Automatic squid cleaning machine

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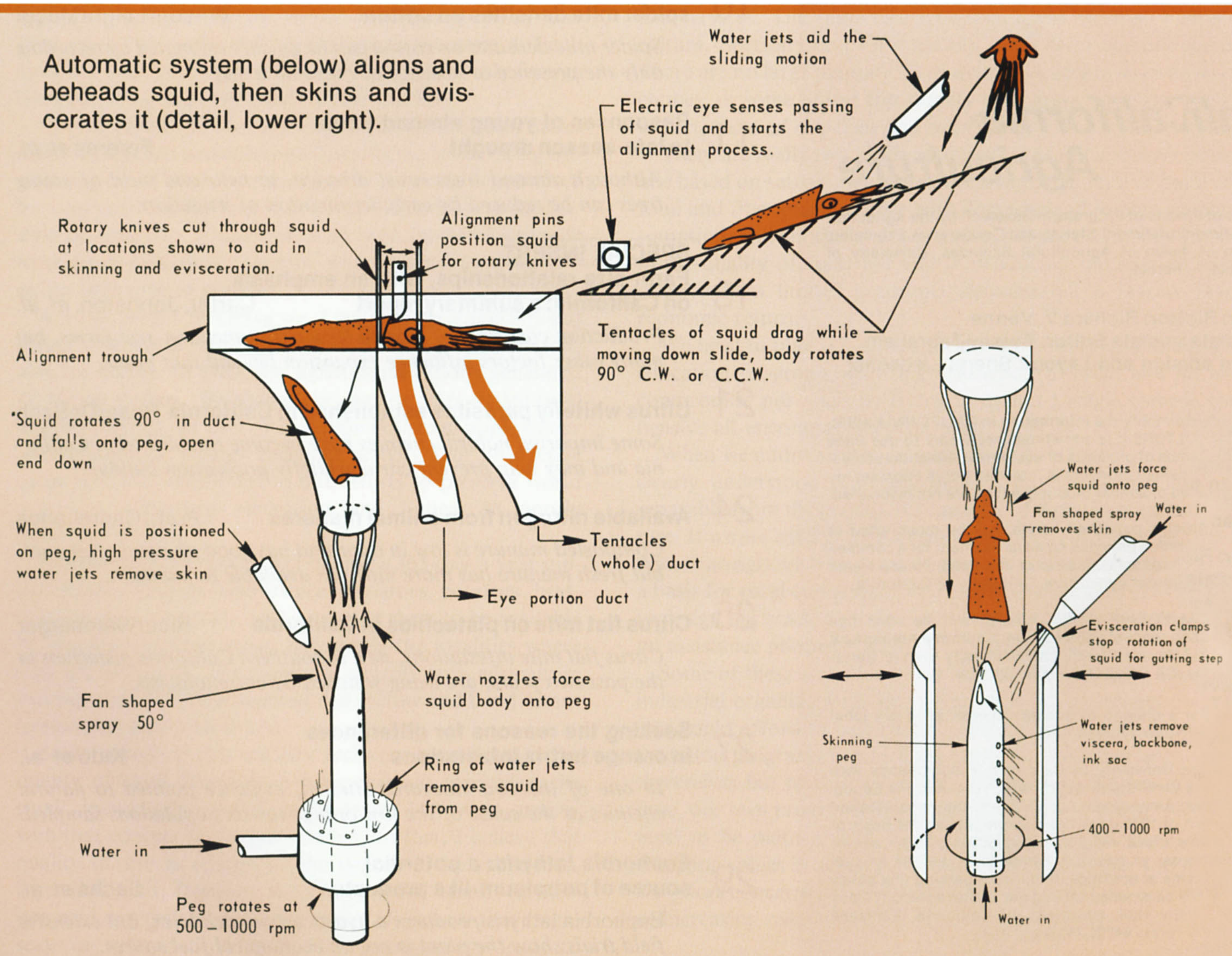
Squid is an important food in many countries, particularly in Mediterranean Europe and the Orient. It is a nutritious seafood high in protein and low in fat, and it is abundantly available. The current world catch exceeds one-half million tons, and it is estimated that this could be increased to a sustainable fishery of over one hundred million tons annually. Squid is potentially the largest single source of animal protein in the marine environment.

One species, *Loligo opalescens* Berry (commonly referred to as market squid) abounds off the western coast of the United States. The California squid catch averages 10,000 tons annually, worth $1.2 million. It is estimated that this tonnage could increase to more than one-half million tons annually if demand allowed.

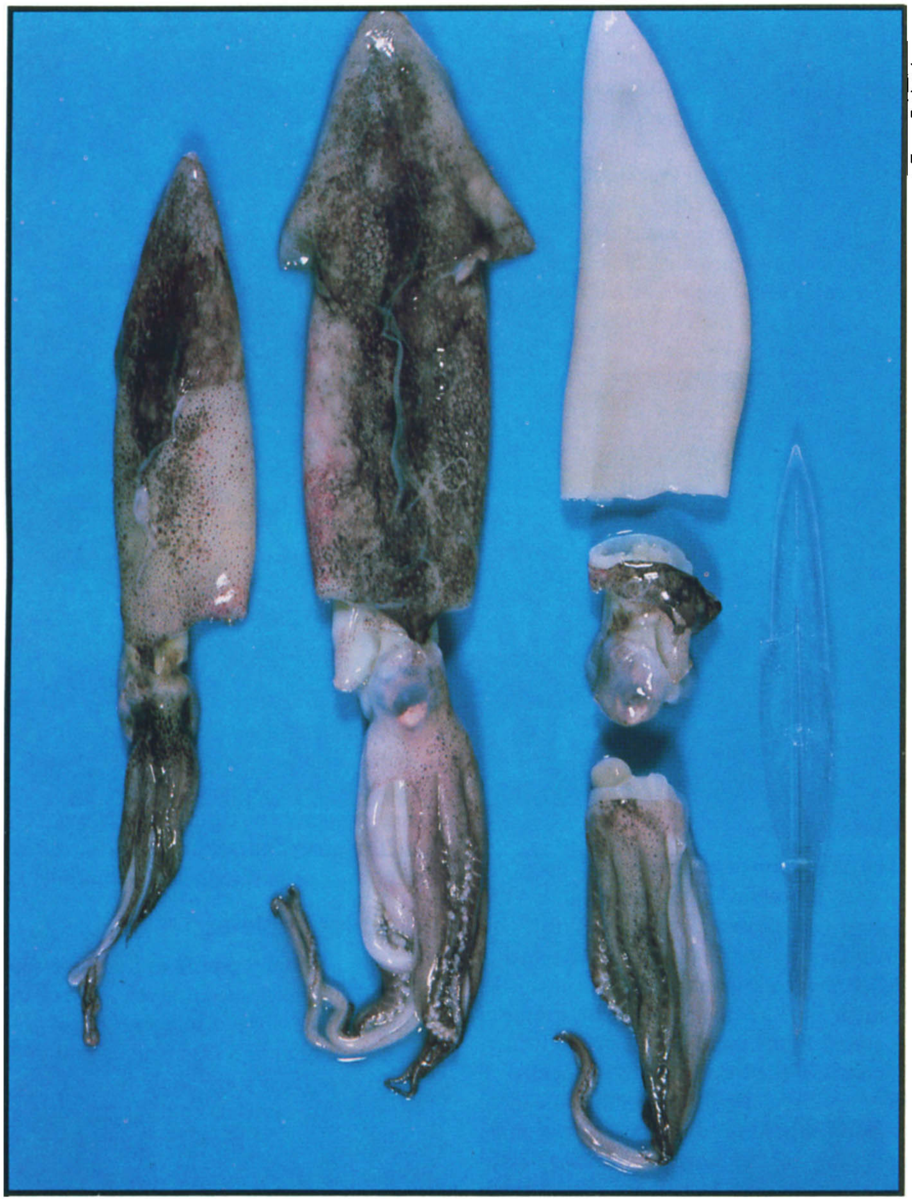
In spite of its excellent food value and delicate flavor, squid is unpopular in North America. It appears unappetizing to many, and the task of cleaning it is laborious and unpleasant. However, prepared fish products, such as snack foods, breaded patties, and cocktail sauces, are quite popular. Prepared foods made from squid meat have been well received, indicating that a market for squid meat products exists in this country. These products require that whole squid be cleaned economically and at a high rate.

Current processing methods are used by the California fishing industry to can whole squid for foreign markets and freeze whole squid for both domestic and foreign consumption. The high cost of manual cleaning ($1.50 to $2.00 per pound) limits its use to small-scale special-order vendors. Cleaning involves removing the head, eyes, skin, viscera, ink sac, and backbone from the mantle, leaving a white flesh cone that can be split into a fillet. The tentacles are saved intact for human consumption.

At present, no mechanical systems are available commercially for cleaning squid. Development of an industrial-scale machine



Automatic system (below) aligns and beheads squid, then skins and eviscerates it (detail, lower right).



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Most squid processed had mantles about 4 to 6 inches long (left). Cleaned squid parts on right are (top to bottom) mantle, head and eye section, and tentacles, and (on far right) the backbone, or pen. Tentacles are considered a delicacy by some.

for economical cleaning could revolutionize this industry. The overall goal of the research reported here was to develop a completely automated squid processing machine.

Design considerations

The cleaned body of the squid, called a mantle, resembles a hollow, flexible cone. The conical shape is used in the alignment, ducting, skinning, and eviscerating processes of the machine.

We obtained the basic data to design the orientation and alignment component in 1979. The sliding friction of squid tentacles was found to be higher than that of the mantle. This difference causes the squid to slide mantle-first into the machine. Tests with the machine indicate that the squid orients within its own length.

The squid slides into an alignment trough to be positioned for separation of tentacles and is cut near the body-cavity opening for further processing. Cutting through the squid body ¼ inch from this opening greatly facilitates skinning, evisceration, and backbone removal. Alignment pins engage the protruding lip of the body-cavity opening and push the squid forward in the trough until it is correctly positioned opposite the rotary knives.

The squid is cut quickly and cleanly. Since the body-cavity opening is used as the alignment point, the body length and tentacle/head length may vary without affecting alignment efficiency.

The elongated, conical shape of the squid mantle facilitates its ducting from the alignment trough to the skinning/evisceration peg. The mantle is firm enough to remain oriented longitudinally in a close-fitting duct and can be transported by gravity or with the aid of moving water.

Skinning process

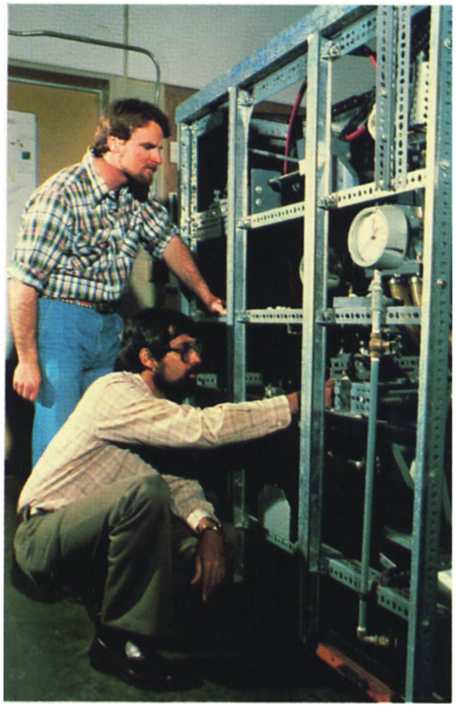
The hollow conical mantle is ducted onto a rotating peg. The viscera, attached to the dorsal side of the mantle interior, are displaced to one side as the mantle slides onto the peg. The mantle assumes the rotation of the peg, 400 to 1,000 rpm, and rotates along its major axis below the water jets used for skinning. The body-cavity opening is kept open and circular as it is ducted onto the peg by a flexible-tube water-jet funnel. The tubes of the funnel support all sides of the flexible mantle wall as it passes through, keeping it circular. Jets of water issue from these tubes along the length of the body, accelerating the conical mantle onto the peg.

One nozzle, producing a fan-shaped water spray, skins the mantle. The mantle, draped over and supported by the peg, receives an even blast of water as it rotates under the water nozzle. The fins are sheared from the mantle by the skinning nozzle and are propelled out and away from the rotating peg. The fins drag much of the skin off with them because of its firm attachment at the edges. The remainder of the skin is peeled down the length of the mantle by the downward blast from the water nozzle.

Evisceration and pen removal

The rest of the cleaning—evisceration, ink sac removal, and backbone (pen) removal—is done by water jets inside the rotating peg, over which the mantle is still draped. A pair of clamps closely matching the cone-shaped mantle exterior engage the squid body, stopping its rotation relative to the peg, and support it for evisceration. The rotating peg's water jets sweep the interior of the mantle, giving an even 360° coverage, shearing off the viscera and membranes holding the backbone. The evisceration clamps keep the mantle from blowing up like a balloon. The viscera are flushed out the open bottom of the mantle.

The cleaned squid mantle is propelled off the peg and out of the machine by a ring of water jets at the base of the skinning/evisceration peg. A deflection plate moves into posi-



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Above: Co-developers Paul Singh (kneeling) and Dan Brown with prototype machine. Right: Squid is cleaned in 15 seconds.

tion between the skinning peg and water-jet funnel. Water nozzles direct the flight of the cleaned mantles out of the machine.

The tentacles and eye/head portion of the squid, severed from the body by the rotary knives, are ducted out of the machine for further processing. No attempt is made to skin the tentacles or to remove the beak. The tentacles are nevertheless highly desirable for human consumption.

Allied design features

Half of the trough, which supports the squid for the cutting process, pivots to allow the three parts of the squid—mantle, head/eyes, and tentacles—to fall into their respective ducts. Water jets clean the trough of squid parts. The contour of the duct into which the body portion falls ensures that the squid is ducted to and inserted on the skinning peg properly, body-cavity opening first.

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

Operation of the pilot-scale squid processing machine is fully automatic. The control system, activated by an electric eye, senses the squid entering the machine via the orientation slide and sets in motion a rotary stepping switch. This activates 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 are required to clean a squid.

Test results

The yield by weight of hand-cleaned squid ranges from 50 to 55 percent. In tests with the pilot-scale machine, previously frozen squid samples yielded 45 percent edible meat, and unfrozen samples 52 percent edible meat. The lower yield in the frozen sample is due to dehydration during storage.

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The dimension of mantle length appears to influence processing rates significantly. The unfrozen sample was sorted by mantle length into three size classes. Squid 4.4 to 6 inches long, numerically composing 70 percent of the catch and 72 percent by weight, averaged 51 percent edible meat. Squid over 6 inches, 21 percent of the catch by weight, yielded 58 percent edible meat. Squid less than 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 the individual squid processed. This indicates the need to develop a size grading device that would allow the system to achieve high processing rates.

The quality of the cleaned squid was evaluated for the desired attributes—samples completely skinned, eviscerated, and boned. Data seem to indicate that the skinning percentage was higher in the frozen sample. The fresher squid appeared harder to skin. Squid larger than 6 inches were very difficult to skin totally; those less than 4.4 inches were easier to skin. Small portions of fins, skin, or both, 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. It is difficult to totally eviscerate squid larger than 6 inches by machine. The evisceration rates in these samples were 33 to 53 percent. Manual separation was largely feasible in the fraction of these large squid that were not eviscerated totally.

During processing, the ink sacs removed with the viscera from the frozen sample came out intact without much ink release. In unfrozen samples, a stream of ink flowed with the evisceration water from the interior of the squid. However, the ink was completely flushed from the squid body cavity and 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 that were cut 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 through the squid at the body-cavity opening helped to sever 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 machine output 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.

Industrial scale-up

In an industrially usable squid-processing machine, it is anticipated that the single channel unit can be divided into two stages: (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 to 8 seconds, and this would double the output from the current four squid per minute or 18 kg per hour (40 pounds per hour). The number of pegs and troughs could then be multiplied to get the required tonnage. At an average of six squid per pound, an operation of eight squid per minute, and a processing goal of 10 tons in eight hours, 30 to 35 peg units would be required.

Squid to each of these units can be hydraulically conveyed in a fluidized ducting system. 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 under way.

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