kg/h	
Large	114 kg/h	141 kg/h	210 kg/h	
Large)Dead fish(	4,680 kg/h	-	7,020 kg/h	

*The conventional method was based on the data collected from the farmer's tilapia culture and for tilapia of mixed sizes.

The conveying rates for the small tilapia were 150, 276, and 402 kg/h. at screw rotation speeds of 100, 125, and 150 rpm, respectively; for the medium tilapia, the rates were 109, 158, and 224 kg/h. at screw rotation speeds of 100, 125, and 150 rpm, respectively; and for the large tilapia, they were 114, 141, and 210 kg/h. at screw rotation speeds of 100, 125, and 150 rpm, respectively. The large dead tilapia had to convey rates 4,680 and 7,020 kg/h at 100 and 150 rpm, respectively.

From Table IV and Figure 6A, it can be seen that the LDH enzyme in the blood of small fish immediately after testing was 802/l and 1008/1 units at 125 and 150 rpm, respectively. This was a significant increase when compared with the LDH level before testing, which was 478 units/l. At a speed of 150 rpm, the LDH enzyme level was significantly different from the level when the conventional method was used (566 units/l). At the speeds of 100 and 125 rpm, the LDH enzyme level at every collected time was not significantly different to before testing or when the conventional method was used, except for when the LDH was taken immediately after testing at 125 rpm (802 units/1).

From Table V and Figure 6B, it can be seen that the LDH enzyme levels of the medium-sized fish at 150 rpm was 984 units/l, which represents a significant increase when compared with before testing (484 units/l) and when the conventional method was used (516 units/l). However, one day after testing, the LDH level decreased. The LDH enzyme levels after testing at 100 and 125 rpm were not significantly different to before testing or when the conventional method was used, except for when the LDH was taken immediately after testing at 125 rpm (746 units/l), which was the same pattern as for the small fish.

However, for both fish sizes, at one day after testing, the LDH enzyme activity had decreased. The LDH enzyme level of each condition gradually decreased to the point where there was no significant difference in the fish before testing and two days after testing.

From Table VI and Figure 7A, it is shown that at a rotation speed of 150 rpm, the AST of the medium-sized fish immediately after testing was 41.42 units/l, which was significantly higher than before testing (21.42 units/l) and significantly different from the conventional method (25.29 units/l). For the AST at the other rotation speeds, it was not significantly different to before testing and from the conventional method, except at 150 rpm.

From Table VII and Figure 7B, the same trend as the medium-sized fish can be observed. The AST immediately after testing at 150 rpm rotation speed was 38.39 units/l for the large fish, which was significantly different to 19.16 units/l and 17.70 units/l for before testing and from the conventional method, respectively.

III. Fish mortality

It was found that all sizes of fish after being transported at various screw speeds could survive for more than seven days after testing.

TABLE IV

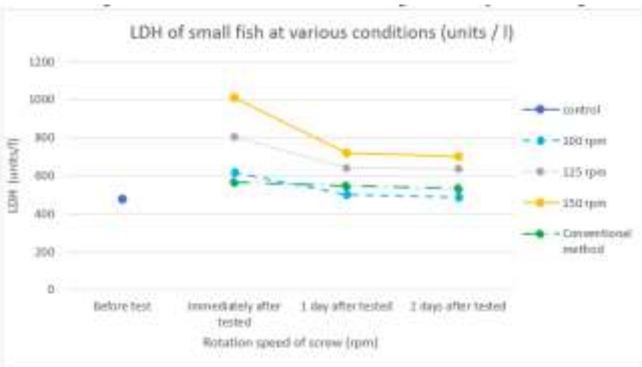
LDH OF SMALL FISH AT VARIOUS CONDITIONS (UNITS/L)

Collected time	Control	Rotation speed of screw			Conventional method
		100 rpm	125 rpm	150 rpm	
Before testing	478a	-	-	-	-
Immediately after testing	-	618ab	802bc	1008c	566ab
1 day after testing	-	498a	638ab	720ab	546ab
2 days after testing	-	484a	636ab	700ab	534ab

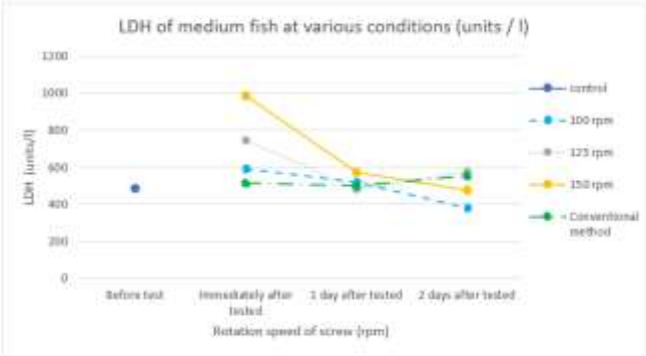
TABLE V

LDH OF MEDIUM FISH AT VARIOUS CONDITIONS (UNITS/L)

Collected time	Control	Rotation speed of screw			Conventional method
		100 rpm	125 rpm	150 rpm	
Before testing	484a	-	-	-	-
Immediately after testing	-	592ab	746bc	984c	516ab
1 day after testing	-	518ab	480ab	570ab	498ab
2 days after testing	-	380a	578ab	476ab	552ab



A) LDH OF SMALL FISH AT VARIOUS CONDITIONS



B) LDH OF MEDIUM FISH AT VARIOUS CONDITIONS

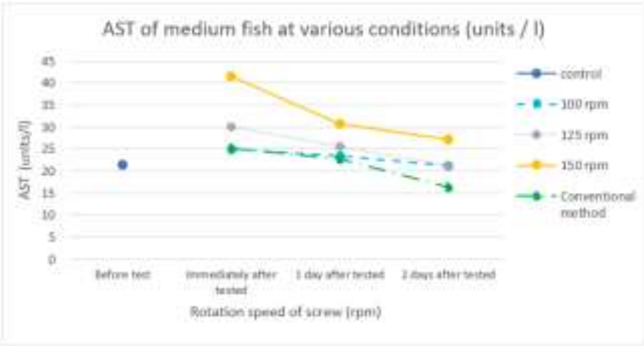
FIGURE 6
LDH OF FISH AT VARIOUS CONDITIONS

TABLE VI
AST OF MEDIUM FISH AT VARIOUS CONDITIONS (UNITS/L)

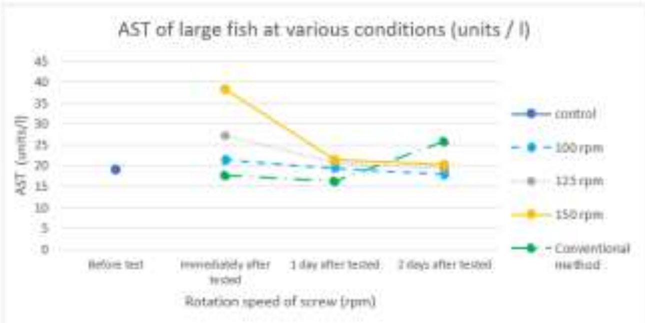
Collected time	Control	Rotation speed of screw			Conventional method
		100 rpm	125 rpm	150 rpm	
Before testing	21.42ab	-	-	-	-
Immediately after testing	-	24.94ab	30.08b	41.42c	25.29ab
1 day after testing	-	23.52ab	25.63ab	30.73b	22.80ab
2 days after testing	-	21.19ab	21.26ab	27.09b	16.40a

TABLE VII
AST OF LARGE FISH AT VARIOUS CONDITIONS (UNITS/L)

Collected time	Control	Rotation speed of screw			Conventional method
		100 rpm	125 rpm	150 rpm	
Before testing	19.16ab	-	-	-	-
Immediately after testing	-	21.34ab	27.20b	38.39c	17.70ab
1 day after testing	-	19.43ab	20.61ab	21.38ab	16.25a
2 days after testing	-	17.93ab	19.35ab	20.15ab	25.90b



A) AST OF MEDIUM FISH AT VARIOUS CONDITIONS



B) AST OF LARGE FISH AT VARIOUS CONDITIONS

FIGURE 7
AST OF FISH AT VARIOUS CONDITIONS

DISCUSSION

I. Dead fish

From Figure 5, it was found that the average damage at 100 rpm speed was less than that at 150 rpm speed except in the caudal zone, which had higher damage at 100 rpm. On the other hand, from Table I, it was found that the amount of damage to the fish fin tail area at 100 rpm was higher than at 150 rpm. Because at 100 rpm, the screw rotated more slowly, which meant the fish also moved slowly, thereby causing the caudal zone and the fish fin tail area located at the end of the fish to get stuck between the screw and the screw housing. At 150 rpm, most of the damage that occurred was in the dorsal zone and abdominal zone due to the higher speed at which the screws were rotating. This made the fish move faster and collide with the screw blade and screw housing, which caused more damage.

II. Live fish

From Table II, it can be seen that the screw conveyor rotation speed of 150 rpm was too fast as it caused the fish to move too rapidly into the fish elevator, resulting in them colliding with the screw blades and incurring much damage more so than at the other speeds. Small fish has a smaller total area than large fish, which meant that the average damage area per fish was more for these small fish than for the medium-sized and large fish at the same speed.

As can be seen from Table III, there were lower amounts of fish in all three sizes compared to the conventional method, although there were more small fish than medium-sized and large fish. This suggests that a high number of fish got away from the fish feed tray. The larger fish are more powerful than the smaller fish, which enabled more of the larger fish to escape from the fish feed tray, resulting in lower feed rates due to the lower capacity. However, if a large amount of fish is fed, it can increase the feed rate. Conversely, the large dead fish can be conveyed continuously and in large quantities because the dead fish cannot escape from the fish feed tray.

Regarding internal damage, the LDH and AST levels in the small fish immediately after testing at 150 rpm were statistically different from the levels after using a dipnet in all fish sizes.

From Tables VI and VII, the AST values were consistent with those reported by Hrubec *et al*. [12]. The AST values ranged from 9-102 u/l and 5-124 u/l. The densities of different cultivars were 120 g/l and 4.3 g/l, respectively.

CONCLUSION

The optimum results in terms of the size of fish and the rotation speed of the screw conveyors were large dead fish at a rotational speed of 150 rpm. Under these conditions, the damaged area was just 1.26%, with no statistical difference from dipnets. This condition could also produce the highest capacity compared to all other conditions at 7,020 kg/h.

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