REPORT OF EXPERIMENTS ON THE COLD STORAGE OF HERRINGS CARRIED OUT AT NORTH SHIELDS (JUNE AND JULY, 1919)

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The following experiments form part of the general scheme of research undertaken with the object of providing a sound scientific basis for methods of fish preservation and storage.

The bacteriological part of the investigation was first undertaken by the author a year ago and the time has been spent in endeavouring to become acquainted with the peculiarities and characteristics of herring bacteria. There is still a large amount of work to be done in this field before practical experiments on a large scale can be carried out to yield really satisfactory results.

This spring, however, the large cold store at North Shields was put at the disposal of the Food Investigation Board, and it was determined to carry out a few preliminary experiments there.

A store designed for commercial use in the height of the herring season does not lend itself to exact bacteriological investigations. The following report therefore must be considered as dealing with a preliminary survey of a field to be explored more thoroughly later.

SERIES I. DRY-FREEZING AS COMPARED WITH BRINE-FREEZING.

On June 16th at about 6 a.m. a large number of herrings were trawled 14 miles E. by N. of North Shields. They were of various sizes, but mostly small and apparently underfed, the result being that whether gutted or ungutted their keeping qualities were inferior: all damaged fish were discarded. The herrings under experiment were divided into two lots, one lot being gutted and the other not. At about 11.30 a.m. (8·5 hours after capture) half of the gutted and ungutted fish were put into dry cold-storage, being piled up on trays, at a temperature of 18° F. At the same time the others were put into a brine bath at 10° F. for 1·5 hours. The gutted fish[1] were kept separate from the ungutted by means of a partition dividing the large iron basket in which they were placed. After 1·5 hours they were taken out and put into cold storage with the others. Twenty-four hours later, about ten specimens

[1] Compare with Gardiner and Nuttall (19. i. 1918): Frozen Fish, Dry Freezing, Brine Freezing, *Fish Trades Gazette*, London.

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from each lot were removed and placed in trays covered over as protection from the dust and left for another 24 hours at 60°–65° F. They were put where the sun could not shine directly on them. Both dry- and brine-frozen herrings were frozen stiff when taken out of store.

Observations.

(*a*) *Physical examination.* After 24 hours a few of the gutted and ungutted specimens were taken from the dry- and brine-frozen lots and the internal and external appearances very carefully compared. Each day up to the fourth or fifth day they had been exposed to ordinary temperature. The differences were very marked in every way, the brine-frozen being much superior in appearance and keeping qualities. The flesh of the brine-frozen specimens was firm and white after four days and still entirely inoffensive in smell. The flesh of the dry-frozen on the other hand was soft, much greyer in colour and after four days at the same temperature had a very distinct putrefactive smell[1].

(*b*) *Bacteriological examination.* Several Petri dishes of fish agar were inoculated with slime from the gills of the dry- and brine-frozen herrings after they had been 24 hours at ordinary temperatures. On examining and comparing these plates after two or three days' incubation, it was found that in nearly every case the plates from the brine-frozen fish showed very much less growth and fewer kinds of colonies than the dry-frozen ones[2].

This result suggests that either the bacteria are destroyed in larger numbers by the brine method of freezing owing to the lower temperature and the more rapid freezing of the tissues, or that the temperature used in the dry-freezing process was too high to entirely prohibit the slow growth of the bacteria and consequently putrefaction. Unfortunately the cold store was in poor running order at the time and it was impossible to carry out any experiments at a lower temperature than 18° F. whilst the store was often as high as 20°–25° and could never be entirely relied upon.

Taking everything into account, however, it seems there is little doubt that the brine method is the best and most satisfactory, provided the brine tank is kept clean and well filtered. The longer the herrings are kept in it the better, up to four or five hours, so long as the temperature of the brine is never allowed to rise above 10° F.

[1] It should be mentioned that the brine used in the tank for all these experiments was made from fishery salt with the addition of 1·5 % caustic soda and its freezing point was 9° F.

[2] A fuller account of the numerous kinds of bacteria isolated from "dry-stored" and brine-frozen herrings will be given later when more work has been done upon them. At present it will suffice to mention that the bacteria obtained belonged chiefly to the *Proteus*, *B. coli*, *Sarcina*, and Phosphorescent Groups. The *Proteus* Group and Phosphorescent forms were the most prevalent on the whole.

SERIES II. BACTERIOLOGICAL EXAMINATION AND COMPARISON OF HERRINGS BRINE-FROZEN, DRY-FROZEN, AND FRESH.

Samples of brine- and dry-frozen fish were brought out of store and placed on trays with an equal number of perfectly fresh herrings straight from the drifter. These were left away from the sun and wind at a temperature of about 60° F. for two or three days and then bacteriological samples were taken from them and inoculated into fish broth.

OBSERVATIONS.

(*a*) Brine-frozen herrings produced the least amount of bacterial growth.

(*b*) Dry-frozen herrings produced by far the greatest amount of growth.

This experiment, like the first, shows that bacteria do continue to multiply at a temperature of 18°–20° F., whereas the brine-freezing method not only inhibits growth but kills many of the forms of bacteria present before they have time to spore.

SERIES III. APPEARANCE AND KEEPING QUALITIES OF HERRINGS GUTTED BEFORE AND AFTER BRINE-FREEZING AND LEFT UNGUTTED.

Having shown that under the above conditions brine-freezing is the most satisfactory, the following experiments were carried out using this method only. Several gutting experiments were made during the next three weeks under the following headings:

A. Comparison (physical and bacteriological) of frozen herrings gutted before freezing and left ungutted.

B. Comparison (physical and bacteriological) of frozen herrings gutted before freezing and gutted after and exposed for a few days to ordinary temperature.

C. Comparison of herrings gutted in the normal commercial way and gutted by means of searing irons.

D. Bacteriological examination and comparison of herrings gutted and ungutted while still in a frozen state.

A.

Comparison of frozen herrings gutted and ungutted before freezing.

A large number of fish straight off the drifter were placed, gutted and ungutted, in brine and dry-frozen for a week at an uneven temperature between 18° and 25° F. The largest and best looking specimens were then chosen out of this lot, each placed on trays, and left lightly covered from the dust for four days at a temperature of about 60° F.

OBSERVATIONS.

(*a*) *Physical examination.* Altogether about 50 gutted and ungutted fish were examined carefully externally and internally, and comparisons made. Each fish was cut down the length of the spine and opened out like a kipper for inspection. Little difference in external appearance could be detected between gutted and ungutted fish but much difference was apparent internally. Comparisons were best made after the fourth day at ordinary temperature.

The flesh of the ungutted herrings was still fairly white, firm, and in most cases free from any putrid smell. The muscle tissue immediately round the spine was inclined, on the whole, to be more bloodstained than was the case with the gutted ones, but in spite of this the flesh was firmer, whiter and in better condition.

The flesh of the gutted ones, on the other hand, was much yellower and more discoloured although not so bloodstained down the spine. They also had a very strong oily smell which was completely lacking in the ungutted ones, in fact the general appearance and smell of them was not nearly so good.

(*b*) *Bacteriological examination.* A large number of fish-agar Petri dishes were inoculated with samples of muscle from gutted and ungutted herrings after four or five days at ordinary temperature and comparisons were made of the amount of bacterial growth produced. The result was that in about two-thirds of the total number of plates the largest amount of growth came from gutted herrings. In view of the fact that the bacteriological samples were taken with extreme care in every case and the muscle always taken from the same part of the fish, it was proved pretty definitely that more bacteria made their way into the muscle tissues of the gutted than of the ungutted specimens.

This result is due to the gutting process wherein a large amount of gut contents are left behind upon the inner body wall, and, although much of it is washed off in the brine tank, a large number of gut bacteria penetrate the flesh and start putrefaction more quickly than in the case of the ungutted fish, where the bacteria are imprisoned within the gut whose wall has first to be penetrated. Moreover in the case of the gutted fish the inner as well as the outer surface is exposed to foreign contamination of all sorts, particularly after coming out of store, and this certainly hastens putrefaction more than when only the outer surface of the fish is open to infection.

It ought perhaps to be mentioned that the colonies produced on all the plates were chiefly of the same kind, namely moist, round, buff-coloured, fairly large, irregular sized, Gram-negative diplococci. All the plates gave off a very strong smell of ammonia after the third day.

B.

Comparison of frozen herrings gutted before and after freezing.

Several gutted and ungutted brine-frozen herrings were brought out of storage. The ungutted ones were gutted as soon as they were thawed and placed on trays alongside the already gutted ones and left in a clean place at a normal temperature of about 60° F. for a few days. They were examined carefully each day during this period and at the end of four days fish-agar Petri dishes were inoculated with samples of muscle from each kind of herring including ungutted ones as controls.

OBSERVATIONS.

No very definite conclusions could be formed from this experiment. The appearance and keeping qualities of the fish gutted before and after freezing seemed the same. But there is no doubt that gutting after freezing is neither so practical nor so clean, for the gut during the process of freezing becomes brittle and easily broken. It is therefore difficult to remove it entirely and any gut left behind does more harm than if the whole had been left undisturbed.

The amount of bacterial growth produced on the plates was about equal.

C.

Comparison of herrings gutted in the usual way and by means of searing irons.

A dozen or so of the finest and largest herrings were obtained straight off the drifter, they had been dead about seven hours and were in perfect condition. Half of them were immediately gutted in the usual way and the other half gutted by means of hot searing irons, taking great care that in each case after gutting the inner body wall was seared all over to exterminate any gut bacteria which might have been left behind. The two lots were put into the brine tank and frozen for 1·5 hours, then taken out and left in cold storage for 24 hours. The next day they were brought out and placed as usual on trays protected from the dust and left at ordinary temperature for three or four days. At the end of this time they were carefully examined, and physical and bacteriological comparisons made.

OBSERVATIONS.

(*a*) *Physical appearance.* Very little difference was to be detected in the internal and external appearance and keeping properties of the two kinds. On the whole the seared specimens were not in quite such good condition but perhaps this was due to their having been handled more.

(*b*) *Bacteriological examination.* Plates of fish agar were inoculated with pieces of muscle by means of carefully sterilised instruments and comparisons

made of the amount of bacterial growth produced. It was found that the plates inoculated with the seared fish gave the least amount of growth.

This experiment also helps to sustain the contention that the ordinary method of gutting does more harm than good on account of the gut bacteria left behind.

D.

Bacteriological examination and comparison of herrings gutted and ungutted while still in a frozen condition after brine-freezing and cold-storage.

Several fish-agar plates were inoculated with muscle samples from gutted and ungutted herrings immediately they were removed from the cold store and before they were allowed to thaw. The samples were taken from three different lots of fish and put into store for different periods, viz.:

(1) Brine-frozen 1·5 hours, 25 days in cold store;

(2) Brine-frozen 2 hours, 18 days in cold store;

(3) Brine-frozen 4 hours, 11 days in cold store.

Observations.

A large amount of bacterial growth was produced on all the plates inoculated from gutted specimens and much less growth on the plates from ungutted fish. This again leads to the conclusion that putrefaction is slowly going on while the fish are in cold store or at any rate that the bacteria are slowly multiplying. Regarding the effect of the cold store on the growth of the bacteria, the result obtained was doubtful, as one set of experiments showed the longest stored fish to have produced the greater amount of bacterial growth, the other set of experiments showed the reverse. It is possible, however, that the latter result was due to contamination of the plates and unfortunately there was no time to repeat the work.

It had been intended to carry out experiments on non-oily fish for comparison with those on herring above described, but unfortunately during the time available at North Shields only the herring drifters were going to sea, the trawlers being on strike. Fish could have been obtained from other ports but it would not have been fresh enough for the purpose.

It would have been of extreme interest and importance to note if non-oily fish of the same size as herrings, when treated in the same way, gave similar results. It is well known that herrings disintegrate and deteriorate more rapidly than other fish, but whether herrings are the more rapidly attacked by bacterial growth or not remains, in my opinion, to be elucidated. The flesh of the herring is very delicate and therefore more quickly and easily attacked and altered in autolysis, and moreover the oil of the herring very quickly discolours the flesh and becomes rancid. This was particularly noticeable in herrings which had been gutted, thus giving the fish the

appearance of having started to putrefy before this was strictly the case bacteriologically.

CONCLUSIONS.

The general conclusions from the investigations at North Shields are:

(1) That brine-freezing is more satisfactory than dry-freezing at 18° F. both for gutted and for ungutted fish.

(2) That the keeping properties of ungutted frozen fish are superior to those of the gutted ones.

(3) That if herrings are to be gutted it is cleaner and more practical to gut them before freezing.

It is very regrettable that some of the experiments carried out lose much of their value because air temperatures lower than 18° F. were not available. It is very unlikely that any temperature above 14° F. will entirely prohibit the growth of putrefactive fish bacteria. Hence a store run at 18°–20° F. will only serve to retard the process of putrefaction, and, owing to the slow multiplication of bacteria in fish thus stored, the keeping properties of the fish after removal from cold storage will be much inferior to that of freshly caught fish.

It is interesting to note that the gutting of warm-blooded animals before cold-storage has also been found to be unsatisfactory. Miss Pennington gives an account of this in her paper on "The Handling of Dressed Poultry a Thousand Miles from the Market[1]." She states that poultry should not be eviscerated until they have arrived at their destination and are about to be cooked, although she does not give the scientific reason for this recommendation. It was doubtless found, as in our case, that the eviscerating process, although it can be effected in a cleaner and more scientific way than is possible with small fish, gave rise to more rapid bacterial growth and relatively quicker putrefaction. In dealing with poultry it might well be anticipated that the difference in the results obtained by the two methods would be much more marked than was the case with herrings, as the advantage of being able to clear out the intestinal tract by special treatment just before the birds were killed is a very important factor. It is well known of preserved fish that the keeping properties of full gutted specimens are not nearly so good as in specimens whose gut is nearly empty, provided the fish is in otherwise good condition. If some practical method could be found by means of which the fish, instead of being gutted before cold storage, could be thoroughly cleared out, that is, if the intestinal contents could be removed without internal or external injury it might be confidently anticipated that the keeping properties would be still further improved.

Dr Prince of the Canadian Biological Board gives a good account of how sea fish should be cold stored and handled on a large commercial scale, and recommends that all large fish should be gutted before freezing, but that

[1] *Yearbook for* 1912; U.S. Department of Agriculture.

small fish can remain ungutted. It would be interesting to know if he has found by scientific investigation that small fish *only* keep better when cold-stored in an ungutted state. Speaking from a bacteriological point of view and without special experience, the author would anticipate that the same rule would apply to large fish such as cod, salmon, etc., as in the case of small fish like herrings.

GENERAL OBSERVATIONS.

Before the cold storage of herrings or of any other kind of fish, whether stored in an ungutted state or not, can become a really satisfactory proposition, it is absolutely essential that more cleanly methods should be employed. The present methods of handling and packing herrings in our country are open to the strongest criticism from the bacteriological point of view. As the author has personally observed, the fish is handled as it arrives on the quay without any attempt at cleanliness. The fish, if "washed" and gutted before being exported, are dipped quickly into a slimy liquid culture of mixed fish bacteria (so-called clean water), and, in the case of herrings, they are packed with ice or ice and salt in large deep barrels previously soiled with a layer of slime and scales from many thousands of other herrings which have been packed in the same barrels over a period of months or even years! The herrings become thoroughly contaminated in this way and, however fresh, are rendered liable to quick putrefaction; they are afterwards conveyed to various parts of the country, or, if there is a glut, are sent to the local or nearest cold-storage plant which is probably being run at a fluctuating temperature of anything between 20° and 30° F. The final result of all this is, that if the weather is hot, tons of fish arrive at their destination either unfit for food or in a very doubtful state.

The cost of organising proper machinery for preventing this waste of valuable food, would in a short time be repaid tenfold by the enormous saving effected. If at present no practical method can be devised for equipping drifters with their own brine-freezing apparatus, there is at any rate no reason why every fishing port should not have its own cold storage on the quay ready to receive fish directly it is landed and run at a constant temperature of 14° or at most 15° F. If all fish to be exported to other towns were frozen directly after landing by being put into brine tanks in cold store, and then packed for export in well insulated boxes whilst still in a frozen condition, we should not only save the fish landed during a glut but it would arrive at its destination in a condition so much superior to that of the unfrozen fish that the public would not only lose their prejudice against frozen fish but would soon come to prefer it.

Another point is that herrings whether previously frozen or not should never be packed in deep barrels but in shallow cases. When packed carelessly in deep masses they deteriorate much more easily. They get bruised and therefore are more liable to putrefaction. Also the boxes in which they are

packed ought never to be used a second time without being thoroughly swilled out, or better still, scrubbed out with soap and water to which some antiseptic has been added. The bloody slime and scales which stick to the sides of the boxes act as a splendid breeding ground for the bacteria, and should never be allowed to accumulate.

Finally, if fish when gutted cannot be washed in *running* water, they are far best left unwashed altogether. When public opinion demands that these elementary measures of cleanliness should be carried out and effective means of supervision are provided, then, and not until then, will the Fishing Industry benefit fully by the solving of such scientific problems as arise in connection with the cold storage methods of preservation.

I desire to express my best thanks to Mr Wilson at the cold store at North Shields and to the authorities at the School of Medicine, Newcastle, for the kind assistance given during the work. I have also had an able assistant in Mr G. Ll. Rogers.