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Strides are being made toward tapping a large oceanic protein source.

Squid—Its Potential and Status as a U.S. Food Resource

VINCENT G. AMPOLA

INTRODUCTION

There are about 350 species of squid that inhabit the oceans and seas of the world. They belong to the division of molluscs known as cephalopods, the "head-footed" animals, close relatives of the cuttlefishes and octopi, and more distantly related to clams, oysters, and scallops. In fact, the fringe of appendages surrounding the head area of all cephalopods is a modification of the fleshy foot of their primitive molluscan ancestors, and the single, slender chitinous "pen" that lines the internal dorsum of the body is all that remains of the shell. The distinctive morphological features of a typical squid are shown in longitudinal section in Figure 1.

All squids propel themselves by taking in and forcibly expelling water from the mantle cavity through the siphon. The force and direction of the water expelled plus the undulation of fins and body determines the direction and speed of the animal. They move opposite to the direction of the water ejected from the siphon and so can move forward or backward with great rapidity. The circulation of water through the mantle also provides oxygen for the gills which hang free within the forward part of the mantle cavity.

All cephalopods are carnivorous, and when young, subsist on small invertebrates such as copepods, euphausiids, and gastropods. Older squids live on fish such as capelin, cod, crustaceans, and other molluscs. Squids usually have ten appendages arranged in five pairs around the head. Eight are short and heavy and are called arms; the fourth pair down, as one counts from the dorsum, are called tentacles and are about twice as long as the arms.

The ink sac is a reservoir containing a brown or black viscous fluid which is ejected through the siphon when the squid is alarmed. This "ink" not only forms an effective screen behind which it can escape, but it is believed that the alkaloids present in it paralyze the olfactory sense of the enemy, thus aiding the squid in its escape.

The unusual coloration of cephalopods is caused by the presence of pigment cells or chromatophores in the integument that contain red, blue, yellow, and black pigments in concentrations specific to each species. The chromatophores are controlled by muscles which are actuated to expand or contract by visual or olfactory stimuli, thus changing the colors of the animal. It has been observed by the author and fishermen that after death, it is the release of these pigments into the flesh of the animal that is an indicator of the onset of spoilage.

WORLD POTENTIAL OF THE RESOURCE

For centuries, squids have been used as an important and palatable source of food in the countries bordering the Mediterranean Sea and in the Orient. They are found in all the seas and oceans of the world, and are so numerous that they can be considered one of the greatest untapped sources of protein to be found in the marine environment. Their fecundity and exceptionally high growth rate combine to help ensure a substantial fishery.

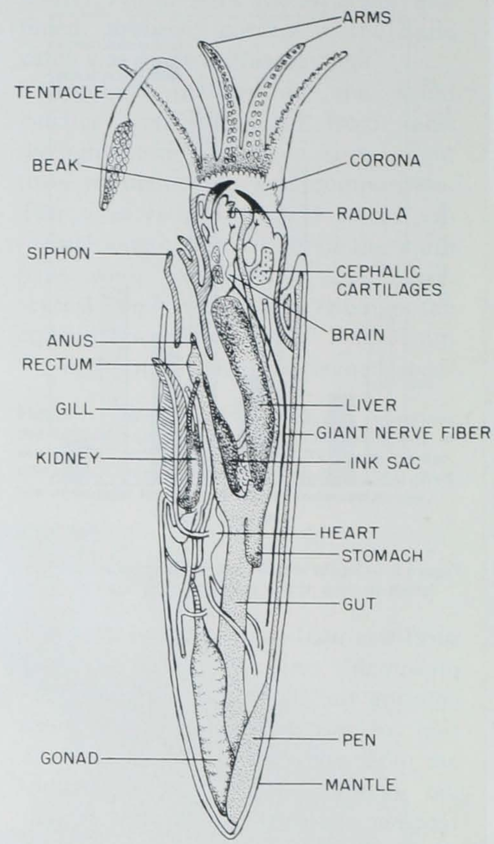

Figure 1.—A squid in longitudinal section, excluding tailfins.

According to Voss, who is cited in an article in *Fishing News International* (Anonymous, 1973), those parts of the seas from the middle of the continental slopes to the shoreline where cephalopods are presently being fished constitute less than 10 percent of the total ocean surface. Present catches are derived mostly from inshore species and those oceanic squids that migrate to inshore waters during part of their life cycle. The squid resource is therefore underexploited in about 90 percent of the world's ocean area. In the same article, other experts estimate that the annual potential production of oceanic squids probably lies within the range of 90 to 280 mil-

Vincent G. Ampola is a Research Food Technologist at the Northeast Utilization Research Center, National Marine Fisheries Service, NOAA, Emerson Avenue, Gloucester, MA 01930.

lion metric tons. From 1968 to 1971, the reported world catch of all species averaged 600,000 metric tons.

Additional and pertinent information on the world biomass and distribution of oceanic squids, and the present gear and the numerous methods used in harvesting them, is given by Filippova (1970, and 1971), Anonymous (1973a), Voss (1973), and Zuev and Nesis (1971).

THE UNITED STATES SQUID FISHERY

From 1968 to 1971, the reported yearly United States harvest averaged 13,300 metric tons (Anonymous, 1969, 1970, 1971, and 1972). About 90 percent of this catch consisted of *Loligo opalescens* caught in southern Californian coastal waters. The fishery is conducted year-round, with maximum hauls taken from May to July. Most of this catch is canned or frozen, but lately much of it is being sold fresh, as it is rapidly becoming a popular entrée in west coast restaurants.

Another species of squid harvested in the United States is the long-finned or "bone" squid (so called because of its broad pen and a tail half the length of its body), *Loligo pealei*, which inhabits the western Atlantic from Venezuela to Nova Scotia but is most commonly found from Cape Hatteras to Cape Cod. They inhabit the inshore waters of the continental shelf of the middle and south Atlantic States in the summer and autumn and the outer part of the continental shelf in the winter and spring. The bulk of the reported catch is brought in as incidental catch to the trawl fishery, and a smaller amount is taken closer to shore by traps. Data from the ICNAF Redbook (Anonymous, 1973b) indicate that from Cape Cod southward to the Baltimore and Wilmington canyon areas, a yearly maximum sustainable yield of 71,000 metric tons of *Loligo pealei* is possible. Until 1973, about 75 percent of the catch was sold to the fresh market, but lately more of the catch is being frozen and exported to European countries, as demand there has risen considerably.

The other commercially important species caught off the eastern coast of the United States is the short-finned (the tail fin is about one-third of the body length), "summer," or "Newfoundland" squid, *Illex illecebrosus*. It occurs southward to the Gulf of Mexico but is most commonly found in the summer and fall from Cape Cod northward to the Maritime Provinces. Its greatest use in the past century or so has been as cod bait both in Canada and the fisheries of Portugal and the Scandinavian countries. In this country, this species is taken incidentally to trawling operations, and very little is sold to the fresh market.

The distribution, biomass density, some biological data, and the methods and gear used in capturing these Atlantic species are reported by Nesis (1968), Noskov and Rikhter (1971), Rathjen (1973), Serchuk and Rathjen (1974), Squires (1957), Vovk (1969), and Vovk and Nigmatullin (1972).

NUTRITIONAL ASPECTS

Compared to other marine animals eaten by man, squid have a larger proportion of edible parts to the whole body. With vertebrate fishes, the recoverable edible portion ranges from 20 to 50 percent; and in the commonly eaten shellfish, the edible parts are from 20 to 40 percent. In squids, the edible portion—which consists of the mantle, tail, arms, and tentacles—is from 60 to 80 percent of the weight of the animal, depending on the species and its size.

Squid meat is equal to fish meat in protein content (16-20 percent) and amino acid composition and can be considered as an excellent source of protein (Takahashi, 1965). Its food energy equivalent is about 85 calories per 100 grams of raw meat.

The fat content of squid flesh has been reported as varying from 1 to 5 percent (Kitabayashi, Nakamura, Shudo, and Ishikawa, 1963). This fat contains a considerable amount of cholesterol; but since the quantity of fat is low, the amount of cholesterol present does not constitute a health hazard even to those who are on restricted diets (Korobkina, Danilov, Kalinina, Tsurkova, and Andreeva, 1968).

A definite advantage of squid meat over fish is that in some cases, no matter how well the fish are filleted, the meat could still contain some bones; but for squid, once the beak and "pen" are removed in the cleaning process, there are no remaining bones to concern the processor and, ultimately, the consumer. In addition, there are no data in the literature at the present time that indicate that squid flesh harbors any parasites that are harmful to man.

MANUAL PROCESSING

In order to hand-clean squid for further processing, it is necessary to wash each one under running water in order to remove any adhering foreign matter or ink which will stain the meat. The squid is then laid flat, and the arms and tentacles are severed from the body by cutting through the head just in front of the eyes. The beak, which is located in a pouch in the base of the corona of appendages (Fig. 1), is removed by simply squeezing the pouch out from its attachment with thumb and forefinger.

To clean the body, insert a knife blade into the mantle cavity and slit the mantle down to the base of the tail. Pull out the visceral mass, including the "pen," and discard. Lay the mantle flat, and with the knife edge scrape away any visceral remnants and ink as well as the pair of gills adhering to the inside of the mantle wall. Some processors simply squeeze out or manually pull out the visceral mass and "pen" in order to leave the body intact. Wash the cleaned parts under running water. Removal of the skin from the mantle, arms, and tentacles is optional and laborious and can be accomplished in some species by hand-peeling or by scraping. Sometimes, blanching the meat in hot water (75°-85°C) for a few seconds will facilitate this process. Japanese researchers and others have been studying the use of proteolytic enzymes in conjunction with agitation as a means of removing the skin (Okuda and Kon, 1965).

MECHANICAL PROCESSING

In order to make a squid fishery economically feasible, fast, efficient mechanical means of heading, eviscerating, skinning, and cutting the flesh into appropriate size pieces must be developed.

Recently, mechanical skinning of

flat-cleaned squid mantles, as well as eviscerated, intact mantles, was achieved by passing them skinside down through a modified Jensen Type B fish fillet skinner (manufactured under license by Kitchen of the Sea, Inc., Malden, Mass.[1]). In this procedure, round-cleaned squid, and also uneviscerated, headed squid were skinned on one side only. For complete skinning, the body is turned and run through the skinner again so that each side is, in turn, exposed to the cutting knives. It is possible that other models of fish fillet skinners now in use can be modified to skin squid in this manner. It is also possible that machinery of this type can be modified to eviscerate as well as skin squid.

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

High-speed mechanical cutting of squid flesh into slices has successfully been accomplished by passing the flesh through an Urschel Model J dicer (manufactured by Urschel Laboratories in Valparaiso, Ind.) Figures 2 and 3 show the cutting end of the apparatus and the shape of the pieces produced in one pass. The cleaned mantles and arms are fed onto a high-speed conveyor belt which carries them to serrated circular cutting knives which are adjusted by the use of spacers so that a selected width of cut can be achieved. The strip thus formed is then crosscut into squares or strips. The efficiency of the dicer, as measured by the number of acceptable cuts per unit of weight, is about 75 percent when flat mantles were passed through at ambient temperature. When the mantles were stiffened by being partially frozen, the efficiency was increased by an additional 12 percent. Pieces that emerged uncut, due to doubling over of the mantle, can be run through the machine again, and tailings or pieces that are too small to be acceptable can be separated from acceptable cuts by being forced through the apertures of an appropriate size sieve by a strong jet of water. If squid rings are desired, the knives are set to a narrow width cut, the crosscut blades are removed, and the intact, whole eviscerated mantles, without tail fins, are passed crosswise into the cutting knives.

For further processing, breading and packaging machinery as well as precooking, canning, bottling and sterilizing units are now available as on-line production equipment.

The solution, then, to achieving processing automation is the development of an apparatus that will behead the squid and remove the mouth sac, and one that will completely eviscerate the squid and remove the pen. With the advent of this type of machinery, a completely automated production line to process squid from dockside to finished product would be possible.

ICED SHELF LIFE

Several experiments were performed in order to determine the length of on-ice shelf life of the two local commercial species. In the first series of experiments, freshly caught, iced, and refrigerated squid were brought to the Northeast Utilization Research Center within 18 to 24 hours after capture. The ice was removed and they were packed in wooden boxes together with flake ice in a ratio of one part of squid to one part of ice (by weight), two parts of squid to one part of ice, and five parts of squid to one part of ice. This was accomplished by placing the appropriate amount of ice on top of the squid and simulated poor icing technique. The boxes were then stored in a refrigerated room (3°C ± 1°), and the top ice lost due to melting was replenished as needed. Sensory testing was done on each lot daily in order to determine the shelf life of the squid.

In the last three experiments, squid trawled by the vessel *Valkyrie* (char-

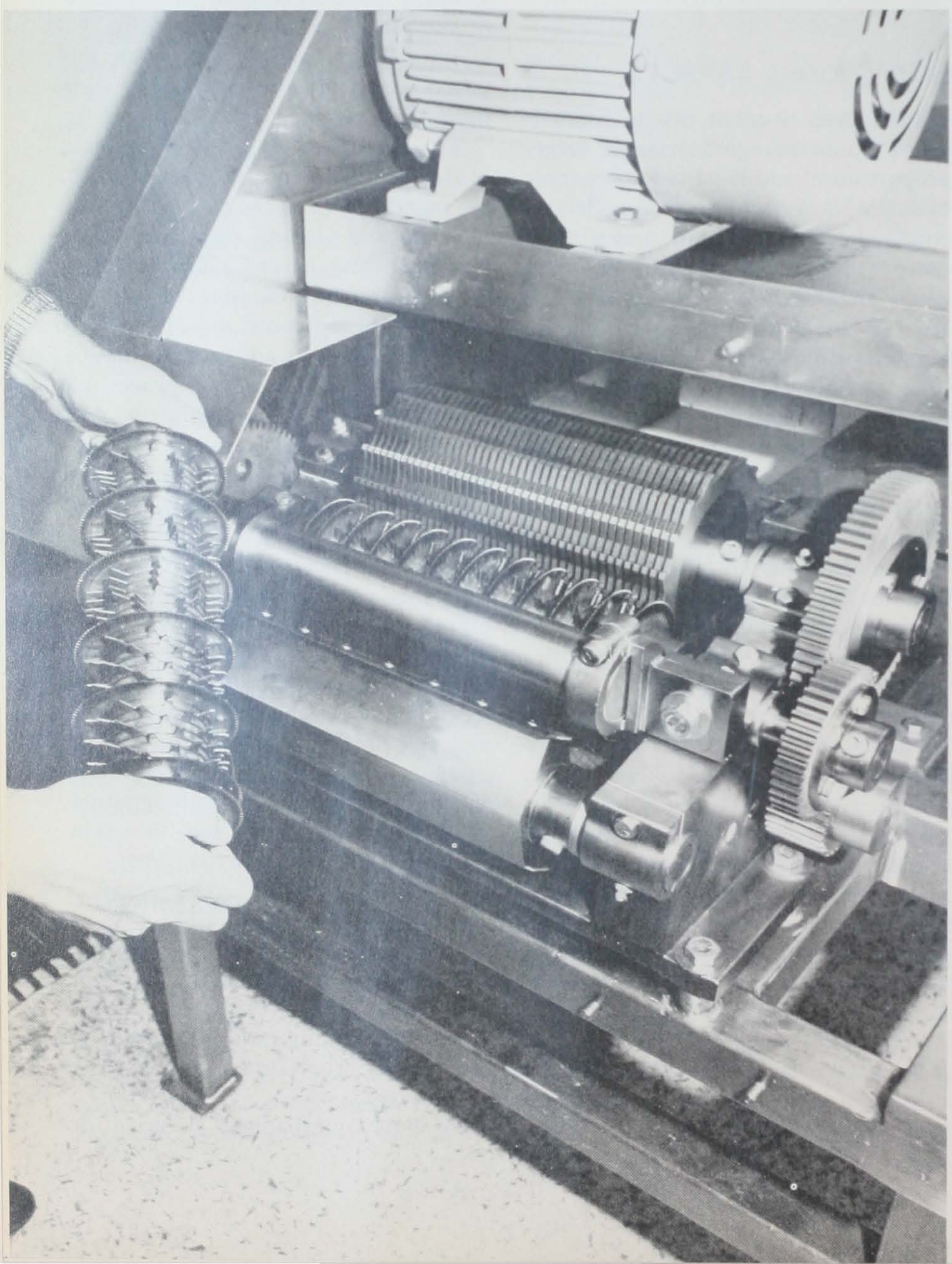

Figure 2.—Model J Urschel Dicer showing stripping and crosscut knives.

Figure 3.—Machine cut squid mantle (*Illex illecebrosus*).

tered by the National Marine Fisheries Service to test the feasibility of directed squid fishing), and heavily iced in crushed block ice immediately after capture, were kept that way during extended refrigerated storage to test optimal conditions. The results shown in Table 1 indicate that, in all probability, the time of year the squid were harvested, as well as the amount of ice used during storage, has a definite beneficial effect on the shelf life of squid.

Table 1.—Iced shelf life of round squid held in ice at an ambient temperature of 3°C ± 1°.

Squid to Ice Ratio	Month Caught	Shelf Life (days)
Illex spp.		
1:1	July	5
2:1		5
5:1		4
1:1	September	8
2:1		8
5:1		7
Loligo spp.		
1:1	May	6
2:1		6
5:1		3
1:1	January	9
1:1	January	9
1:1	February	10

PRODUCT DEVELOPMENT

At present, the only commercially prepared squid products produced in the United States are squid canned with or without its ink in brine, in oil, and in tomato sauce. The 1970 canned pack was about 1 million pounds and was probably destined for strictly ethnic markets. Among the present functions of the Northeast Utilization Research Center are product development and preservation, and the promotion of underutilized marine species, both to help the fishing industry and to introduce new and palatable foods from the sea to the American public. Squid is a prime example of an underutilized species.

Many squid recipes were formulated and tested for acceptability by taste panels with excellent results. These include squid in chowder, in thermidor, and in various tomato sauces. Squid meat was used as an ingredient in stuffing, alone, and in combination with clam meats and textured vegetable protein. With the addition of binders such as starches, albumen, or homogenized fish flesh (Learson, Tinker, and Ronsivalli, 1971), portion-controlled, breaded, precooked patties were developed. The development of rancidity in raw or processed squid products was never a problem, even when they were held in frozen storage for a period of several months.

Two products that show definite promise as consumer items are frozen breaded squid, and marinated squid. Breaded squid are prepared by cleaning and machine cutting the mantles and tails into bite-sized pieces, which are then battered, breaded, packaged, and frozen. They can be deep-fat fried directly from the frozen state for consumption. Studies by marketing personnel of the National Marine Fisheries Service and by personnel at the Northeast Utilization Research Center indicate excellent acceptance of the product even after months of frozen storage.

Preliminary packs of marinated squid were made by mixing diced, precooked squid, including arms, with vinegar, olive oil, and spices. They were packaged in glass jars and kept under refrigeration below 3°C. The quality of the product was highly acceptable for a 12 month storage period. Total bacterial plate counts on Eugon agar incubated at 37°C ranged from a high of 1,400 organisms per gram to zero at the end of the storage period.

COOKING CHARACTERISTICS

Fresh squid can be cooked in either of two ways. They can be quick-cooked as in frying or sautéing or given a long cooking when used as an ingredient in a sauce or casserole. If the squid pieces are to be quick-cooked, weight loss will be minimal (about 3-7 percent), and the meat will retain a characteristic snap or bite due to its turgidity. If the squid meat is to be boiled to achieve the desired end product, it will lose about 35-40 percent of its weight during the first five minutes of active boiling and up to 55 percent after 30 to 40 minutes. Squid meat should be taste-tested regularly for texture during prolonged cooking until the optimal degree or desired level of tenderness has been achieved and then served or processed immediately. Small squids are cooked a shorter time than larger ones. Overcooking should be avoided because the flesh will toughen or become gummy and friable, and will lose flavor.

In general, higher sensory acceptance scores were obtained when squid meat was prepared with its skin on, although to some members of our taste panel, the appearance of white, skinless flesh was more acceptable.

USES FOR SQUID WASTE

The sepia or ink of cephalopods has been refined and used as a colorant by artists for many years. It is also frozen and used as an ingredient in ethnic cephalopod cookery. Japanese researchers have been studying means of extracting a high viscosity glue from squid skin (Nakamura and Kitabayashi, 1964). When properly processed, a high grade nitrogenous fertilizer or animal feed supplement can be made from the viscera and "pen" which comprise 20-40 per cent of the animal's weight. Squids not suitable for human consumption can be similarly treated.

FISHERY PROBLEMS

The problems that arise in the development of a stable squid fishery are many. As noted, data are needed on the biomass distribution, biology, the reproduction and life cycle patterns, and migrations of all the utilizable species of squid. Existing fishing gear and methods for an expanding inshore fishery can be refined as demand increases, but new methods of locating, herding, and capturing less accessible oceanic squids should be developed. For instance, research on the effect of continued or pulsed, mono or polychromatic illumination, as mentioned by Zuev and Nesis (1971), to attract squid could be researched more intensively. The use of acoustics and the potential of electrofishing for squid should be investigated.

The development of automated mechanical means of completely processing squid, either aboard ship or ashore, is desirable from the standpoint of efficiency and cost reduction.

A constant and reliable source of supply of squid is essential for the development of a stable fishery. Maximum sustainable yield per species and area should be determined and overfishing avoided. At this time, especially in the United States, an intensive promotional and marketing effort is needed. A market for squid should be created and developed in areas where, at present, none exists. If this were done, the latent world squid resource could materially add to the world's portein supply. Much has been written in this same vein for many years, but it seems clear that now, in this period when more abundant food resources are urgently needed, is the time for concerted action for the utilization of squid in the United States.

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