THE BACTERIOLOGY OF DEHYDRATED FISH

III. OBSERVATIONS AND EXPERIMENTS MADE DURING SMALL-SCALE COMMERCIAL PRODUCTION

By J. M. SHEWAN, Ph.D., B.Sc., F.R.I.C.

Department of Scientific and Industrial Research, Torry Research Station, Aberdeen

(With 1 Figure in the Text)

INTRODUCTION

The present communication completes the series of war-time studies (Shewan, 1945, 1953) on the dehydration of fish, and is concerned with certain aspects of the bacteriology of the small-scale commercial production of dehydrated fish (herring, kipper, fresh and smoked cod), carried out in the summers of 1944 and 1945 by the Ministry of Food in a factory at Aberdeen. During these commercial trials, samples of fish were taken each day for a routine bacterial count and examined for the presence of food-poisoning pathogens. Several other tests were made from time to time in order to elucidate special points, such as the adequacy of the cooking procedure and the occasional incidence of high bacterial counts. The following is a summary and review of these results; with some recommendations for future production.

METHODS

(1) *The drying process.* Reference should be made elsewhere (Cutting, Reay & Shewan—to be published) for a full description of the process and of the plant and its operation. The following brief description merely emphasizes the points of possible bacteriological significance.

The herrings, landed at Fraserburgh in the early morning a few hours after catching, were well iced in boxes and despatched to Aberdeen, arriving at about noon on the same day. In the afternoon of the day of arrival, they were scaled mechanically, headed, split and boned by machine, and kept well iced in boxes until next morning. On Saturday, when double quantities of herrings were received, one half were treated as above and kept well iced until Tuesday morning. The other half were iced in the 'round' condition, and scaled, split, etc., on Monday morning.

The split fish were laid on cooker trays, not more than two deep and autoclaved, usually at 6 lb. pressure, for 20 min. The trolleys with trays of cooked fish were then transferred to a cooling tunnel (air speed 5–6 ft./sec.) and cooled to about 30° C. in 30 min. After cooling, the fish were taken through to the drying room, minced, spread on dryer trays and dried in the kiln in 4 hr. The temperature of the air was maintained at 80° C. for the first hour and a half and thereafter at 70° C. The relative humidity was maintained for the first hour at 22 % and thereafter allowed to fall without control to below 10 %. Normally the dryer was allowed to

run for half an hour with the heat off after drying was considered complete, in order to cool the dried product quickly, the trays were then either unloaded into the holding bin or left in the dryer overnight, and the fish transferred next morning to the holding bin, which was fitted with a heavy lid to keep out dust, vermin, etc.

(2) *Bacteriological methods.* Normally two samples of about 200 g. each of dehydrated herring were taken in the morning either from the dryer trays left in the kiln overnight or from the holding bin. They were placed by means of a large sterile spoon into sterile 500 ml. wide-mouthed bottles with screw-capped metal lids. The subsequent examination was similar to that already described in Part I (Shewan, 1945).

As in the laboratory experiments, whenever pathogens were suspected confirmatory tests were carried out at the Bacteriology Department, Aberdeen University, under the direction of Prof. J. Cruickshank.

In addition, tests were carried out in 1945 at the Pathological Department, University of Cambridge, for the presence of thermophilic anaerobes and for the toxicity of enrichment cultures (inoculations into mice).

RESULTS

The results of these day-to-day analyses may be summarized as follows:

(i) In the 1944 season the viable counts, both at 20 and 37° C. ranged from 'near sterility' to over 120,000 per g. For the first month, only three out of twenty-four samples exceeded the arbitrary limit of 10,000 per g. provisionally fixed for a first-quality product. The counts in question were 18, 20 and 32×10^4 per g. In the second month, ten out of twenty-seven samples exceeded the limit, and in the third month twelve out of twenty-five. In other words, as production proceeded there was a progressive deterioration in the quality of the product from the bacteriological standpoint. Probable reasons for this will be adduced later.

During 1945, the viable counts both at 20 and 37° C. were uniformly low throughout the whole season, the majority being below 100 per g. The highest counts, 2000 (herring at 20° C.) and 2400 (cod at 37° C.) per g., compare very favourably with the peaks of 120,000 per g. which occurred so frequently the previous year. From the figures already given for the 1944 season it will be seen that about 30 % of the viable counts were 10,000 per g. or more compared with 3 % above 1000 per g. in 1945. The lower counts in 1945 can probably be accounted for by two important alterations in the factory technique: namely (1) the use of hypochlorite solutions (containing usually about 2·5 mg available chlorine per 100 ml.), for washing the benches, trays, mincers, floors, etc., every morning and evening before and after each day's run; and (2) the longer drying time—on the average, about 1 hr. longer in order to avoid the presence of 'wet patches'. Experiments showed that by the use of hypochlorite solutions in the above concentrations, the counts at 20° C. on the mincing trays fell from 200 to about 10 per sq.cm. of surface. It is almost certain, however, that the longer drying time had a much more pronounced effect in reducing the count of the final product. This decreased load was, however, offset by slightly more scorched and altered flavours in the dried fish.

(ii) Growth was never found to have occurred on the deoxycholate-citrate agar, and on two occasions in 1944 and twenty in 1945 anaerobic spore bearers were found to be present, these being non-pathogens. In the latter season, thermophilic spore bearers occurred in six out of forty samples tested.

(iii) In double-strength tetrathionate broth growth occurred in fifteen out of the seventy-five samples examined in 1944 and never in 1945. A total of eighteen colonies picked off from the MacConkey re-plates were typed in 1944 and of these four were rods, two being spore bearers, and two non-spore bearers (probably *Proteus* spp.); the rest of the colonies consisted of micrococci and staphylococci (*S. albus*, etc.).

(iv) On MacConkey's medium growth occurred in thirty-five samples in 1944, but no samples were tested in this medium in 1945. High counts at 37° C. were generally, but by no means invariably, accompanied by growth or overgrowth on the MacConkey plates. Most of the lactose-fermenters isolated and typed were cocci.

(v) Good growth almost invariably occurred on the blood agar and alkaline agar plates, and in general high viable counts at 37° C. were accompanied by high counts on the blood agar and alkaline agar plates. Of the 1390 colonies isolated from these media in 1944, some 170 (about 12 %) were found to be coagulase-positive. None of the cocci tested in 1945 was coagulase-positive.

(vi) None of the enrichment cultures inoculated into mice was found to be pathogenic.

(vii) The material was remarkably free from food-poisoning pathogens.

(viii) The viable count at 20 and 37° C. in general bore no relationship to the growth or numbers occurring in the selective media.

It has already been stated that during 1944 the viable counts, which up to about the eighth week had been well below the set limit of 10^4 per g., were thereafter generally above it. The occasional high counts which had occurred previously could possibly be explained as due to preliminary troubles in the cooking technique or to inadequate day to day sampling. Thus, on the one occasion when twenty-five random samples were taken from one day's run, instead of the normal two, the counts ranged from 10^2 to 10^5 both at 20 and 37° C. and all previous values including the high ones, fell within these limits.

As previous experience on the laboratory scale had shown that the most likely reasons for increased bacterial load of the product were inadequate cooking, contamination during mincing and spreading, or holding at favourable moisture-contents and temperatures during drying, each of these points was examined in greater detail. The results showed that the normal cooking conditions 20 min. at 6 lb. steam pressure, reduced the count to near sterility. Immediately after mincing and spreading, however, the counts had considerably increased, but drying again reduced the count in all parts of the dryer to the expected level of 10^2 to 10^3, except at the exhaust end where the values were in the region of 10^4 to 10^5. Subsequent examination made it appear likely that the temperature and humidity conditions at this end of the dryer during the first 3 hr. of drying would enable bacterial growth to take place, and this fact probably accounts for the

higher final counts during the latter part of 1944 when heavier loadings of the dryer also occurred. A reversing of the trucks halfway through the drying period would probably eliminate this effect.

These results were subsequently confirmed during the 1945 season when a bacteriological survey was made of the dehydration process up to the packing stage with results shown in the histogram, Fig. 1. It will be noted that there is a progressive fall in the viable counts (at 20 and 37° C.) after scaling and splitting, an increase after standing overnight in ice, and a marked fall after cooking and cooling. Mincing and spreading on trays increases the count almost to the original values, but drying again reduces the counts very considerably. As already stated the final count was usually very much smaller than during the 1944 season.

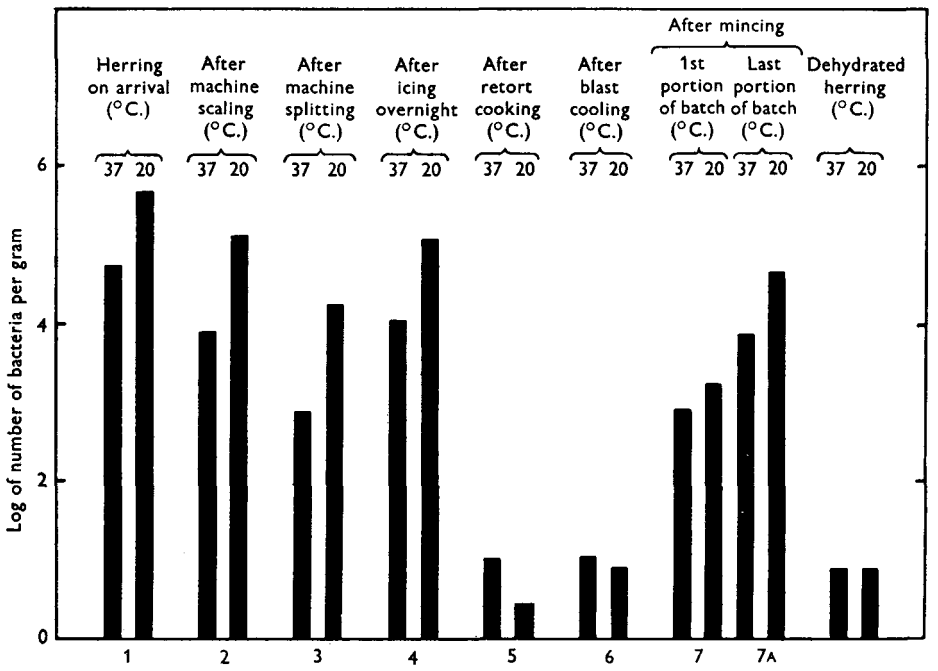

Fig. 1.

RECOMMENDATIONS

As a result of the above experiments as well as a consideration of all the data collected over the two seasons, 1944–45, the following recommendations are suggested for any future commercial production of dehydrated fish, using this particular drying technique.

(1) In the specification for dehydrated fish the maximum permissible viable count at 37° C. may be put at 10^4 micro-organisms per g. of product.

(2) To comply with this requirement the following precautions are necessary:

(*a*) Strict attention must be paid to adequate cooking. Fillets should be evenly spread on the cooking trays, avoiding over-loading. Venting of air from the retort before cooking must be complete so that temperature control may be accurate; temperatures as well as pressure-readings should always be taken. Adequate

cooking with near-sterilization of the fish, is obtained by processing for 20 min. at a steam pressure of 6 lb./sq.in.

(*b*) Clean air should be used for cooling.

(*c*) The loaded trolleys should be introduced into the dryer within 2–3 hr. of the commencement of mincing, in order to avoid bacterial multiplication at this stage.

(*d*) The trolleys should be reversed half-way through the drying period in order to eliminate unevenness of drying.

(*e*) At the end of each day's run, unloading-trays, mincers, receiving vessels, spreading rakes and dryer trays should be kept thoroughly clean by washing with hot water and soda ash, followed by spraying with dilute hypochlorite. In addition, only clean fish boxes and ice barrels should be used at the stage where the fish are iced before processing.

(3) The precautions mentioned above will go far to realize the requirements in the specification that pathogenic organisms be excluded from the product, but special care must also be observed with regard to personal hygiene. In particular, workers on stages of the line following cooking must be specially careful regarding personal hygiene and those known to be suffering from colds, boils, etc., should be relegated to some pre-cooking stage in the line.

(4) The dried product should not be left lying in the open, where it can readily come in contact with vermin (rats, cockroaches, etc.), but should either be canned, or temporarily stored in a closed holding bin.

CONCLUSIONS

1. Day-to-day viable counts on dehydrated fish (herring, kipper, fresh and smoked cod) produced on a small scale commercially during the summer of 1944 showed that the numbers ranged from almost sterility to over 170,000 per g., about one-half of the samples exceeding the arbitrary limit of 10,000 per g. provisionally fixed for a first-class product. By slight alterations in the technique the counts the following year were uniformly low and never went beyond 2400 per g.

2. By the use of selective media it was shown that the dehydrated products were usually free from food-poisoning pathogens. In 1944 about 12% of the colonies isolated from blood-agar and alkaline-agar plates were coagulase positive micrococci; none of these were encountered in 1945.

3. Bacteriological analysis of the whole dehydration process showed that during mincing and spreading on trays after retort cooking, the count could increase almost up to the values on the original raw fish. It seems almost certain that it is also at this stage in the process where the main danger of infection by food-poisoning pathogens, particularly staphylococci, from human handling, may occur.

4. Recommendations for any future commercial production of dehydrated fish are suggested.

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REFERENCES

CUTTING, C. L., REAY, G. A. & SHEWAN, J. M. (1954). The dehydration of fish. *Spec. Rep. Fd Invest. Bd, Lond.* H.M. Stationery Office. (In the Press.)

SHEWAN, J. M. (1945). The bacteriology of dehydrated fish. I Qualitative and quantitative studies of the drying process. *J. Hyg., Camb.*, **44**, 193–209.

SHEWAN, J. M. (1953). The bacteriology of dehydrated fish. II. The effect of storage conditions on the bacterial flora. *J. Hyg., Camb.*, **51**, 347–58.

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