Evaluation of a Prototype Fish Cleaning Machine With Proposals for a Commercial Processing Line

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Background

Heading and gutting small fish by hand is both time consuming and labor intensive, making it an expensive operation. In cases where special handling is absolutely necessary or where the products can command a high price, processing fish by hand may be economically feasible; but where the fish product has to be competitive in price with other high protein foods, or the value of the fishery product is relatively low, machine processing must be used. Not only must the economic aspect be considered but where the need to produce a headed and fully cleaned fish for further processing is important, a machine must clean the fish completely in order to be justified. This is especially evident where the fish must be headed and completely freed of viscera and belly lining, particularly when the lining is pigmented as in the case of whiting, *Merluccius bilinearis*, prior to processing in a meat/bone separator. As a solution to heading and fully cleaning whiting, a LaPine Model 22 smelt processing machine[1] was extensively modified (Mendelsohn et al., 1977).

Preliminary Results

The modified machine (Fig. 1) was laboratory tested for processing various sizes of whiting 8-16 inches (20.3-40.6 cm) in length in test runs involving 500 pounds (225 kg) to 5,000 pounds (2,250 kg) of fish. Fish outside of this size range were culled and discarded because the processing effectiveness of the machine was not acceptable for these. Since the machine was designed to handle fish that varied in length by no more than 4 inches (10.2 cm), we adjusted the machine to handle fish in the range of 10-14 inches (25.4-35.6 cm) because this is the center of the 8- to 16-inch (20.3- to 40.6-cm) range.

The results of the laboratory tests indicated that the prototype machine had a capacity of about 3,600 fish/hour and that it could effectively head and clean the fish and remove most of the peritoneum (black belly lining) of whiting. Subsequent trial runs before industry further demonstrated the machine's potential, and only an evaluation of the machine's performance under actual commercial conditions was necessary to encourage its assimilation by industry. Coordinated by the authors, the machine was tested by a Boston processor under contract to the New England Fisheries Steering Committee (NEFSC)[2].

Processing in Commercial Plant

Gloucester-landed whiting were brought to the Boston commercial fish processor for heading and cleaning by the modified LaPine machine. The

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[1]Reference to trade names or commercial firms does not imply endorsement by the National Marine Fisheries Service, NOAA.

[2]NEFSC is a nonprofit educational association organized to further the interest and welfare of all those engaged in the domestic New England fishery (Anonymous, 1977).

ABSTRACT—A prototype heading and cleaning machine for small whiting was evaluated under commercial conditions. The major finding was that the machine is sound in theory and principle but needs some of its components redesigned for high speed production. Throughput was found to be about 2,250 fish/hour (less than was expected) of which about 95 percent were cleaned well enough for further processing or to be frozen directly as a reverse-butterfly or pan-ready product.

From these tests, we believe that new machines could be built to handle fish from 6 to 18 inches (15.2-45.7 cm) at production rates up to 12,000 fish/hour. For increased production, three machines should be used together in a system comprising auxiliary equipment. Each machine would process a specific size range of fish with an expected total output from the three machines of about 36,000 fish/hour. The fish would be scaled, graded, oriented, conveyed, headed, and cleaned automatically with maximum recovery of edible fish flesh and with minimum waste.

size range of the fish varied from well below 6 inches (15.2 cm) to well above 18 inches (45.7 cm). Although the machine was laboratory tested for a size range of 8-16 inches (20.3-40.6 cm), an attempt was made to head and clean whiting between 6 and 18 inches (15.2 and 45.7 cm) to determine if the enlarged size range could be acceptably accommodated.

Those fish below 6 inches (15.2 cm) and above 18 inches (45.7 cm) in length were culled and discarded. Again, as in the laboratory experiments, we adjusted the machine to handle the middle of the range 10-14 inches (25.4-35.6 cm). Once set, the controls were not changed during the runs.

This sequence was followed in a typical run using either penned[3] (5-6 day old) or day-boat (1-2 day old) whiting in the heading and gutting machine in the commercial fish processing plant:

1) Boxed iced whiting, landed in Gloucester, Mass., in the morning, were trucked to the plant in the afternoon and held overnight in a cooler at 35°F (2°C).

2) The next morning, the fish were scaled in a commercial rotary scaler.

3) The scaled fish were manually placed on the wooden cleated conveyor leading to the heading and gutting machine.

4) Every fish was headed and gutted by the machine.

5) Each fish was inspected as it left the machine. Uncleaned fish were hand-cleaned or discarded.

6) If the fish were to be sold as pan-ready (reverse-butterflied) fish, they were frozen in 10 pound boxes.

7) If the fish were to be deboned, they were transferred to a conveyor leading to the Bibun Model 18 meat/bone separator. The minced fish flesh was collected and made into 18.5-pound minced blocks and plate frozen. Frozen fish blocks are used as the raw material in the manufacture of fish sticks, portions, and other specialty items (Ryan, 1978).

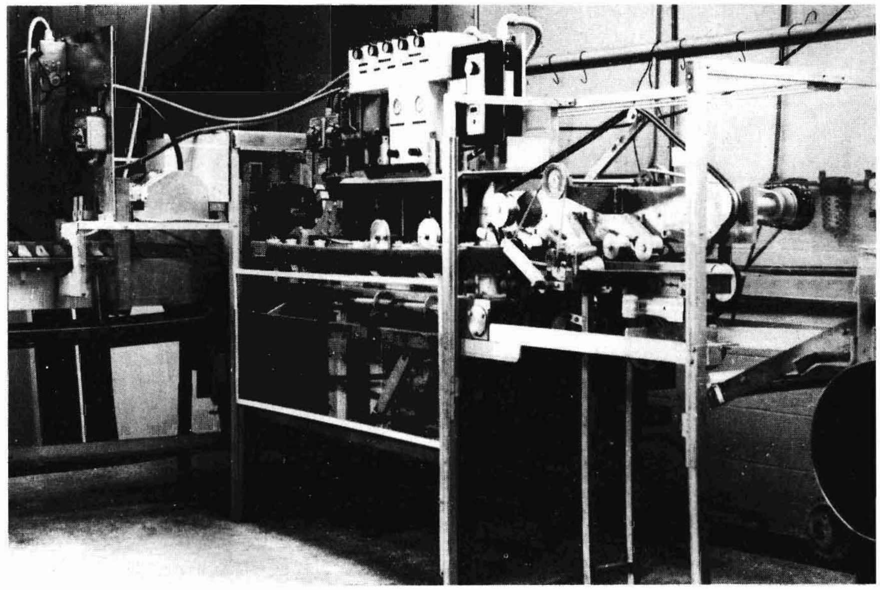

Figure 1. —Prototype fish heading and cleaning machine.

Results and Discussion

Operation Under Commercial Conditions

Operation of the machine under commercial conditions indicated that while the theory and the principles employed were sound and effective, the theoretical capacity of 3,600 fish/hour could not be met. The maximum processing rate reached was about 2,700 fish/hour with four people operating the machine—two people feeding the machine, one person keeping the machine running properly, and one person inspecting the fish. Even at this rate, the machine had to be stopped for about 4-5 minutes every 25 minutes for a complete wash-down to remove viscera collecting at the cleaning wheels which would otherwise impede the smooth flow of fish through the machine.

With a throughput of 45 fish/minute for 25 minutes operating time and almost 5 minutes cleanup, the machine would head and gut about 2,250 fish/hour. With the weight of the whiting averaging about one-half pound, the machine throughput was about 1,125 pounds/hour. Even if the machine throughput could be doubled by experienced operators, it would fall far short of the production rate desired by the larger processors.

Still, the economics of using the machine compare favorably with manual gutting and heading of whiting. The speed of an experienced person that hand processes whiting is about 30 fish in 9 minutes or about 200 fish (100 pounds)/hour. Even if a person could continue to handle 100 pounds/hour throughout the day, the prototype machine works over 11 times faster, with no loss in speed as might occur with a human as the day wears on. Thus while the machine might fall short of commercial processor expectations, the fact that one machine plus four workers can replace 11 skilled cutters is evidence that it still represents an economic advantage. Also, the quality of the fish remains constant in machine processing, whereas the quality of the manually processed whiting

[3]Penned whiting refers to fish from boats that have been out fishing 4 to 5 days. These whiting are 5 to 6 days old prior to processing. Day-boat whiting refers to fish from boats out fishing for only 1 day. These fish are 1 to 2 days old prior to processing.

is variable and generally poorer, especially as the workday wears on.

Yield Recovery

Starting with whole whiting, the recovery of headless and fully cleaned reverse-butterfly whiting (pan-ready) was determined. Results from two separate runs showed that from a mixture of sizes of whole whiting (6-18 inches or 15.2-45.7 cm), yields of 46.0 percent and 46.3 percent were obtained. These yields were approximately 5 percent lower than that found under laboratory conditions. This can be explained somewhat because only whiting between 8 and 16 inches (20.3 and 40.6 cm) were used in the laboratory tests. With fish of large size ranges, the yield is appreciably decreased for the machine was set for maximum recovery in the 10- to 14-inch (25.4- to 35-cm) range.

Even if whiting are to be sold as a headless and dressed item, the 46 percent yield from the prototype machine as compared with a 50 percent yield from the conventional headless and dressed operation should be no deterrent, especially as the quality of the former is better than that of the latter.

The improved appearance of the fish with all of the viscera removed and the potential shelf life extension of the product from the prototype machine should be able to command a higher price than that of conventional headless whiting. Most whiting processed in the conventional way contain a small amount of viscera. Therefore, they cannot be labelled as headless and dressed fish but must be labelled as headless whiting.

However, in a plant under U.S. Department of Commerce inspection, the fish from the prototype machine could carry the U.S. Grade A stamp because they would easily conform to the headless, dressed whiting standard. Where the whiting are to be put through a meat/bone separator or are to be further processed, the complete removal of viscera and black belly lining is essential.

Cleaning Efficiency

The number of fully cleaned whiting, requiring no followup hand cleaning, obtained from the machine was taken as a measure of its effectiveness under commercial conditions. Approximately 30 percent of the whiting were found to fit this category. About 65 percent had only a very small piece of black belly lining on them and about 5 percent had both pieces of viscera and black belly lining. An inspector at the end of the cleaning machine should be able to remove bits of black belly lining with a plastic brush or by handpicking so that about 95 percent of the whiting would be completely clean. The remaining 5 percent could be recycled or hand-cleaned at the end of the run.

Although most of the black belly lining was removed by the two cleaning wheels and serrated roller at the end of the machine, it was observed that the 6-inch (15.2-cm) diameter cleaning wheels would only clean small fish whose belly flaps did not exceed 2.5 inches (6.35 cm) in size. The shaft on the wheel restrained the belly flap from being in full contact with the cleaning wheel. Since most of the whiting in the commercial trial were quite large, they tended to have belly flaps longer than those that could be cleaned by the 6-inch (15.2-cm) wheel presently on the machine. This is believed to account for the small amount of black belly lining remaining on the large whiting.

Problems Encountered

In addition to the time lost for washing the machine during the run, several other problems were encountered. One of the major downtime problems was the binding of the shafts in certain sections of the machine. These shafts did not have sealed bearings, and fish juice which seeped into them tended to increase resistance forces until the shafts eventually stopped turning. Prior to each run, they were freed and oiled; but during the run, the fish juice would cause some shafts to stick and/or to stop turning.

Several other minor problems were encountered during the commercial runs. One of these was the turning of the fish head on the cleated conveyor prior to its being removed. Since only the body of the fish is supported by the conveyor, the head resting against a stationary flat plastic guide is retarded slightly under the frictional force as it is dragged along to the heading blade. This causes the part of the fish that meets the rotating heading blade to be cut at an angle. If the head were also conveyed on its own system, the cut could be made perpendicular to the axis of the fish for maximum yield.

Until recently, most conventional heading machines had this inefficient aspect, but the trend is now leaning toward the multiple metal pocket conveyor where the fish are secured in position while the head is being removed and other cuts are being made. This operation, which takes place at the operating speed of the machine, measures the head of the fish as it comes down the conveyor and clamps it in position to sever it at the correct angle for maximum yield. We have concluded that a higher and significant efficiency is possible and should be attained.

Another problem was the wetting of the electronic circuit boards, especially during clean-up operations. The circuitry had been mounted in waterproof housings and all connections had been made waterproof with rubber gaskets and other seals. However, during the moving of the machine from Gloucester to East Boston, Mass., the cables for power, water, and air had to be disconnected and reconnected at their destination. Subsequently, some of the connections leaked and, as a result, the main electronic circuit board broke down due to the water and had to be replaced. As a temporary measure, clear plastic covers were used to protect the electronic gear which will be redesigned so that the controls and other susceptible equipment would be completely protected.

During operation of the machine, a large amount of fish waste collected under it. This is acceptable in small operations; but in a large continuous operation, gurry conveyors should be installed. Most large fish processors already have these conveyors available; therefore, no design work is needed, only installation.

Products From Whiting Machine

Although headed and cleaned whiting can be used as the starting material for a wide variety of fishery products, especially extrudable minced items (Mendelsohn, 1974a), only two types of whiting products—a frozen reverse-butterfly or pan-ready item and a frozen minced block—were prepared. The variety of product types was limited by the equipment that was available in the participating plant.

The pan-ready product needs no further processing and can be sold as a small consumer or large institutional pack. At the processing plant, the clean whiting were packed in layers (head to tail), separated by plastic sheets, in 10-pound waxed boxes and frozen in a plate freezer. After freezing, the boxes were placed into a master carton and the carton kept at −10°F (−23°C). National Marine Fisheries Service personnel and one industry member examined the pan-ready product made from very fresh whiting and judged it highly acceptable. The pan-ready product made from 5-6 day old whiting was judged as somewhat less acceptable due to its slightly "fishy" odor.

The frozen minced whiting blocks were made by putting the cleaned, headless whiting through the meat/bone separator. The minced product was then put into 18.5-pound waxed cartons and frozen in a plate freezer. After freezing, four blocks were placed inside a plastic bag and into a master carton. The cartons were then placed into a freezer held at −10°F (−23°C).

To determine the acceptance of these blocks, they were cut into fish sticks and battered and breaded. The results of an organoleptic evaluation of the sticks made from fresh whiting by laboratory personnel showed that they were highly acceptable. They received an overall score of 7.3 (good to very good).[4] Sticks made from the penned whiting (5-6 days old) using the same processing conditions were rated 6.4 (fair to good).

The largest quality differences between the penned whiting and day-boat whiting were recorded in their appearance and flavor. In the sticks made from the older fish, more black spots appeared because of their softer skin which tended to squeeze through the holes in the meat/bone separator drum and be collected with the edible portion.

Recommendations and Conclusions

The result of our tests indicated that the prototype whiting processing machine performed largely as expected. However, the commercial operation uncovered the need to further modify it and to add accessory equipment in order to attain its maximum production potential.

Even though the throughput of the prototype machine is too low to meet the demand in the larger processing plants, there is still a sizeable economic advantage in using a machine of this type. Based on current labor practices in the Gloucester area, where fish processors pay about $7.70/hour (including fringe benefits) for general help and $8.65/hour for cutters and semiskilled workers, we have calculated the annual cost for processing a similar volume of fish using the prototype fish heading and cleaning machine and compared it with the cost of heading and cleaning the fish manually. We assumed that the cost of building the prototype machine to be $40,000. This estimate is based on our experience with other fish processing machines. Interest rates were calculated on 12 percent per annum, and the machine was amortized over a period of 5 years. Utility costs were calculated from actual commercial water and electricity bills. The total costs are itemized and tabulated in Table 1.

As shown in Table 1, using the prototype machine with its limited capacity could save a fish processor over $115,000 on a yearly basis. Coupled with a more consistently cleaned product of higher quality, we conclude that it would be worthwhile for a commercial whiting processor to purchase a machine similar to the prototype machine described in this article.

After careful consideration of the cost and complexity of the modifications needed to increase the speed and efficiency of the prototype heading and cleaning machine, we recommend building a completely new second generation heading and cleaning unit rather than modifying the existing prototype machine. The second generation model would have improved features to: 1) Increase throughput of fish; 2) lower number of rejects requiring further handling; 3) reduce down-time (for any reason); and 4) maximize effectiveness of operating components in the production line.

The new line of machines would be built around the successful engineering principles found in the prototype machine but would have a much larger throughput. In the smaller plants, one machine would be sufficient to handle their production while in the larger plants, as many as three machines would be installed, depending upon the amount of fish to be processed.

The proposed high capacity fish processing line is shown in Figure 2. Each unit would have a throughput of about 200 fish/minute; and if all three machines were operating at full capac-

Table 1.—Annual cost of processing whiting in the prototype machine vs. a manual operation[1].

Item	Cost
Prototype machine	
Machine (amortized over 5 yr)	
Principal and interest	$ 10,690
Maintenance	5,000
Labor	
3 General help @ $16,016/yr	48,048
1 Semiskilled help	17,992
Electricity	903
Water	373
Total	$ 83,006
Manual operation	
Labor	
11 Semiskilled help (cutters) @ $17,992/yr	$197,912
Water	186
Total	$198,098
Difference	$115,092

[1]Based on the need for 11 cutters for manual operation for the same production of fish cleaned using the machine and 4 people.

[4]Based on a scale of 9 to 1 where: 9 = excellent, 8 = very good, 7 = good, 6 = fair, 5 = borderline, 4 = slightly poor, 3 = poor, 2 = very poor, and 1 = inedible (Mendelsohn, 1974b).

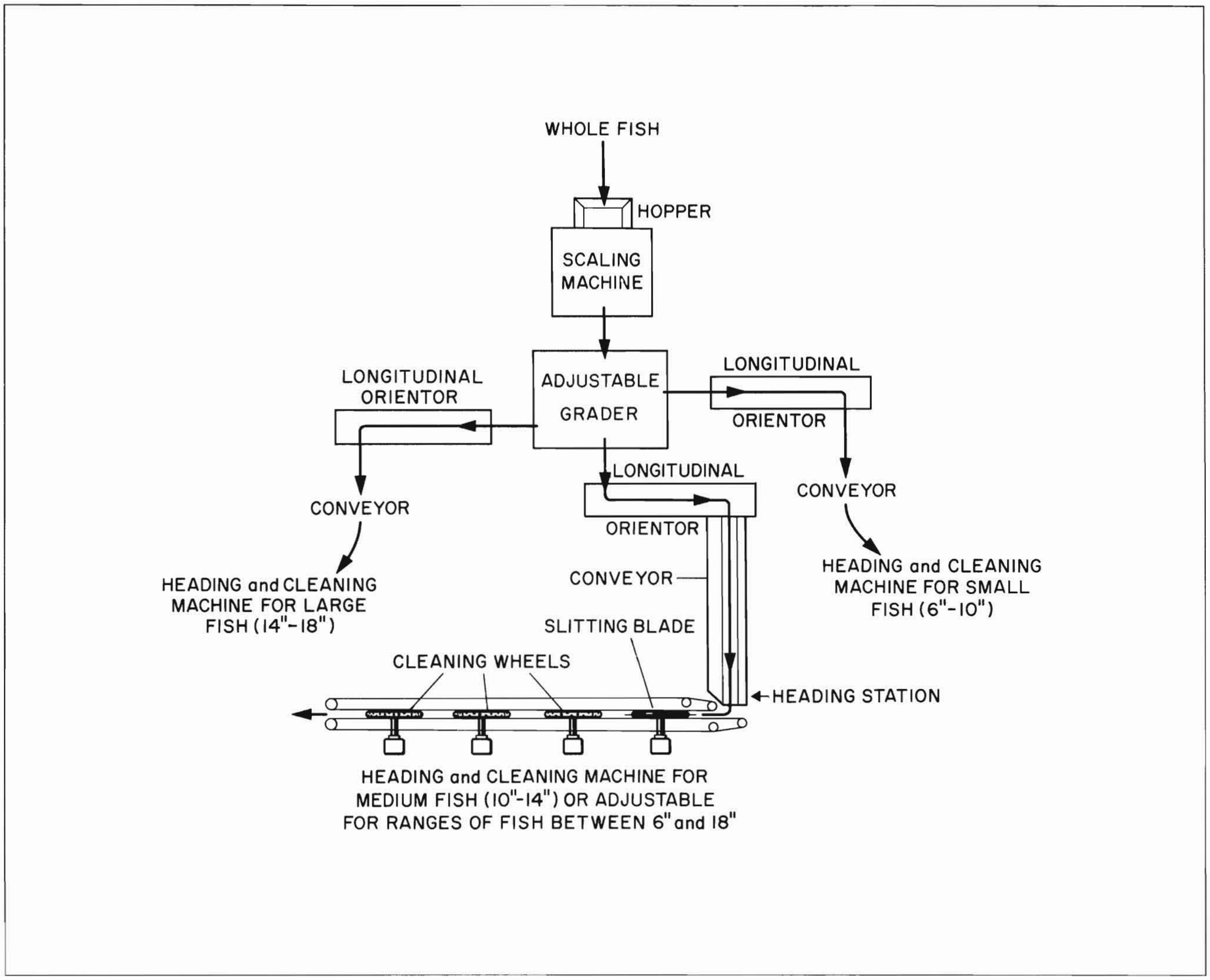

Figure 2.—Proposed high capacity processing line to head and clean 6-18 inch (15.2-45.7 cm) fish.

ity, the line would be able to handle 600 fish/minute varying within a size range from 6 to 18 inches (15.2-45.7 cm) in length.

As shown in Figure 2, the high capacity processing line would contain the following pieces of equipment:

1) An in-line rotary scaling machine to scale all the fish while they are still in the round. In the conventional processing of whiting, the scaling operation is done by a rotary scaler in a later part of the processing sequence. We are suggesting to do it as a first step when the fish are in the round to eliminate immediately the problems caused by the scales.

2) An adjustable size grader which will separate the fish into three size ranges, 6-10 inches (15.2-25.4 cm), 10-14 inches (25.4-35.6 cm), and 14-18 inches (35.6-45.7 cm).

3) A reservoir to hold each size of

fish until they are ready to be conveyed into a machine that: a) Orients the fish longitudinally, and b) orients the fish vertically.

4) A machine to position the fish to be loaded automatically four at a time onto the infeed conveyor.

5) A conveyor to move the fish into an automatic device which measures the length of the head and sets the cut-off knife to remove the head with a minimum loss of fish flesh.

6) An offloading device that transfers the fish to the processing conveyor where the fish is held in position between the carrier belts of the cleaning machine.

7) Semiautomatic air pressure controls to change the pressure adjustments to regulate: a) The depth of the rotary slitting blade used to open the fish's belly; b) the lateral pressure on the belts that hold the inner portion of the fish against the cleaning wheels; c) the vertical downward pressure on the hold-down rolls which keep the fish tight over the cleaning wheels that remove the viscera along the backbone. The size of the fish passing through the machine determines the pressure that each pressure control should apply to do the cleaning job without losing excessive fish flesh. Sorting the fish into three size categories and running one size category at a time makes it possible to adjust one set of regulators at a time to handle the one size category of fish to its best advantage. In a small plant with only one cleaning machine, each set of regulators would be preset and controlled by a selector switch to handle a single size range of fish. The size of the range would be no greater than 4 inches (10.2 cm) in length. By pressing the preselector button, the control system that had been in command for one size category would be shut off, and the controls for the size category to be run would be cut in. The time for switching controls will be in the order of 5 seconds. In the larger processing plants where three heading and cleaning machines are needed to handle their throughput, the controls on each machine would be preset for one size range of fish—also not to exceed 4 inches (10.2 cm) in the variability of length. Although each machine would have the capability of manually switching from one size range to another, it would be unnecessary when using the three machines. This system increases the effectiveness of the machines by matching the size range of the fish to the pressure range of the controls. One range of pressure settings does not work for a full size range of fish.

8) Cleaning wheels of increased diameter (from 6 inches (15.2 cm) to 12 inches (30.4 cm)) in addition to a third cleaning wheel.This change should greatly improve the quality of cleaning the belly cavity, especially in regard to the black belly lining in the larger fish. With a 12-inch (30.4-cm) cleaning wheel, the carrier belt can be 7 inches (17.8 cm) wide to hold the entire belly flap against the side of the wheel with optimum pressure to remove all of the black peritoneum. With three 12-inch (30.4-cm) cleaning wheels, the extension conveyor at the end of the present machine equipped with a conical skinning wheel to clean up the tips of the belly flaps will be unnecessary. This system should give adequate internal cleaning so that the carrier belts can release the fish directly onto the inspection belt which then drops the cleaned fish onto a conveyor for further processing.

9) Carriers with high belt speeds and a transfer system for conveying 12,000 fish/hour.

10) A large and efficient waste disposal system. In the prototype machine, the gurry disposal system was overtaxed necessitating shutdowns to clean the gurry ducts and areas where buildups occurred. A solution to this problem is to install one or more high pressure fan-jets at each station where fish parts and gurry accumulate. The hoses to the fan-jets would be secured to a rack connected to an air or hydraulic cylinder which would operate on time intervals of 15 minutes. At the preset time cycle, the hoses would make one traverse and then return to a starting position. Fish parts which had accumulated during the previous minutes would be washed down the gurry ducts to conveyors for quick removal, thus making it a smooth continuous operation and eliminating the need to stop the machine for cleaning.

A system of machines as described above is not only commercially feasible but is necessary for processing large quantities of fish between 6 and 18 inches (15.2 and 45.7 cm) in length to keep production costs competitive with costs in other food industries. Also, since more and more emphasis is being placed on quality, the proposed processing line would produce consistently high quality seafood products.

Acknowledgments

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