Inland transport of live cod

by

GUNNAR SUNDNES AND MICHAEL E. U. TAYLOR*

Fiskeridirektoratets Havforskningsinstitutt

Commercial inland transport of live cod was carried out during the period from World War I to World War II between Trondheim and Oslo using railway wagons which were specially equipped for live fish transport. The water was circulated in a closed system in which it was aerated and all undissolved particles were removed by a filtration unit. After World War II the inland transport of live cod was re-established and the "Danish System" was introduced. This used tanks in which there was no circulation, the water being aerated with oxygen. This system has been used in Norway in both railway wagons and road trucks, but like the others this system imposes a time limitation on the transportation. This has been a problem with all the systems used for transportation over distances as far as from Trondheim to Oslo (560 km) or further.

In closed aquaria systems such as those used in the transport of marine fish a number of factors are of importance for the survival of the fish, but the major lethal factors are lack of oxygen, abnormal temperatures, and pH changes. This was discussed by HJORT-HANSEN (1951) in connection with the pre World War II transport of live fish. In the "Danish System" the lethal factor which imposes the time limitation on the duration of transport is the large pH change which occurs in the tanks (SUNDNES 1957). The same pH effect was also found by MCFARLAND and NORRIS (1958). The rate of pH change depends on the degree of crowding of the fish in the water. For commercial use a load of 1 kg of fish per liter of water is necessary. With such a load the self buffering capacity of the seawater is only sufficient to give a maximum transport time of 14 hours (SUNDNES, loc.sit.). This time is the minimum necessary for a journey of 500—600 km on Norwegian roads and leaves no time for delays which may occur during the transport. The obvious approach to this problem is to buffer the seawater to maintain the pH within a suitable range. Work along these lines was first reported by MCFARLAND and NORRIS (loc.sit.) who recommended the use of "tris", 2-amino-2-hydroxymethyl —1.3-propandiol. This buffer is too expensive for commercial use, so we tried to find a suitable cheap substitute.

* Present address: Cawthron Institute, Nelson, New Zealand.

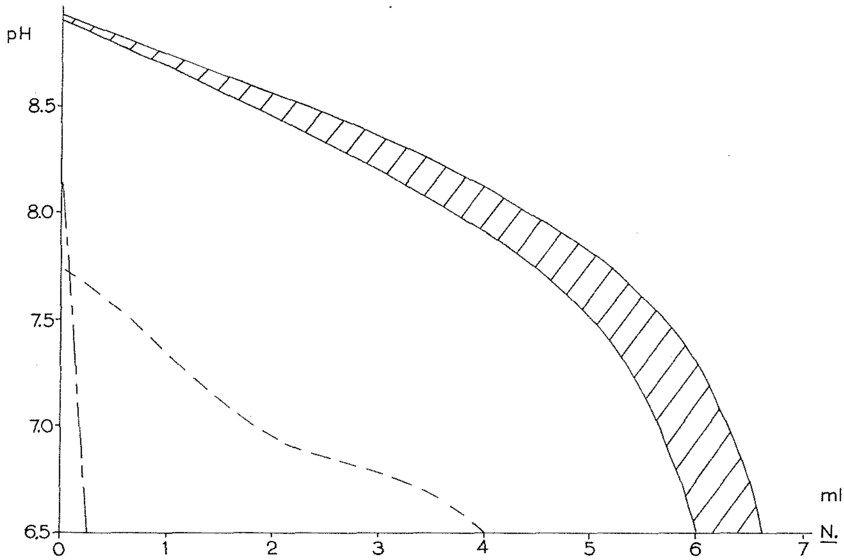

Fig. 1. pH versus ml N hydrochloric acid added to 1 g of buffer dissolved in 100 ml of seawater. — ——— — ——— Buffer curve of seawater. — — — Buffer curves of borax, "tris", glycylglycine and taurine lie within this envelope. /////// Buffer curve of sodium bicarbonate.

Material and methods

We sought a suitable buffer among the naturally occurring salts in the sea. Here the major buffers are the carbonate-bicarbonate and the borate systems.

The carbonate-bicarbonate system is the one augmented by the respiratory products of the fish and has its main buffering action in the pH range intolerable to the fish (Fig. 1). The pH of seawater appears to be maintained at its normal high level of 7.9—8.3 mainly by the borate system which buffers strongly between pH 7.5 and 8.5, the minor fluctuations which occur in seawater being caused by alteration in the balance between the borate and carbonate systems. A major change in this balance such is caused by gross overcrowding and hence enormous increases in the carbon dioxide content leads to marked changes in pH, which may become lethal. Addition of borate should partly restore the balance and retard the pH changes. Of a large number of buffer systems investigated three organic buffers, "tris", taurine, and glycyl glycine, gave very similar buffer curves to borax. From the commercial point of view borax is far cheaper.

The live cod used in the experiments were of ordinary commercial quality with regard to physiological condition. For public health reasons tests were made on the borate content of the treated fish.

The initial transport experiments were made in small aquaria, but later full scale commercial tanks were used. In the full scale experiments the tanks were loaded with 600 kg live cod in 600 liters of seawater and parallel experiments were run with and without borate buffer added. The water was aerated by the "Danish System" using pure oxygen. One gram of buffer mixture containing 2 parts of sodium borate and one part of boric acid was added per liter of seawater in the tank.

Borate analyses

There are restrictions upon chemical additives to fish for human consumption and these also affect fish which have been swimming in seawater with borate added.

Some experiments were therefore performed to get information on the borate content in the fish in seawater containing borate buffer (Gast and Thompson 1958).

In these tests seawater of a much higher borate content was used than in the transport experiments and the time that the fish were kept in the solution was increased. In the transport experiments 1 gram of the buffer was added per liter of seawater and the time that the fish lived in this solution was 1 day (24 hours). In the borate tests we added 4 grams of the buffer per liter of seawater and kept the fish there from 4—6 days. The borate contents of the fish in the tests are shown in Table 1.

Table 1. *Borate content in fish.*

Fish from untreated seawater	Fish from treated seawater	Unwashed fish from treated seawater including adhering salt
0.0013—0.0016 %	0.0015 %	Max 0.009 %

Aquaria test of the borate buffer

Small scale transport experiments were performed in aquaria which were aerated with pure oxygen as in the commercial transport system. Two parallel experiments were run, one with untreated seawater and one with seawater treated with a sodium borate/boric acid buffer. 1 gram of the buffer to 1 liter of water gave a good buffering effect and had no toxic effect on the fish. The "loading density" was 0.7 kg fish/liter of water. This loading is not dense enough for commercial use. The temperature during the experiments was 12—13° C.

Here again we found the typical pH changes (Fig. 2) but in the borate treated water the buffering effect increased the time of the pH

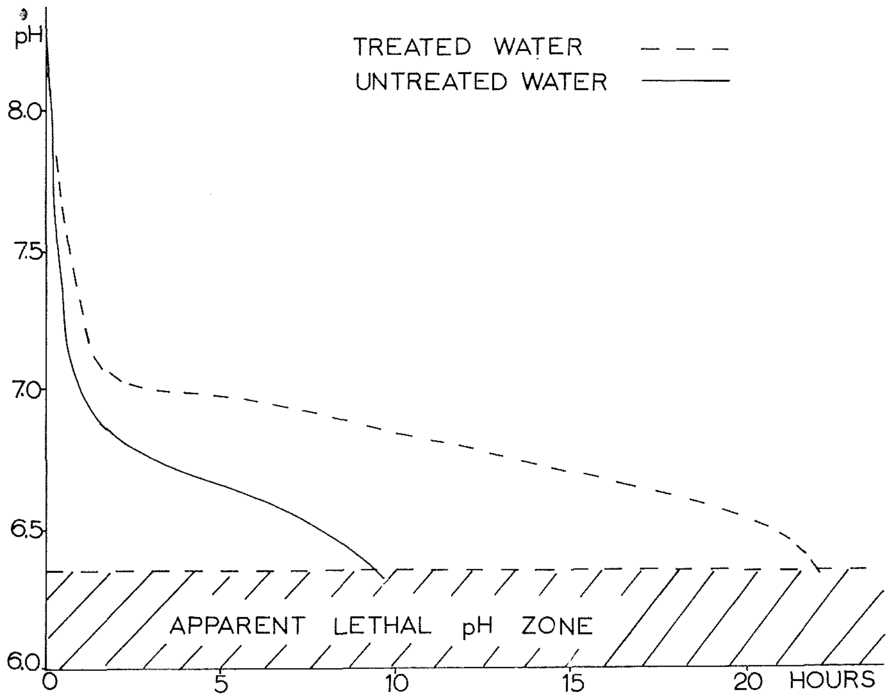

Fig. 2. pH versus time in a tank loaded with 35 kg cod/ 47.5 liter of untreated seawater and a tank loaded with 35 kg cod/ 47.5 liter of borate buffer treated seawater.

change. As can be seen from the figure the "transport time" was doubled. This indicated that full scale experiments would give results in the same direction.

Transport experiments in full scale tanks

These experiments were performed in extremely cold winter conditions, the water temperature was 2—3° C. Two parallel experiments were run, one with seawater only and one with borate buffered seawater. The tanks contained 600 kg of fish in 600 liters of seawater.

In Fig. 3 the pH curves versus time are shown. In the untreated water we see that as in the former experiments (SUNDNES 1957) the maximum transport time was 13—14 hours. By using the borate buffer we see from the curve that another 6 hours can be added to the transport time. This would mean safer transport on a 600 km journey or alternatively other new markets at a distance of 800 km could be reached.

In these heavily loaded tanks we do not get such a good relation-ship between the treated and untreated water as in the aquaria experiments.

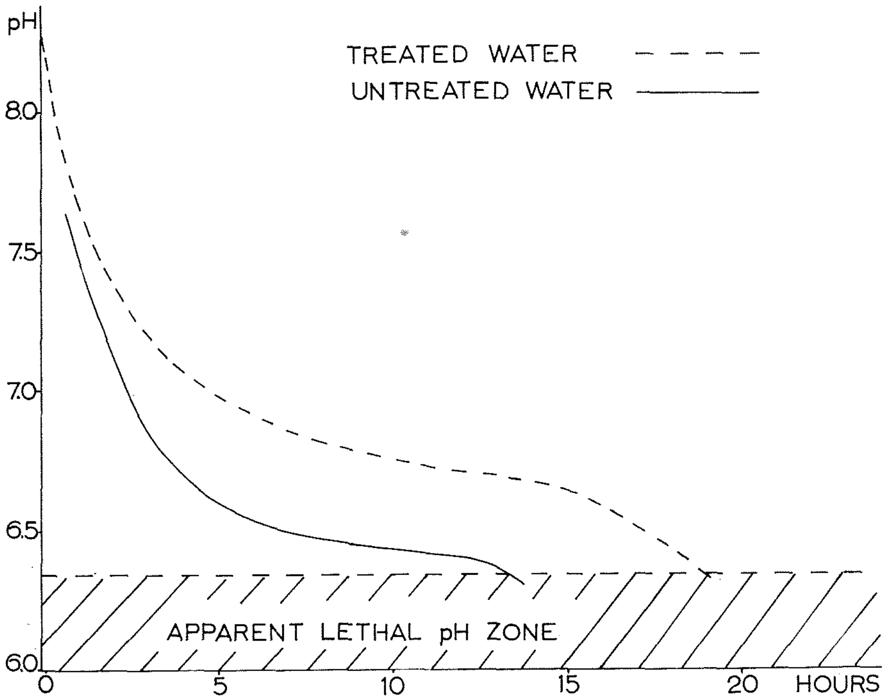

Fig. 3. pH versus time in a tank loaded with 600 kg cod/ 600 liter of untreated seawater and a tank with 600 kg cod/600 liter of borate buffer treated seawater.

This is due to the more dense loading which is absolutely important in commercial use and which diminished the buffer effect as a whole compared with the smaller concentrations in the aquaria experiments. In cases where it was possible to make further buffer additions during the journey however, the transport times could be even further extended.

Comments

Biological experiments with technological application do not always give basic biological and physiological data, but these experiments are based on basic data from which the technological experiments were derived. The aim is to give a technological answer to the biological demand from the fishg. The technical systems do not always give optimum environmental conditions, but because of the excellent regulation mechanism in the fish these can survive if the conditions are not too extreme.

In seawater with 80—90% oxygen saturation a decreasing pH gives a slight decreasing energy metabolism in the fish. When the pH falls below 7.3—7.2 there is a steeper fall in the metabolic rate. In the present transport system this stress on the fish is diminished by aerating the water with pure oxygen. The environment is therefore always supersaturated with respect to oxygen and the metabolism is not affected at higher pH in the same way as in normally oxygenated seawater.

Commercial

Inland transport of live cod is a far cheaper method than wellboat transport. On the other hand the physiological stress on the fish is much higher and it can by no means be compared with wellboat transport in this field. The primary limitation on land transport was the time taken for the pH to change, but this drawback has now been partly overcome by using a borate buffer with a cost of less than 10 Kr. (or £ 0-10-0) per metric ton of live cod.

Acknowledgement

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