PRESERVATION OF FISH BY ANTIBIOTICS

by

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ABSTRACT

Reviews and summarizes the earlier work done on use of antibiotics for preservation of fish and current position regarding their use.

INTRODUCTION

From earliest times man's attempts to utilize fishery resources for food have been seriously hampered by the ease with which fish and related edible forms spoil. This is true both for marine and fresh water species and is an especially serious factor in the warmer countries. It was long ago established by fishery scientists that this spoilage is very largely caused by bacteria which grow quite well even at cool temperatures, and much more rapidly at the undesirably high temperatures to which fish are so frequently exposed under tropical conditions. For many years the only available forms of fish preservation were by simple drying, heavy salting or a combination of these. Later, canning became a major method of preservation, especially for the more oily species such as salmon, tuna, herring and sardines. In the last few decades freezing has become a valuable preservation method. However, all these methods of final preservation depend on obtaining fresh fish in good, edible condition. In the older and more industrialized countries this is accomplished to an increasing extent by use of more modern and faster vessels, equipped with icing facilities, refrigerated sea water installations or freezing equipment. For some situations other methods of preservation are still required and are used. One of these is that of use of comparatively trace amounts of certain antibiotics which have so far proven far more effective than other types of chemical preservatives previously employed. For those who are interested there is now abundant information available concerning the research which led to use of antibiotics in

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certain fisheries, and a short list of useful references is therefore appended. For the present purpose it is felt that a discussion of methods of application and results obtained in typical applications will prove more useful.

So far the only two antibiotics which have received official permission for application to fish in several countries are those which are described chemically as chlortetracycline (CTC or Aureomycin) and oxytetracycline (OTC or Terramycin). Special preparations of these antibiotics are sold for preservation of fish under the trade names Acronize and Biostat. Both of these substances have closely similar properties as regards their potential ability to prevent growth of bacteria which cause fish spoilage. Under actual practical conditions CTC is somewhat more effective than OTC, and the reason for this is not known.

In early work it was recognized that it is only by treatment of strictly fresh fish that antibiotics exhibit maximum effectiveness. Treatment of fish which has already lost its initial freshness is not only unethical but is usually rather ineffective.

METHODS OF APPLICATION AND RELATED PROBLEMS

Three general methods of applying antibiotics to fish have been used experimentally or practically, and these are: incorporation of about 5 parts per million (p.p.m.) of the antibiotic in ice; immersion of eviscerated fish in solutions containing 50 to 100 p.p.m. followed by icing them with ordinary antibiotic containing ice; and the addition of the antibiotic to refrigerated sea water. One p.p.m. is equivalent to about 1 ounce of pure, or 5 - 6 ounces of food grade antibiotic in 28 tons of ice.

Three difficulties have been encountered in practical application. These are: lack of even distribution in blocks of ice; inactivating and precipitating effect of hard waters, particularly when used in ice manufacture; and inactivation by residual active chlorine residues in chlorinated water supplies.

When rapidly frozen flake-type of ice is made, the distribution of an antibiotic is no problem. On the other hand, when block ice is prepared in the usual manner, particularly when aeration is used, there is a tendency for dissolved substances such as CTC, and undissolved substances, to concentrate in a core towards the bottom of the block. Experiments showed that this could be avoided by the addition of certain gel-forming "hydrocolloids" to the water containing the antibiotic, and industrial antibiotic ice formulations now contain such substances. Suitable hydrocolloids include food-grade naturally-occurring marine carrageenin and certain alginates, or chemically prepared

carboxymethyl-cellulose. It is unfortunate that when these colloidsare used, hard waters containing magnesium, calcium and iron salts form complexes with, and tend to remove, the antibiotics as insoluble curdy precipitates containing the gel, antibiotic and calcium or magnesium salts. Though this precipitate contains active antibiotic, it is no longer appreciably soluble in water and thus is removed from the sphere of activity as a bacteriostat. So far the only way of overcoming this has been the use of soft or demineralized waters in the preparation of antibiotic ice.

The presence of free chlorine in water supplies intended for use with antibiotics is extremely detrimental for chlorine destroys the tetracycline antibiotics very rapidly. Various methods of removing chlorine have been used experimentally or otherwise, and these include ion exchange or charcoal treatment to remove chlorine, addition of small amounts of reducing agents such as bisulphite, use of so-called "sequestering" agents such as citric acid, and finally by taking advantage of the fact that soluble fish proteins themselves will rapidly react with an inactivate chlorine. This last-named fact can be utilized by immersing some fillets in the water used in a dipping tank prior to adding the antibiotic. In conclusion, it would appear that these obstacles are not insurmountable but must be properly recognized and overcome before antibiotic treatment is undertaken.

EXPERIENCE WITH ANTIBIOTIC ICE

The first industrial trial with CTC was made in 1954 on the west coast of Vancouver Island, British Columbia, at the request of one of the larger fishing companies. About four tons of antibiotic-containing ice were made daily using a small flake-ice type of machine and only one p.p.m. of the antibiotic was added to the ice. Since the water in the particular locality was quite hard, it was found necessary to add 200 p.p.m. of citric acid to stabilize a 60 p.p.m. antibiotic solution which was added at a measured rate to the water used for making the ice.

These trials went on for about two months and hundreds of thousands of pound of salmon were treated. Bacteriological and general organoleptic examinations of the fish, which were carried out under different conditions for up to about 12 days post mortem, indicated that fish stored in the CTC-containing ice remained in good condition for about five days longer than those held in untreated ice. About two years later independent tests carried out in Washington State showed that the keeping quality of salmon was extended for about seven days when ice containing five p.p.m. of the antibiotic was used instead of ordinary ice.

In 1956, again at the request of the fishing industry, trials were undertaken to ascertain the value of ice containing CTC in preserving fish in the British Columbia trawl (ground fish) fishery. A large amount of block ice was prepared using an industrial formulation but only with half the specified concentration, namely 2.5 p.p.m. of the antibiotic. Since in this fishery comparatively low prices are paid for the fish, they are not eviserated, and are by no means as well cared for as are troll-caught salmon. Adequate sampling for quality tests proved impossible in view of the large amounts landed at one time. However, the results again showed a very distinct improvement in the keeping quality of cod, soles or flounders and rock fish held in the treated ice.

About the same time a number of large-scale trials using five p.p.m. of CTC ice were carried out under the direction of the personnel of the Torry Research Station in Aberdeen, Scotland. Cod, haddock,whiting and flat fish were iced at sea with ice containing five p.p.m. of the antibiotic and with normal ice, and were examined on arrival at the ports.

In one report it was stated that, "up to the eighth to tenth day of storage the effects of Aureomycin ice are not really noticeable but from then on become more and more evident as storage time is prolonged". The fish landed were from 5 to 27 days old in the different trials.

Representatives of the fish trade summed up their findings as follows: "There is a definite advantage in using Aureomycin ice, so far as the odour of the fish is concerned, the keeping quality being extended from three to seven days". They also stated that, "On filleting, all species of fish in the Aureomycin ice always give a fresh-looking product, being more translucent and less white and bleached in appearance".

Probably the most extensive commercial trials in all types of fishery have been carried out by the Japanese who have doubtless treated many millions of pounds of fish successfully, and it would be impossible to review even a small fraction of the published data concerning this work. Reports of extensions of keeping quality of up to 13 days were not exceptional. In South Africa the results of tests carried out on a commercial fishing trawler indicated that "fish stored in Aureomycin ice remained edible for approximately seven days longer than those fish stored in ordinary ice which were inedible after 12 days". In the U.S.S.R. extension studies have been made of the use of so-called Biomycin (CTC, food-grade) in preserving ground fish, and quite recently a bulletin describing results of these studies has been published. Other trials with ground fish have been carried out in the United States, India, Germany and French Cameroons.

DIPPING FISH IN ANTIBIOTIC SOLUTIONS BEFORE ICING

Where antibiotic-containing ice is not available it has been found quite satisfactory to dip whole and preferably eviserated fish in sea or fresh water containing about 50 to 100 p.p.m. of CTC and then storing them in ordinary ice. Even better results are obtained if the treated fish are subsequently iced with antibiotic ice. This general method has proved very satisfactory, and in fact has been recommended as the one of choice by a Canadian group who have carried out fairly extensive trials with Atlantic ground fish.

In the writer's experience, this method is no more satisfactory than proper use of antibiotic ice and involves an addition step in handling, which is most undesirable in many cases.

ANTIBIOTIC IN REFRIGERATED SEA WATER

Extensive studies have been undertaken in Canada and Japan concerning use of CTC in refrigerated sea water, and in general it may be stated that from about 1 to 10 p.p.m., when used in refrigerated sea water, causes a definite improvement in keeping quality, but this is not so marked as the keeping quality extension experienced with antibiotic ice. Reason for this is not definitely known, but in view of recent experiments it is thought it may be possibly due to the "chelating" effect of divalent ions such as magnesium which are present in large concentration in the sea water.

TREATMENT OF FILLETS AND STEAKS BY DIPPING

This is one of the most obvious and simple methods of treatment with antibiotics, but fillets and steaks used must be cut from strictly fresh fish. It appears that most of the experimental work and commercial applications with this type of treatment have been carried out on the North American continent. In Canada during the past few years many millions of pounds of fresh fillets have been satisfactorily treated in this way. Immersion of fillets or steaks for from a few seconds to about one minute in a solution containing approximately 10 p.p.m. of CTC is usually advocated, though weaker and somewhat stronger solutions have been used. The dipping solution should be kept cold and treated fillets promptly chilled and refrigerated. If dipping tanks are properly cleaned and use of hard water, or water containing high concentrations of available chlorine avoided, this procedure should prove very effective in prolonging the shelf life of treated fillets.

Experiments on the Canadian Atlantic seaboard have indicated that the keeping quality of white fish fillets can be extended for up to about 10 days provided that treated fillets are strictly fresh, have a low initial bacterial count, and are stored at low enough

temperatures after treatment. This does not mean that it is always desirable to keep fillets for these extended periods (e.g. three weeks) but it does indicate that treatment can be extremely effective. Under most conditions where the storage temperature is between 30 and 32°F., treated fillets should retain excellent quality for 10 days.

PRESERVATION OF SHELLFISH

Some of the very earliest antibiotic experiments showed that with cooked crabmeat very much higher levels of CTC were required to bring about successful preservation than was the case with fish. Subsequent experiments in Florida with headed iced shrimp showed that these shellfish behaved similarly. Though the experimental work with shrimp has not been nearly so extensive as with fish, it appears to be generally agreed that the concentration of CTC in dipping solutions should be between 10 and 30 p.p.m. to bring about successful preservation of raw headed shrimp which are to be stored in ice. Ice containing 10 p.p.m. of the antibiotic also retards bacterial spoilage considerably. Experiments with oysters have also shown that comparatively high concentrations of CTC are required for successful preservation. It is suggested that these high concentrations are required to overcome the chelating or inactivating effect which the rather high levels of magnesium or calcium salts in shellfish may exert.

USE OF ANTIBIOTICS UNDER TROPICAL CONDITIONS

When research on the possible use of antibiotics as fish preservatives was first initiated the goal was to use them in conjunction with icing or other chilling procedures, and no thought was given to their possible value for "emergency" preservation where chilling procedures are not available. Since antibiotics merely extend keeping quality and are thus "transient preservative agents", it is obvious that under conditions where temperatures are high and bacterial spoilage is therefore comparatively rapid, antibiotics will delay spoilage for a much shorter time than at, say, 32°F. (0°C.).

Little actual research appears to have been carried out on this subject. The most detailed study was carried out by Visweswariah et al. (1959) who found that fillets of certain fresh water fish dipped in CTC solutions kept considerably better at 30°C than did untreated fillets. On the other hand, this was not the case when round or eviserated fish were so-treated and stored at this rather high temperature. Georgala (1959) found that pretreatment of South African hake in CTC-ice, or by a CTC dip, caused the fish to keep better even when stored at 59-64°F. Farber (1956) found improved keeping quality of beheaded shrimp stored at 82°F. (27.7°C.) after a 15-minute dip in a solution containing 15 p.p.m. of CTC and 5% NaCl.

From these results it is evident that CTC treatment does retard spoilage of fish which are subsequently held at rather high ambient temperatures. Of course the treatment is only effective in retarding spoilage for hours rather than days.

ANTIBIOTIC RESIDUES IN TREATED FISH AND THEIR ELIMINATION BY COOKING AND CANNING

At the time of writing at least 20 different scientific papers have been published which have dealt with the amounts of CTC which normally occur in treated raw fish flesh, and the effect of heat processing. Very sensitive assay methods capable of detecting less than one part in 10 million of antibiotic have been used in these studies. The antibiotic is usually found in significant concentrations in the skin of iced fish, different investigators having reported between about 0.05 and 3.5 p.p.m. On the other hand, the flesh of fish iced with CTC ice is often free from antibiotic and rarely contains more than one p.p.m. Fillets treated by recommended procedures rarely contain more than half a p.p.m. Since the tetracycline antibiotics, and more particularly CTC, are quite readily inactivated by heat, several cooking procedures will destroy 90 per cent or more of the antibiotic. It is fairly safe to state that after cooking by usual methods, fish treated with antibiotic using prescribed methods will have one part or less or antibiotic in 10 million parts of fish. This concentration is so low that it would take 10 to 20 tons of cooked fish to supply one daily therapeutic 1- or 2- gram dose of CTC. Canning fish completely inactivates CTC.

PUBLIC HEALTH ASPECTS

Cautious individuals have pointed out that use of antibiotics in fish or other foods might be accompanied by sensitization of individuals with a resultant danger of anaphylactic shock; cause an increase in the antibiotic resistance to bacteria in consumers, with attendant loss in response of such individuals to antibiotic therapy; cause cumulative toxidity; favour growth of food-poisoning organisms in treated fish; and cause a change in the normal bacterial content of the human digestive tract with attendant development of unpleasant flavour reactions. That these dangers are more imaginary than real is indicated by experience. Thus, though many hundreds of tons of fish and chicken have been treated with low levels of antibiotic for preservative purposes, so far as the writer is aware none of the above difficulties has materialized in practice. Perhaps we are dealing with the same situation which has been experienced when comparatively low levels of certain antibiotics are fed to young livestocks to promote growth and well-being. In spite of predictions that this practice would be fraught

with many dangers, it cannot be stated that they have as yet materialized. There is also abundant evidence that long-term consumption of comparatively large amounts of tetracycline antibiotics by infants, adults and geriatric patients has not been accompanied by cumulative toxic reactions.

In conclusion, it must be emphasized that it is totally unrealistic to attempt to compare the many undesirable and dangerous situations which have arisen in the use of antibiotics in therapy of human diseases with their use in foods in which the concentrations employed are many thousand times lower. Again, reliable data indicate that the three most common types of food poisoning are repressed rather than favoured by antibiotic treatment of food.

The tetracycline antibiotics, and more particularly CTC, are currently used in number of countries for preserving fish and fish products, but it has proved an impossible task to attempt to determine the extent and nature of all these applications. Regulations under the Food and Drugs Act in Canada were amended in 1956, and again in 1959, to permit use of CTC and OTC on fish products. Treated products must not contain more than five p.p.m. of the antibiotic and its use must be properly declared. A rather similar but less comprehensive permission was granted in 1959 in the United States but does not cover so-called "processed" fish products such as fillets and steaks. Other permissions have been granted in Japan and in Chile. There is evident that there are also considerable applications in Russia and in a number of smaller countries.

If used only on strictly fresh fish with really adequate precautions regarding sanitation and storage temperatures and times, antibiotics could effect considerable improvement in quality of fish, especially of that landed from distant grounds.

Improper use with old fish, or attempts to extend "storage life" so that the consumer does not benefit from the treatment, must be condemned from all stand-points.

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