Contributions from the Biological Laboratory of the U. S. Fish Commission,
Woods Hole, Massachusetts.

IMPROVEMENTS IN PREPARING FISH FOR SHIPMENT.

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It is well known that ice, as ordinarily used in packing, is more or less unsatisfactory. It spoils the freshness, flavor, and firmness of the fish; but, moreover, the moisture of the melting ice favors the development of putrefactive bacteria and thus hastens decay, which is only the result of the activity of certain putrefactive bacteria. If the fish are so handled that the activity of the bacteria is restricted, the process of decay will be retarded; but if the fish are handled so as to encourage the ravages of the bacteria, the process of decay will progress much more rapidly. The pressing of fish by close packing softens the muscles and renders the flesh more susceptible to invasion by putrefactive bacteria. Packing fish in foul barrels and unclean boxes, the contamination from which is conveyed to the fish by the melting ice, also contributes to their speedy decay.

The following investigations, which were carried on at the biological laboratory of the United States Fish Commission at Woods Hole, were undertaken for the purpose of ascertaining to what degree fish are spoiled by carelessness, filth, and bad packing, and to devise methods which might mitigate these evils.

The animals used for the experiments were squeteague, bonito, blue-fish, and tile-fish. The fish from the large trap owned by the United States Fish Commission and located in Buzzards Bay furnished an unlimited supply of material. During July and August squeteague were abundant; their flesh is soft, very susceptible to invasion by putrefactive bacteria, and difficult to preserve by the ordinary methods of packing. Bonito were also occasionally taken; their flesh is firm and hard and relalatively easy to preserve.

The first experiments were to determine the influence of ordinary summer temperatures and of the different methods of killing and handling upon putrefaction; 48 squeteague were hung up by a wire passing through the eyes; 24 had the intestines removed, after which the fish were immediately drained; the other 24 were not opened. The experiment was made in a place protected from the sun, but to which the air had free access. The weather was humid and foggy, the temperature being 68° at 8 a. m., 72° at noon, and 71° at 5 p. m. After 24 hours the fish were examined. Those that had not been opened were putrid and emitted an almost unbearable odor. Those whose intestines had been removed were in better condition, and might even have been used for food. The abdominal cavity was much fresher and putrefaction had not penetrated so deeply into the flesh. The experiment shows that when the intestines are not removed decomposition takes place more rapidly, and that the immediate removal of the viscera delays decomposition. The experiment gives some idea of the rates of putrefactive changes in the two kinds of fish.

The next experiment was with 24 squeteague and 6 bonitos. After removing the intestines, as above, the fish were laid on their sides on a plank, but not in contact with one another. The day was humid and foggy, the temperature ranging from 69° at 8 a. m., and 72° at 12 m., to 71° at 5 p. m. At the end of 24 hours the fish were examined. The squeteague were badly decomposed on the side next the wood; on the other side decomposition had not proceeded so far, although it had progressed to a considerable extent. In the body-cavity decomposition was evident, but it had not advanced very far. The bonitos were in much better condition, although they emitted an odor of putrefaction, the side on which they lay being most affected. The walls of the body-cavity also were in better condition than those of the squeteague. The experiment shows that the free circulation of air about fish retards the process of decay.

After the intestines had been removed from 12 squeteaque the fish were hung up by their tails and allowed to remain 24 hours. The weather was cloudy, and the temperatures were as follows: 8 a. m., 71°; 12 m., 74°; 5 p. m., 73°. The atmospheric conditions were less favorable than on the previous day, yet at the end of 24 hours the fish were found to be in much better condition than in any of the preceeding experiments. There was a decided odor of putrefaction from the outside of the fish, but the abdominal cavity and the muscles showed only slight evidences of decomposition. The fish were in as good condition as many fish found in our markets and generally sold as "fresh." The experiments thus far made show that early cleaning, free circulation of air, and thorough draining retard putrefaction.

Twenty-four living squeteague were decapitated, thoroughly drained, and then their intestines were removed. From another series of equal number the intestines only were removed. The 48 fish were packed in a box in close contact with one another. The weather and temperature conditions were practically the same as on the preceding day. At the end of 24 hours the fish were very soft and had a bad odor. Although the 24 which had been decapitated were in a better state of preservation than the others, all were unfit for use. Those in the top layer, where they were exposed to the air, were in early stages of decomposition. Those on the bottom, away from the air and moistened by the drip from those above, were in advanced stages of decomposition. The experiment indicates the importance of thorough drainage of the flesh by early decapitation. The presence of blood hastens decay.

In all the above experiments the fish were taken from the fish-trap alive, and were immediately prepared to meet the conditions of the various experiments. By this means no decomposition could have taken place before the experiments were begun. The fish were handled as carefully as practicable, to prevent bruising or rupture of the muscular tissue. Cleanliness was assured through copious washing with sea water.

To recapitulate, the experiments show:

(*a*) That putrefaction takes place more rapidly if the viscera are not removed.

(*b*) That moisture hastens the process of decay.

(*c*) That the free access of air retards putrefaction.

(*d*) That drainage of the blood retards putrefaction.

(*e*) That if the head and intestines are removed, and if the fish is suspended by the tail so that the blood is drained from the entire body, the fish will remain sweet for a considerable time without the use of ice.

In none of the above experiments were putrefactive bacteria *prevented from entering the flesh* or directly hindered in their action after entrance. Consequently, further investigations were made to determine the feasibility of delaying bacterial invasion. To do this the fish must be *washed* with a solution which retards the growth of bacteria and is not injurious to the food qualities of the flesh. Various solutions were tried, but only one with success. In all cases control experiments were made on fish taken at the same time and subject to the same conditions, the only difference being that the control fish were not treated with the sterilizing fluids.

(1) The first experiment was with a 0.1 per cent solution of salicylic acid in sea water. 24 squeteague, taken alive from the nets, were carefully dressed, washed with this solution, packed in a box, and allowed to remain for 24 hours. The temperature ranged from 73° to 76°. When examined the next morning there was a perceptible odor of putrefaction; the fish were soft and unfit for market. The control fish were not much worse. Similar experiments were subsequently made with the same solution, but none were successful.

(2) The next preparation experimented with was a 10 per cent solution of potassium nitrate. 18 squeteague, cleaned immediately after being taken from the nets, were decapitated and thoroughly washed with this solution, and packed close together in a box. During the next 24 hours the weather was foggy, and the temperature ranged from 73° to 74°, at the end of which time decomposition had advanced to such a stage that the fish were totally unfit for shipment. There was no appreciable difference between the fish subjected to the potassium nitrate and those of the control experiment. Six more trials were made with this solution, but always with the same result.

(3) A 5 per cent solution of formalin was next used, but, as might have been predicted, the fish did not keep, and they were as bad at the end of 24 hours as those of the control.

(4) The next and most successful experiment was made with a 3 per cent solution of boric acid (B_2O_3) in sea water. 24 squeteague were dressed immediately after being caught, some decapitated, and others packed without removal of the head and gills. All were merely washed in the above solution and then closely packed in a box. The weather was foggy and cloudy, the temperature ranging from 74° to 83°. When examined 24 hours later the fish were in good condition, without odor, and decomposition had evidently not begun; the flesh was hard and firm, the eyes clear, and in fact one of the fish was declared by a native fisherman to have been taken from the water that very morning, and he was not readily convinced that it had been kept without ice for 24 hours. One of the squeteague was baked and served on my own table, and was pronounced excellent. It is needless to say that the control fish were in advanced stages of putrefaction and wholly unsuitable for food.

In these experiments with boric acid the fish were in no sense "embalmed," injected, or even preserved. The walls of the abdominal cavity, after the removal of the viscera, were simply washed with a sponge that had been dipped in the solution. The success of the experiment is of course largely dependent upon (*a*) the immediate removal of the viscera after the capture of the fish; (*b*) the careful handling of the fish, both before and after evisceration; (*c*) the thoroughness with which the walls of the abdomen are washed, and (*d*) the care with which the fish are packed. The use of boric acid will not prove satisfactory if fish are first thrown about, walked upon, carelessly eviscerated, washed in the sterilizing fluid, and then pitched into barrels. Those who prefer to abuse fish in this way will do well to stand by the older and more expensive methods—use ice, and complain of the market.

Mr. E. G. Blackford, one of the largest wholesale dealers in New York, has said:

> As an example of increased returns to the shippers from careful handling, I call attention to the fact that certain shipments of shad going to the New York market from North Carolina bring from 25 to 40 per cent more than other shad from the same locality. * * * What I wish to impress upon the shippers and fishermen is that for every dollar invested in labor and ice in packing the fish they will receive ten dollars in return.

Twenty more experiments were made with the same solution. Some of the animals were decapitated and others were not, but the swim bladders and kidneys were removed from all. If the gills were thoroughly washed in the solution it was found that even fish with the head attached kept as well as those which were decapitated. Nevertheless, in fish treated with boric acid putrefaction first appears in the gills. A bushel of squeteague prepared in this way was put on the deck of the U. S. Fish Commission schooner *Grampus* on the morning of August 12, 1898, and remained exposed to the sun throughout the day; the next morning, when cut up for bait, they showed no sign of decomposition. On another trip, 1,000 pounds of tile-fish were washed in the solution and then packed in ice, where they remained for two weeks; when unpacked they were in a perfectly fresh condition.

It is evident, then, that this solution retards the initial stages of putrefaction, even at the summer temperatures, and for a sufficient time for the fish to arrive at the market, where they may be iced and kept indefinitely. The solution of boric acid thus used is *not a preservative*, and it is not intended as such, but, like soap, it is an *agent of cleanliness*. As the fish are simply sponged over, the amount of the fluid that remains on a single fish is inconsiderable, and careful analysis fails to show more than the least trace in the flesh. Moreover, Chittenden and Gies have shown that boric acid given in doses, even up to 3 grams per day, has no effect upon proteid metabolism or on the nutrition of the body; that it is not cumulative, but is quickly eliminated from the system, and that it produces no renal complications. Its employment, therefore, as above recommended can have no injurious effect on the consumer.

In preventing the growth of the micro-organisms which cause putrefaction we also eliminate the cause of ptomaine formation. Though some of the ptomaines are exceedingly poisonous, this is not characteristic of all, and it can be safely stated that the greater number of those that have been isolated are of a nonpoisonous nature. The kind of ptomaine formed depends on the kind of micro-organism which produces it, the character of the material acted upon, and the circumstances in which putrefaction takes place. As the ptomaines are only transition products, representing mere temporary stages in the great process of decomposition by which the complex organic molecule is transformed into the simple inorganic state, it is evident that the kind of ptomaine present in putrid fish depends on the stage of putrefaction. Ptomaines formed when putrefaction takes place in free atmosphere will differ from those resulting from putrefaction where atmosphere is excluded. Almost any illness caused from infected food is spoken of as being due to "ptomaine poisoning," but in the majority of cases the poisonous bacterial products are not basic, though their true chemical structure is not understood.

It is worthy of note in this connection that poisonous ptomaines do not begin to appear until about the seventh day of putrefaction, and that they finally disappear if putrefaction is allowed to go on for a considerable time. The toxicity of the ptomaines themselves is not affected by cooking, no matter how thorough this may be. It should also be noted that there are two distinct kinds of poisoning that may arise from the use of fish as food. The first is an intoxication caused by the devouring of meat which has become invaded by ptomaine-producing bacteria. The second is an intoxication brought about by fish not necessarily infected with bacteria, but in which the poisons are *leucomaines* produced by the tissues of the fish and their normal product.

The researches of Meisener, Rosenbach, G. Hauser, F. Jahn, J. von Toder, and others have shown that the blood and flesh of healthy animals are entirely free from bacteria. But the contents of the digestive organs are rich in schizomycetes. Popoff has shown that the digestive canal of a healthy new-born animal is, at the moment of birth, free from bacteria. These, however, subsequently obtain access, principally in the food, and the contents of the bowels become extremely rich in microbes.

If a slaughtered animal is left without being disemboweled, these bacteria will make their way from the alimentary tract through the capillary vessels of the intestinal villi into the arterioles, the alkaline contents of which (rich in albumen) are especially favorable to these acidly putrefactive bacteria, so that the entire carcass quickly begins to undergo decomposition. This early decay may be prevented by the immediate removal of the entire alimentary canal, from esophagus to rectum, and if this precaution is taken the flesh (as already shown) will for a time remain free from putrefactive bacteria. If putrefaction afterwards sets in, it is probably due to bacteria from external sources which have obtained access to the flesh.

The gradual penetration of bacteria by way of the blood vessels into the interior of the flesh has been studied by Trombetta and Gartner. Gartner found them in the external layers only of meat 3 days old, but at the end of 7 days they had penetrated 2 cm. below the surface. It is probable, however, that the flesh of fish is not so resistant to the penetration of bacteria. The sources of this bacterial infection can not be entirely removed, but they can be considerably reduced by cleanly procedure, as above recommended, and attempts may be made to restrict the increase of the microbes and thus arrest the process of decay. The most common remedy is cold, but experiment has shown that the temperature must be kept some degrees below freezing to obtain the best results. This method is used not only in the American and Australian abattoirs, but haddock caught in Norway are cleaned and frozen at —50° C. and then shipped in specially constructed steamers. This freezing of fish does not immediately kill the bacteria present, for Koch has found very many bacteria in fish treated in this way, but it prevents the reproduction of the bacteria for the time being.

Foster has found that certain germs increase in meat stored at moderately low temperatures, though actual putrefaction is not produced by them. Moreover, the researches of Frænkel, Bordoin, Uffreduzzi, Prudden, and Heyroth show us that natural ice may contain both putrefactive and pathogenic bacteria. This fact alone should teach us to look with suspicion upon any meat that has been brought in direct contact with ice of unknown origin, especially when the ice is allowed to melt so that the drip soaks into the flesh.