Development of a Squid Skinning and Eviscerating System

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Introduction

Despite its excellent food value, a North American market for squid is virtually non-existent. The appearance of whole squid is unappetizing to many in the market place despite its relatively low retail price ($0.69 to $0.99/pound). The average consumer does not know how to clean or prepare whole squid for consumption. Seafood restaurants serving squid find the demand low and the hand-cleaning costs high. Hand cleaning adds $1.50 to $2.00/pound to the price of squid for the restauranteur. Prepared foods made from cleaned squid meat have been well received in preliminary tests (Berk, 1974), and this shows that there is a potential market for squid in this country.

One species of squid abounds off the coast of California, *Loligo opalescens* Berry (California Market Squid). Current methods for processing squid by the California fishing industry involve canning whole squid for foreign markets and freezing whole squid for both domestic and foreign consumption. The high costs of manual cleaning limits its use to small-scale special-order vendors. Cleaning involves removing the head, eyes, skin, viscera, ink sac, and backbone from the mantle. This leaves a white flesh cone which can be split into a fillet. The tentacles are saved intact for human consumption. Currently, there are no mechanical systems available commercially for cleaning squid. The development of an industrial-scale machine for economical cleaning of squid could have a revolutionary effect on this industry. The overall goal of the research reported in this paper was to develop a completely automated squid processing system.

Design Considerations

Squid and its various components are shown in Figure 1. The body wall thickness is 3-5 mm (0.1-0.2 inch). The cleaned body, called a mantle, resembles a hollow, flexible cone. This conical shape is used in the alignment, ducting, skinning, and eviscerating processes of the machine.

Orientation and Alignment

The basic data needed to design the orientation and alignment component was obtained by Brooks and Singh (1979). The coefficient of sliding friction of the squid tentacles was found to be higher than that of the mantle. This fact allowed the squid to rotate into the desired alignment to slide mantle-first into the machine. Tests with the machine indicated that the squid oriented within their own length. This operation is shown in a schematic in Figure 2.

The squid slid into an alignment trough to be positioned for separation of tentacles and was also cut near the body-cavity opening for further processing (Fig. 2). Cutting through the squid body, 6.4 mm (0.25 inch) from this body-cavity opening, greatly facilitated skinning, evisceration, and backbone removal. The strongest attachment points for the skin, viscera, and backbone were located by Brooks (1978) on the ring of flesh severed from the body cone with the head/eye mass (Fig. 1).

The alignment trough, 19.1 mm (0.75 inch) wide, accepted the squid from the orientation slide in any axial position and supported it so that the

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ABSTRACT–A squid skinning and eviscerating machine was designed for California market squid, Loligo opalescens. *Various operations such as orientation, cutting, skinning, and evisceration were completely automated. Solenoid valves were used to operate the various components for the cleaning operations. The output from the machine was a cleaned white mantle in tubular shape and tentacles. The machine operates with a low consumption of water. The pilot-scale machine cleaned squid at a rate of four squid per minute. Industrial scale-up for processing 10 tons of squid per 8-hour shift is explored in the paper.*

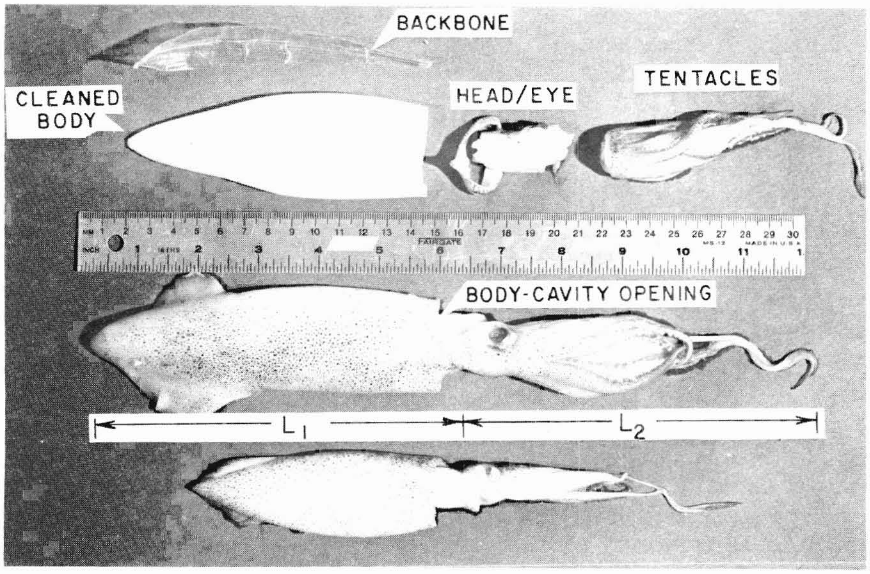

Figure 1.—Cleaned squid parts above, whole squid below

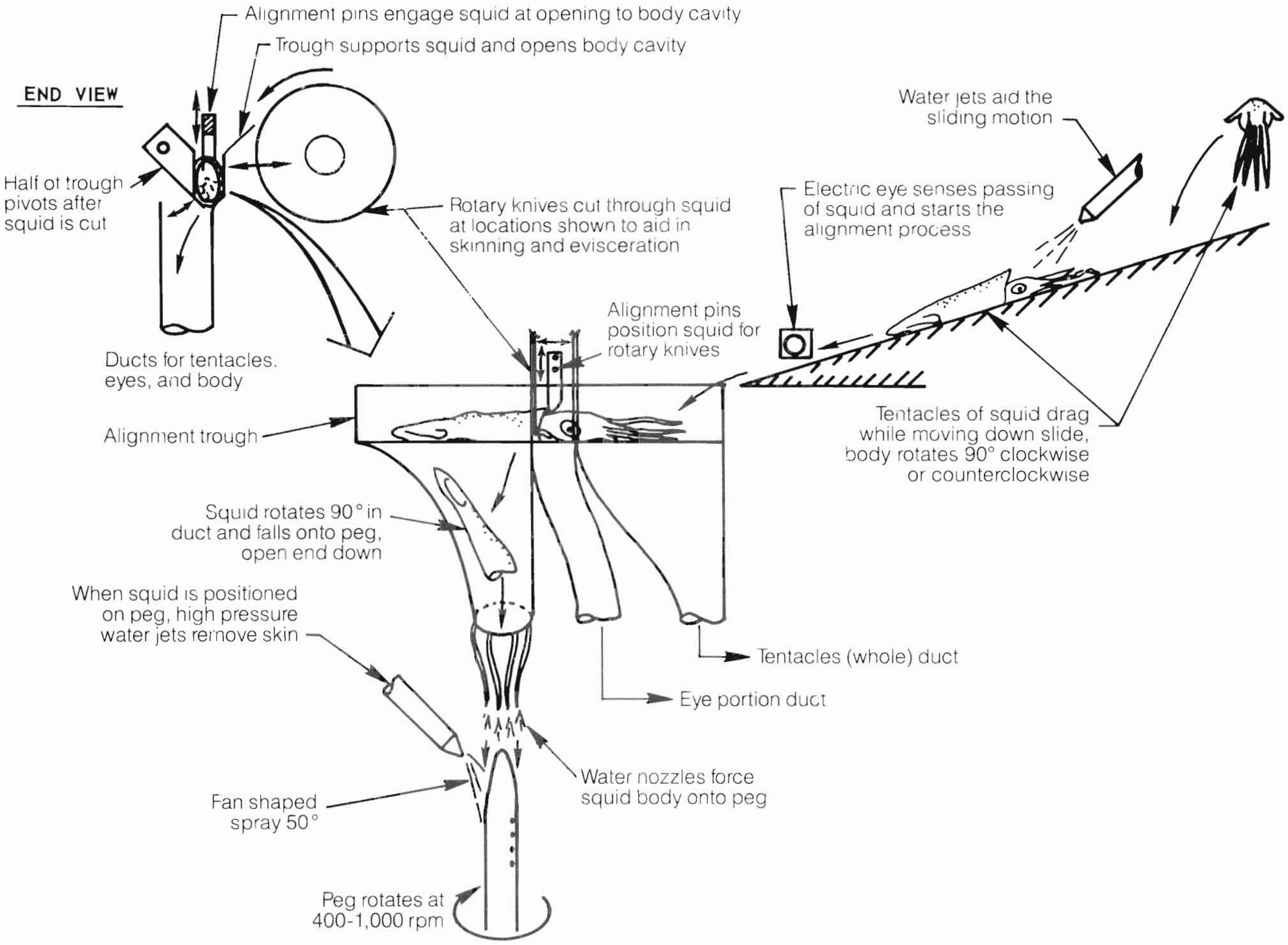

Figure 2.—Alignment, cutting, and ducting systems of squid cleaning machine.

body-cavity opening protruded above the rest of the squid. Alignment pins engaged the protruding lip of the body-cavity opening, as shown in Figure 2, and pushed the squid in the trough forward until it was correctly positioned opposite the rotary knives.

The tip speed of the rotary knives was 5.6 m/second (18 feet/second). The squid were cut quickly and cleanly. Since the body-cavity opening was used as the alignment point, the body length, L_1 (Fig. 1), and the tentacle/head length, L_2, may vary without affecting the alignment efficiency. The length L_1 may vary from 88.9 mm (3.5 inches) to 170.2 mm (6.7 inches) and L_2 may vary by the same extremes (Fig. 1). The size variance and size ratio of tentacles to mantle was therefore eliminated as a factor in aligning and preparing squid for processing.

Ducting of Squid

The elongated, conical shape of the squid mantle facilitated its ducting from the alignment trough to the skinning/evisceration peg. The mantle was firm enough to remain oriented longitudinally in a close-fitting duct, 38 mm (1.5 inches) to 51 mm (2.0 inches) in diameter, and could be transported by gravity or with the aid of moving water over any distance required.

Skinning Process

The hollow conical mantle was ducted onto a rotating peg, as shown in Figures 2 and 3. The viscera, attached to the dorsal side of the mantle interior, was displaced to one side as the mantle slid onto the peg. The squid is shown in place in Figures 4 and 5. The mantle assumed the rotation of the peg, 400-1,000 rpm, and rotated along its major axis below the water jets used for skinning. The longer the mantle, the more of the peg was covered. Again, the size and length variation problems were avoided using this holding technique. The body-cavity opening was kept open and circular as it was ducted onto the peg by a flexible-tube water-jet funnel (Fig. 2, 3). The tubes of the funnel supported all sides of the flexible mantle wall as it passed through, keeping it circular. Jets of water issued from these tubes along the length of the body, accelerating the conical mantle onto the peg.

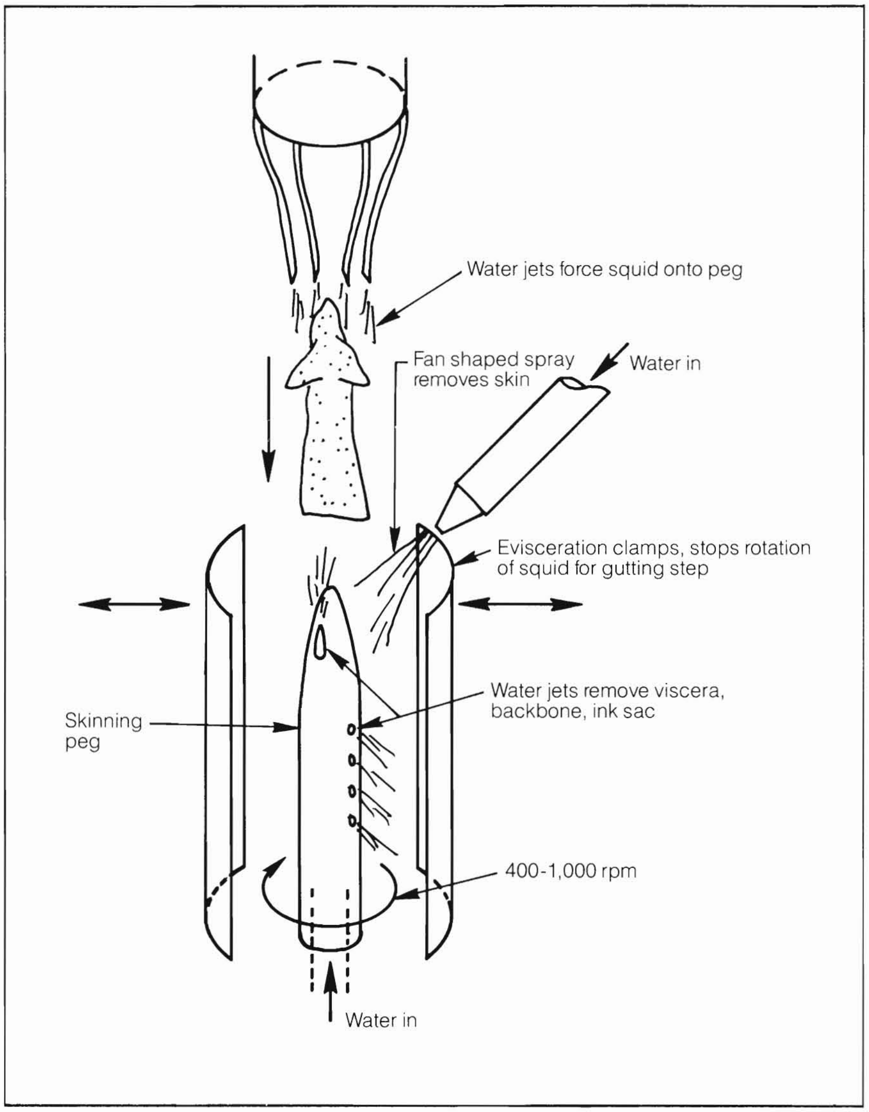

Figure 3.—Squid skinning and evisceration system.

One nozzle, producing a fan-shaped water spray, was used to skin the mantle. The mantle draped over and supported by the peg, received an even blast of water as it rotated under the water nozzle. The fins were sheared from the mantle by the skinning nozzle and were propelled out and away from the rotating peg. The fins dragged much of the skin off with them because of the skin's firm attachment at their edges. The remainder of the skin was peeled down the length of the mantle by the downward blast from the water nozzle.

Evisceration and Pen Removal

The remaining cleaning operations namely, evisceration, ink sac removal, and backbone (pen) removal were accomplished by water jets provided inside the rotating peg (Fig. 3) over

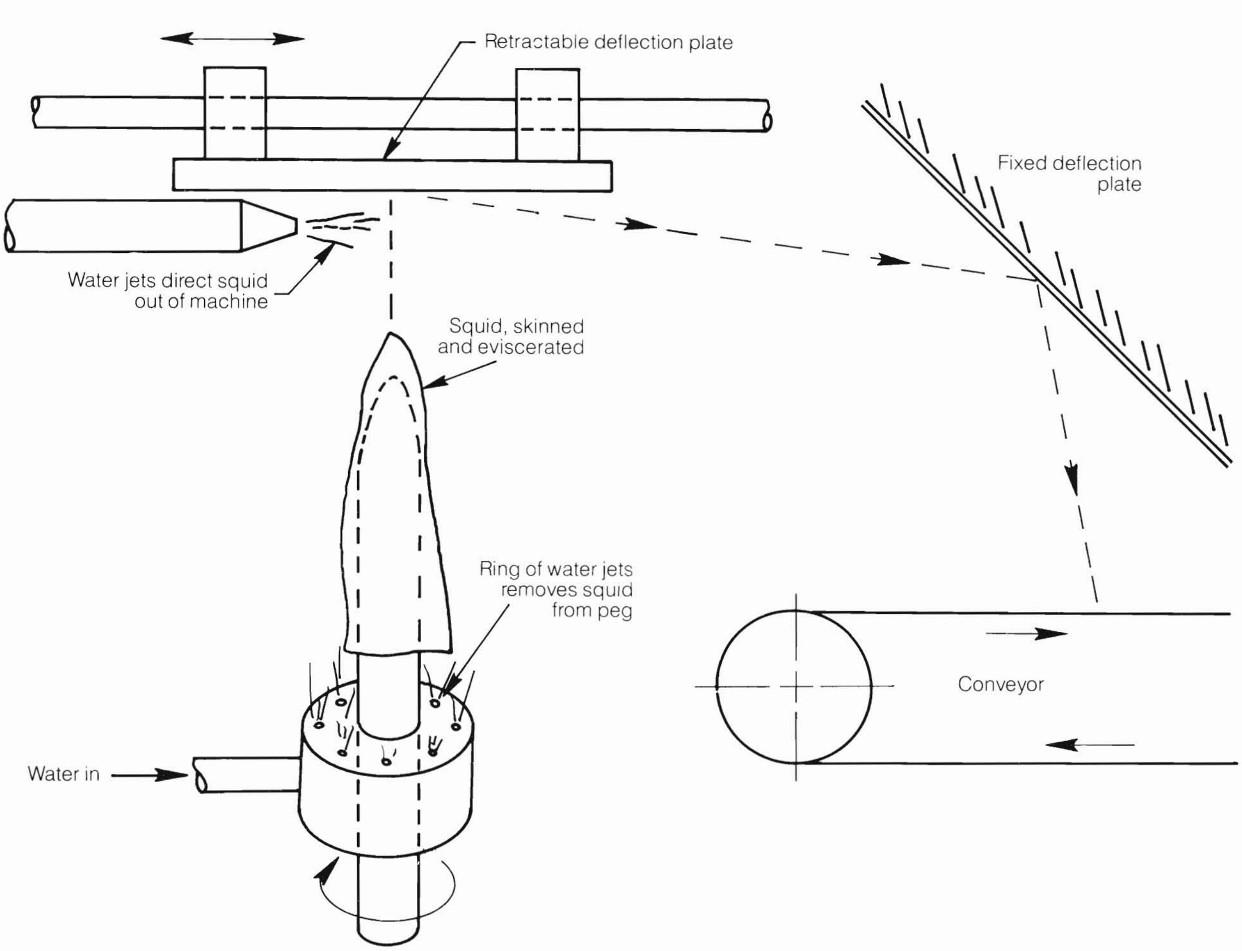

Figure 4.—System to remove cleaned squid from machine.

which the mantle was still draped. A pair of clamps closely matching the conically shaped mantle exterior engaged the squid body, stopping its rotation relative to the peg, and supported it for evisceration. The rotating peg's water jets swept past the interior of the mantle, giving an even 360° coverage, shearing off the viscera and membranes holding the backbone. The evisceration clamps kept the mantle from blowing up like a balloon. The viscera were flushed out the open bottom of the mantle. The viscera, skin, and backbones were collected in a large pan under the machine. The water was drained off.

Removal of Squid From Machine

The cleaned squid mantle was then propelled off the peg and out of the machine by a ring of water jets at the base of the skinning/evisceration peg (Fig. 4). A deflection plate was moved into position between the skinning peg and water-jet funnel. Water nozzles directed the flight of the cleaned squid mantles out of the machine.

The tentacles and eye/head portion of the squid, having been severed from the body by the rotary knives, were ducted out of the machine for further processing (Fig. 2). No attempt was made to skin the tentacles or to remove the beak from them. The tentacles are nevertheless highly desirable for human consumption.

Allied Design Features

Half of the trough, which supported the squid for the cutting process, pivoted to allow the three parts of the squid—mantle, head/eyes, and tentacles—to fall into their respective ducts, as shown in Figure 2. Water jets aided in cleaning the trough of squid parts. The contour of the duct into which the body portion falls (Fig. 2) ensured that the squid was ducted to and inserted on the skinning peg properly, body-cavity opening first.

The water nozzle used in skinning produced a thin fan-shaped high-velocity cutting sheet. The operation pressure used was 60-80 psi. Water supplied to the nozzles and other water jets was controlled by solenoid valves mounted on a manifold. The manifold was pressurized by a positive displacement roller pump.

The water jets used in evisceration cut in the support peg are visible in Figure 3. The peg was hollow and the water supply to it was also controlled by a solenoid valve. A rotary seal at its base allowed for its rotation.

The operation of the pilot-scale squid processing machine (Fig. 6) was fully automatic. The control system for the various functions performed by the machine was activated by an electric eye. It sensed the squid entering the machine via the orientation slide (Fig. 2). It set in motion a rotary stepping switch. This activated the solenoid valves supplying water to the nozzles, or the solenoids, providing linear motion to devices like the alignment pins or evisceration clamps. Fifteen seconds was required to run through the sequence producing a cleaned squid. Another squid was then inserted into the machine initiating the sequence again.

Performance Trials

The pilot-scale squid processing machine has been tested extensively to obtain information on its performance. Two samples of squid were used. The first was obtained frozen in 1.5-kg (3.3-pound) boxes from Meredith Fish Co.[1], Sacramento, Calif. The second sample was obtained 24 hours after it was caught in the ocean from Sea Products Co., Moss Landing, Calif. This sample had been placed in cold storage in 10-kg (22-pound) plastic-lined boxes. The top layer of squid in these boxes was found to be frozen and the remainder was unfrozen. These squid had been stored in ice water prior to packaging. The unfrozen squid were sorted into three groups by mantle length before being fed into the machine. The groups were: 80-110 mm (3.2-4.4 inches), 110-150 mm (4.4-6 inches), and 150+ mm (6+ inches).

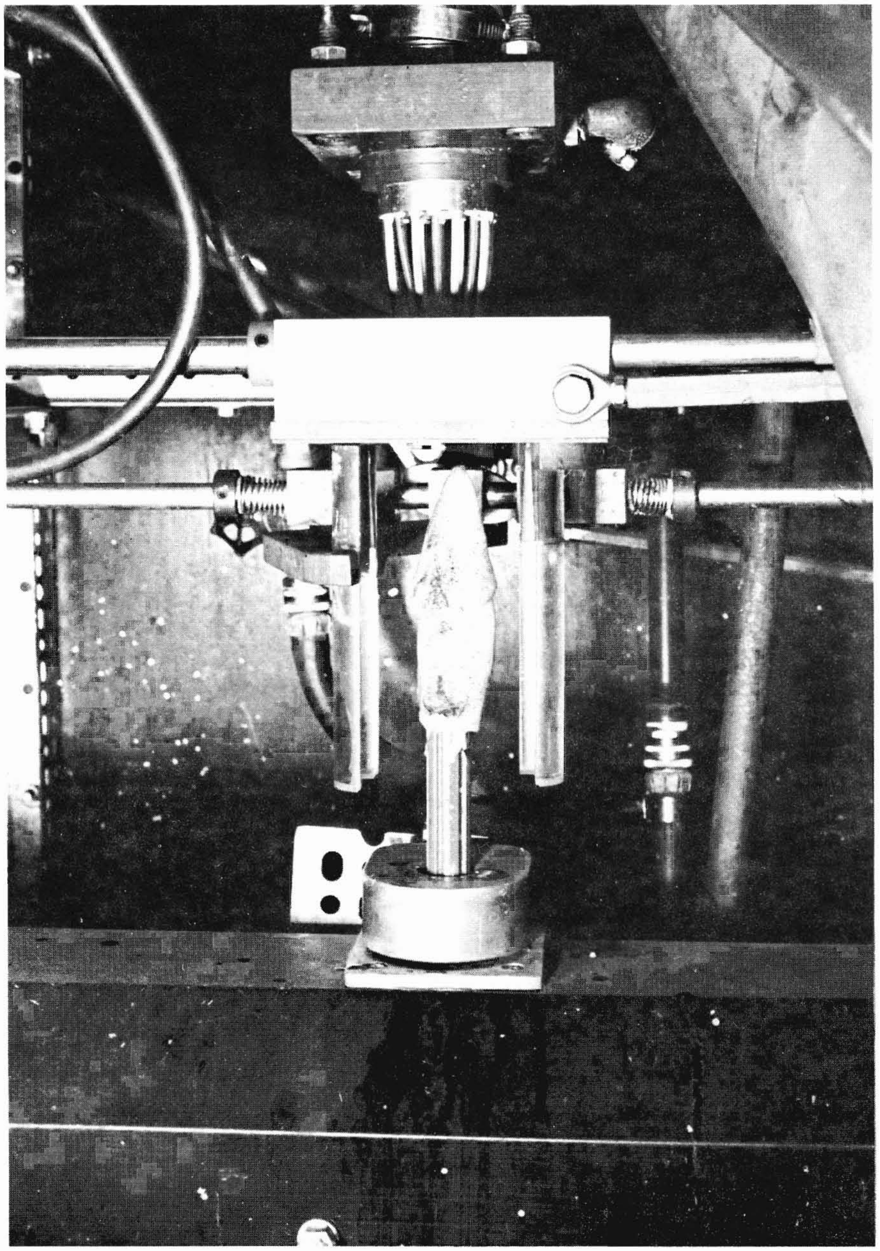

Figure 5.—Squid mantle in place on skinning and evisceration peg.

Frozen whole squid were thawed, drained of excess water, and weighed before being fed into the machine. The output of the machine was also drained and weighed. The yield by weight consisted of cleaned mantles and severed tentacles (beak not removed) drained of water. In 22-25 percent of the sample output the viscera were still connected to the body by a thread of tissue even though the viscera had been removed from the body cavity. These viscera and bits of skin could be separated easily by hand. These squid were included in the yield by weight data. Those squid which were clearly not an acceptable product, i.e., unskinned or uneviscerated, were not included in the yield weight.

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

Results and Discussion

An important parameter in mechanically assisted cleaning of squid is the yield of edible portion. The yield by weight of hand-cleaned squid ranges from 50 to 55 percent according to Ghio[2]. In the tests performed with the pilot-scale machine, the previously frozen squid samples yielded 45 percent edible meat, and the unfrozen samples 52 percent edible meat as shown in Figure 7. The lower edible meat yield in the frozen sample is due to dehydration of the frozen sample during storage.

The dimension of mantle length appears to have a significant influence on processing rates. The unfrozen sample was sorted by mantle length into three size classes. The 110-150 mm (4.4-6 inch) squid, numerically composing 70 percent of the catch, and 72 percent by weight, averaged 51 percent edible meat return as shown in Figure 8. Squid over 150 mm (6 inches), 21 percent of the catch by weight, yielded 58 percent edible meat. Squid less than 110 mm (4.4 inches) yielded 36 percent edible meat. These small squid may not be worth processing since they compose only 14 percent of the catch numerically and only 7 percent by weight. Thus, yield of edible meat from the pilot-scale machine depends on the initial size of individual squid processed. This fact clearly indicates the need to develop a size grading device that would allow the system to achieve high processing rates.

It should be noted that a small portion of the trailing edge of the mantle is cut and discarded in the alignment step. In addition the fins are removed during the skinning step. However, these operations do not significantly reduce the yield since, although these lost pieces are edible, they are very thin in cross section.

The quality of the cleaned squid was evaluated in terms of the desired attributes, e.g., samples completely skinned, eviscerated, and boned. Data in Figure 7 seem to indicate the skinning percentage was higher in the frozen sample. The fresher squid appeared harder to skin. Data presented in Figure 8 indicate that squid greater than 150 mm (6 inches) were very difficult to skin totally; squid less than 110 mm (4.4 inches) were easier to skin. Small portions of fins and/or skin could be easily removed manually. Only those squid from which all of the viscera had been removed by the machine were counted as being part of the fraction totally eviscerated. Figure 7 indicates that 63-73 percent of the squid were totally eviscerated. An additional 22-25 percent of the output was then included in the yield after hand separation of the viscera, removed from the body by the machine but still attached by a thread of tissue. It is clear in Figure 8 how difficult it is to totally eviscerate the squid over 150 mm (6 inches). The evisceration rates in these samples were 33-53 percent. Manual separation was largely feasible in the fraction of these large squid that were not eviscerated totally.

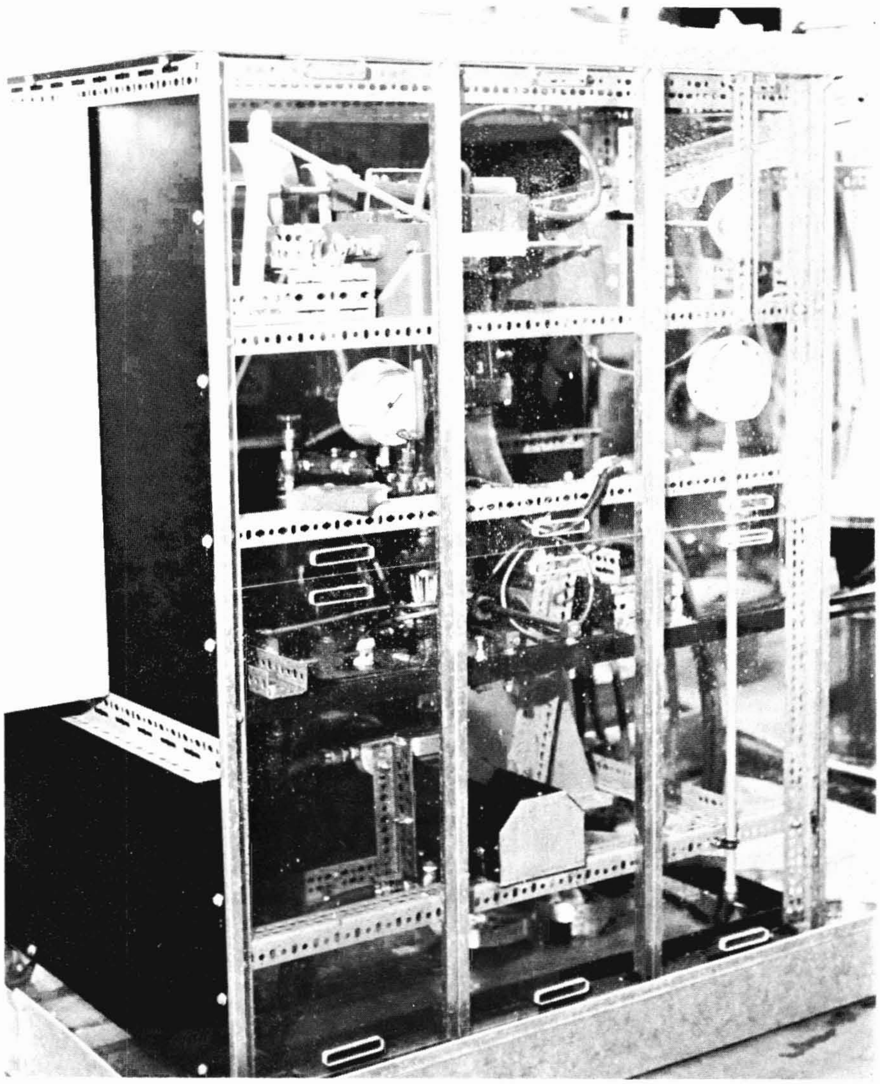

Figure 6.—The squid skinning and eviscerating machine.

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[2] Ghio, T. 1979. Ghio Seafood Products, Inc., San Diego, Calif. Personal commun., 10 July.

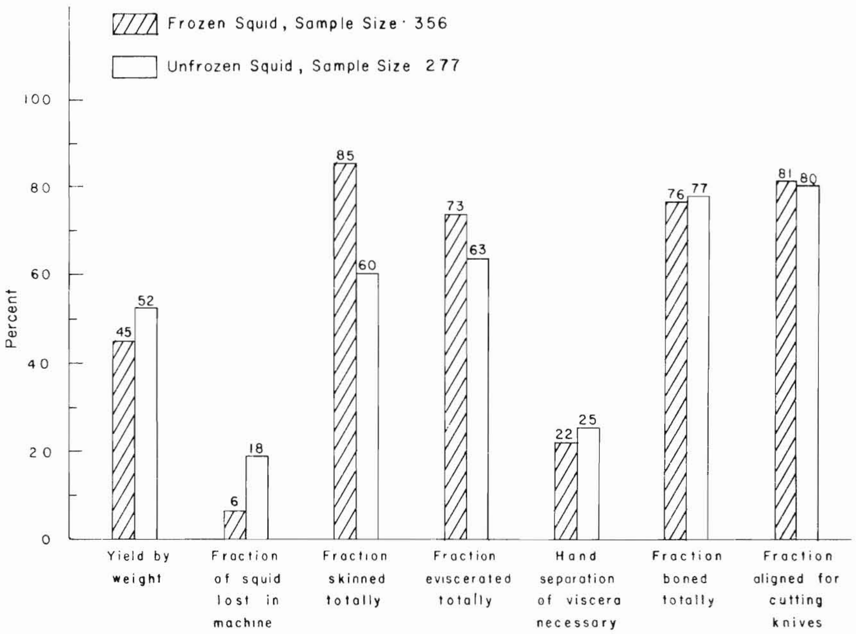

Figure 7.—Processing data for frozen and unfrozen squid.

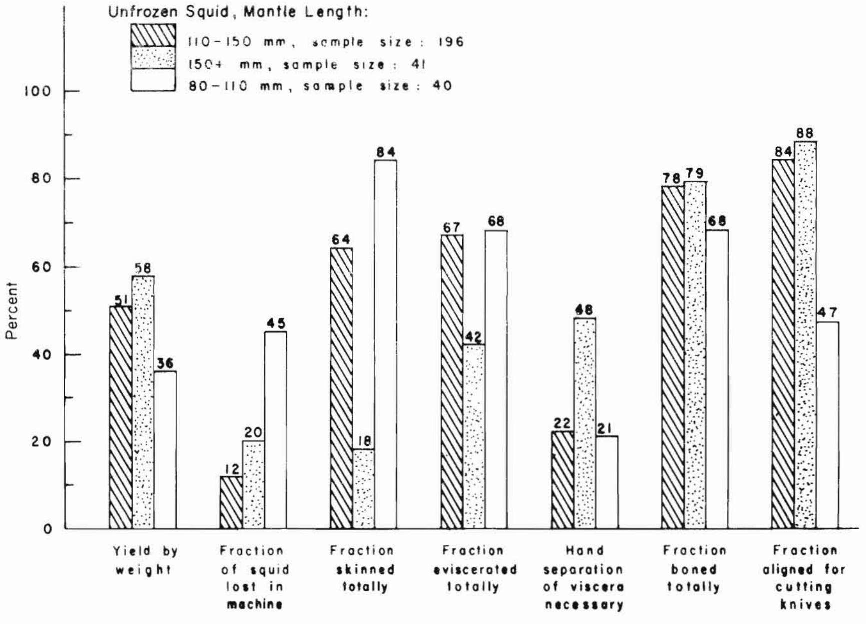

Figure 8.—Processing data for unfrozen squid sorted by mantle length.

During processing it was observed that the ink sacs removed with the viscera from the frozen sample came out intact without much ink release. However, in unfrozen samples, a stream of ink flowed with the evisceration water from the interior of the squid. The ink, however, was completely flushed from the squid body cavity, and it did not contaminate or discolor the meat.

A squid was counted as boned totally if the pen was completely removed and not retained by the body or unremoved viscera. The fraction boned totally was high. The pen was at times hung up in the viscera which was out of the body but still attached by a thread of tissue. These squid were not counted as being boned totally and the pens were removed manually.

The cut provided through the squid at the body-cavity opening assisted in severing the attachments for the pen and viscera making them easier to remove. Proper alignment ensured that this cut was made with the minimum loss of edible meat. Inspection of the output from the machine indicated that the fraction of squid aligned properly for cutting knives was very high. The proper cut was made in at least 80 percent of the squid fed into the machine. The data for unfrozen, sorted squid show that squid over 110 mm (4.4 inches) were aligned at an 84-88 percent rate (Fig. 8). Squid under 110 mm (4.4 inches) were aligned at a significantly lower rate (47 percent) in this sample. In addition, they were boned at a slightly lower rate (68 percent vs. 78 and 79 percent for the 110-150 and 150+ mm (4.4-6 and 6+ inches) squid, respectively). However, in the 80-110 mm (3.2-4.4 inch) sample the squid were headed, skinned, and eviscerated at a high rate compared with the other size ranges. Their smaller size probably makes them easier to skin and eviscerate, despite improper alignment.

Flesh firmness also had an effect on the frequency of alignment. Squid bodies that were not firm were not engaged properly by the alignment pins. The edible meat loss was then higher than necessary.

Water consumption rates were measured in operating the pilot-scale machine. The maximum water consumption rate was 0.38 *l*/second (6.0 gallons/minute).

Industrial Scale-up

In an industrially-viable squid-processing machine it is anticipated that the single channel unit can be divided into two stages, namely, 1) alignment trough, and 2) skinning and evisceration peg. Each stage could be controlled independently and thus could process squid simultaneously. The processing time for each stage is 7-8 seconds and this would have the effect of doubling the output from its current 4 squid/minute or 18 kg/hour (40 pounds/hour). The number of pegs and troughs could then be multiplied to get the required tonnage. Using a 6 squid/pound average, an 8 squid/minute operation, and a processing goal of 10 tons/8 hours, from 30 to 35 peg units would be required.

Hydraulic conveyance of squid to each of these units can be accomplished with a fluidized ducting system of a 38-51 mm (1.5-2.0 inch) diameter tubing. This has been tried on a small scale in our laboratory. Squid were separated from a batch loaded holding tank and ducted to another location one at a time. Further work on this component of processing squid is currently underway.

In summary, a pilot-scale squid cleaning machine has been developed to automate the cleaning process. The edible yield from the machine, 45-52 percent of the total body weight, was comparable to hand-cleaned squid. The yield depended on initial size of the individual squid and prior handling operations. The processing efficiency was highest for squid with a body length of 110-150 mm (4.4-6 inches). The pilot-scale machine forms the basic unit around which an industrial-scale squid processing machine could be built. The processing rate in the pilot-scale machine was 4 squid/minute or 18 kg/hour.

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