AN EXPERIMENTAL INVESTIGATION OF DRY FISH MANUFACTURE

by

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ABSTRACT

The importance of the dried fish industry in Ceylon and the disadvantages in the local methods of fish curing are discussed. Results of some chemical and bacteriological studies into the preservation of fish by salt are described.

After investigating several methods of curing, the most satisfactory results were obtained by a process involving the removal of guts and gills and the extraction of surface blood by a dip in 10% brine prior to salting in brine maintained at saturation. But salt alone was found to be insufficient to prevent bacterial decomposition especially due to strains of red halophiles, to which however a 0.5% aqueous solution of citric acid proved inhibitory and a 2% solution bactericidal. The viability of common food poisoning pathogens in saturated salt was also decreased and the growth of fungi prevented by this concentration of citric acid. Citric acid besides its bacteridical and fungistatic properties, increased the initial rate of salt penetration, thus shortening the period of time during which the fish is most liable to decompose.

The salt-citric acid protection permits slow air drying without deterioration; apart from its superiority to direct sun-drying, the process is thus made independent of adverse weather conditions.

INTRODUCTION

The manufacture of dried fish in Ceylon was at one time one of the major industries of the Island. Deraniyagala (1953) has traced the main causes that led to its decline, which were the imposition of taxes on the product as well as repressive levies on the salt upon which the industry mainly depended.

Furthermore, the increase in facilities for the storage, transport and distribution of fish favoured the use in its fresh form of a greater proportion of the raw material formerly available for curing. Various attempts to revive the industry such as the abolition of the fish tax, an import duty on dried fish and a scheme for subsidised salt production had limited success.

Nevertheless, even today the dried fish industry is of considerable local importance. Fish, fresh or cured, is a rich source of protein the lack of which has been reported as one of the major nutritional deficiencies in the local diet, especially among the poorer classes (Nicholls and de Silva, 1954). Fresh fish requires special facilities, such as refrigeration, for its transport and storage, which limit its distribution making the cured product the only form of fish available in many areas. Curing fish is also a useful cottage industry as it often supplements the meagre income of fishermen enabling them to make the best use of occasional surpluses and of less popular varieties. Further, several fishing areas such as the islands off the northern coast are out of contact with the fresh fish markets and curing is the only way of utilizing the catch.

In recent years the quantitative increase in the catch of rough (unpopular) fish in the trawler landings (Sivalingam, 1954) also makes the economic utilization of these varieties one of the important problems of local commercial trawling. Curing will partly solve this problem by the conversion of this unmarketable fish into marketable cured fish.

In Ceylon, fish are cured commercially by three main methods. On the hot sands on the beaches of the dry zone, small species are dried whole without any treatment or addition of salt. By its nature this method has a very limited application. The second method uses salt only in a dry cure but relies on a hot sun for drying

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and is thus altogether dependent on the weather. The third method uses "Coraka" (the dried carpels of the fruit of *Garcinia cambogia*, whose active preserving agent seems to be an acid), in a wet cure which gives a type of pickled fish. Methods of preparation and variations in flavour from district to district suggest that this last method is a complicated cure involving fermentation. Other types of cure, such as smoking are done on so small a scale that their output is negligible.

All these methods have remained antiquated and unhygienic, and they result in a product of poor quality, the exposure for sale of which has often acted to the detriment of the entire cured fish industry. Rehabilitation of the industry therefore necessitates not only an improvement in methods of manufacture but also the education of the producer to the recognition of the need for sanitary curing yards, clean utensils and the use of clean salt and undecomposed raw material. The present work was directed towards the solution of one aspect of this problem to the development of a satisfactory commercial curing process for dry-salted fish.

METHODS AND RESULTS

The preparation of dry fish may be divided into three stages: preliminary treatment of raw material, salting and drying:

Preliminary treatment of raw material: Fish are not bled at sea and it seems impractical to do so on board local craft. Large size fish are gutted on board trawlers but even this practice is unfamiliar to most of our fishermen. After the catch is landed, the first operation found necessary is the removal of gut and gills as retention of these organs soon leads to serious decomposition. The head and backbone sections tend to discolour due to exudation of oil which is also liable to turn rancid. It is therefore suggested for good quality fillets that these bony portions be processed separately from the flesh. Our experiments have shown that the presence of scales does not interfere with curing if the fish are filleted nor are incisions necessary for a successful cure. As the flesh was not bled, surface and diffused blood was effectively removed as suggested by Jarvis (1950) by brining for about half an hour in approximately 10% solution of salt.

Salting: In order to simplify the investigation of the salting process, preliminary work was done on cleaned cubes of flesh of catfish *Tachysurus (Netuma) thalassinus* (Ruppell) one of the varieties commonly chosen for curing.

Rubbing dry salt into incised flesh followed by sun-drying proved unsatisfactory as the salting appeared uneven and the exposed flesh attracted flies during the early stages of the cure. Rubbing with dry salt allowing a brine to form with the addition of saturated salt solution to cover the flesh, proved more satisfactory as the brine protected the flesh and ensured even contact with the salt. Peterson and Weerakoon (1951) reported similar observations. The exact strength of the salt solution required was investigated by the immersion of pieces of flesh in brines of varying salinity. The stable solution was found to be a saturated solution containing solid salt. Flesh in 10% and 15% brine decomposed in two days, in 70% brine in 13 days, in 100% brine in 20 days while flesh in saturated brine with solid salt remained stable for over two months. In all solutions fat separated out slowly on the surface and after a few days supported a fungal growth which was skimmed off. The entire solution was changed occasionally when the fungus could not be removed completely from solution.

When flesh is immersed in brine, the moisture in the flesh diffuses into the brine and salt from the brine penetrates into the flesh. To follow this process, analyses of moisture and salt were done on flesh immersed in saturated brine containing solid salt. Before immersion, moisture was 77% and salt negligible. After two days the moisture content fell to 55% and salt increased to 21%. After a week the moisture was still 55% and salt 21%. This ratio represents a 27% w/w salt solution in the flesh, a solution which is saturated. In other experiments the salt content rose above 27% probably due to the absorption effects of the material. Hence within two days salt penetration is complete and the salt is in equilibrium as a saturated solution in the flesh and in the outside liquor. A saturated solution in the flesh is possible only with a brine containing solid salt.

The oil content of the flesh showed a decrease during processing. Raw flesh contained 22% oil calculated on dry weight, which decreased to 11% after salt saturation and to 4% after prolonged air drying.

Drying : Several workers have urged the adoption of air-drying in preference to sun-drying in the manufacture of dried fish. Jarvis (1950) points out that oxidation, rusting and sun-burn set in warm climates if sun-drying is practised. Linton and Wood (1951) have shown that under conditions of rapid drying an impervious salt-protein crust is formed which inhibits further drying. This crust is more likely to form under local conditions of sun-drying. A further disadvantage of sun-drying is its dependence on the weather.

The rate of air-drying is controlled by a number of factors, chiefly humidity, air velocity and temperature. Air-drying under cover is slower than sun-drying and consequently tends to form an encrustation of salt crystals which considerably detracts from the the appearance of the final product. Similar surface deposits have been observed by Cooper and Wood (quoted by Linton and Wood, 1945) during slow air-drying. The formation of these deposits was reduced by an increase in air velocity. The wind velocities at the main curing stations are well within the optimum range recommended by the Torry Research Station (Katugampola, 1950 unpublished). But the figures for humidity (Observatory Annual Reports) are outside the range of 40-50 suggested as optimum by Linton and Wood (1945). Fortunately, the high air velocities and high temperatures at our curing stations compensate for the high local humidity.

Drying on the beaches in covered sheds which permit free circulation of air thus provides sufficiently favourable conditions for a satisfactory cure if the tendency of the flesh to decompose can be controlled during this comparatively slow process.

Control of Bacterial Decomposition: Preservation is basically an interruption of the natural changes which occur in dead tissue. These changes are oxidative, autolytic and bacterial in nature. The preservative action of salt is chiefly due to the withdrawal of moisture from the tissues thus inhibiting the growth and activity of spoilage bacteria. Among other factors involved are the direct action of the salt itself on the tissues, the enzymes and the bacteria (Shewan, 1949; Tressler and Lemon, 1951).

The general bacterial flora of fresh fish caught in our waters include *Micrococcus*, *Achromobacter*, *Flavobacterium*, *Pseudomonas* and various bacillary forms. Most of these are proteolytic and able to cause rapid spoilage changes in the fish muscle, but are generally inhibited by a concentration of approximately 15% salt. However, certain strains of marine bacteria are able to tolerate high concentrations of salt while a few find salt essential for their growth. These latter are called 'Halophiles' and certain pigment producing groups, the 'Red Halophiles', together with certain fungal molds, are the chief agents responsible for deterioration in salted fish.

The control of bacterial reddening and fungal molds has been recognised as one of the major problems of the salt fish industry. (Lobell and Puncochar, 1947). Improvements in processing methods, use of pure sterilised salt and chemical additives to the final product have been suggested as a means of control in this connection. Sterile methods of operation are impractical under local conditions of manufacture and even if it were possible to obtain a sterile final product, exposure during storage and transport will make it liable to subsequent contamination leading to spoilage. Chemical methods of control therefore seem to us the only alternative.

Various chemical additives are in commercial use in different countries. These include boric acid, benzoic acid, sodium or magnesium benzoate and sodium propionate. Their use in the industry is restricted either by their cost or the terms of Food & Drugs Acts. Recently, the use of sorbic acid has been recommended for dry salted fish but it has proved ineffective against red halophiles. (Boyd and Tarr, 1955). In local commercial practice lime juice (citric acid) vinegar (acetic acid) and 'Goraka' (tartaric acid) are used as preservatives. Goraka and vinegar are used to obtain a distinctly flavoured specialty product while citric acid is used mainly for its preservative action. Therefore the use of citric acid as a chemical preservative for dry fish was investigated.

Mixed strains of red halophiles were isolated from salt fish and cultured using the improved Lockhead's Medium (Dussault and La Chanee, 1952). A concentration of 0.5% citric acid incorporated into the medium was sufficient to inhibit the growth of these bacteria.

Concentrations beyond 2% killed them and inhibited almost all types of contaminating fungi.

Survival of bacteria of epidemiological importance was also studied from inoculations made into sterile juice from fish muscle, equal volumes of sterile juice and saturated salt, and similar juice and saturated salt to which had been added 2% citric acid. Within the first two hours all the bacteria were killed by a saturated salt solution containing 2% citric acid, while *B. coli*, *Staph. aureus*, *Strep. faecalis*, *Shigella* and *Salmonella* survived this period of time in fish juice with or without an equal volume of saturated salt. Experiments on the survival of these organisms in salted fish cured in brine containing 2% citric acid gave closely similar results.

Besides its bactericidal and fungistatic properties, citric acid increased the initial rate of salt penetration thus shortening the period of time during which fish is most liable to decompose. In experiments using 5-gram samples, a time lag of 10 minutes was observed between the time taken for the salt concentration to reach the same value (in the 5-15 % range) in two pieces of flesh, one in salt and the other in salt-citric acid. This time lag increased to one hour when samples weighing 50 g. were used. Such an increase becomes significant under conditions conducive to rapid spoilage such as the high temperature prevailing in the tropics. The application of these results in a commercial process was achieved by using as brining solution, a 2% citric acid to which excess salt was added. Although the water from the flesh diffusing into the solution diluted it (by about 50%). sufficient citric acid penetrated into the flesh to attain the inhibitive range of over 2% in the final product. When maximum protection was required, a 2% solution was made available from the start of the cure by adding citric acid equal to 2% of the total water (free and in fish) present in the curing vat. For salting 100 lb. of catfish fillets (obtained from 200 lb. of gutted raw material) it was found necessary to use 4 gallons of water to which were added 35 lb. of salt and 2 lb. (2% of total water) of citric acid. After three days brining (to ensure complete salting) the loss in weight of the fillets was10 lb. After complete air drying the fillets weighed 55 lb. (35% moisture). Heads and bones (approx. 50% of raw material) processed separately yielded 45 lb. of cured product. In commercial practice it should prove possible to re-use the salt-citric acid solution thus making the process more economical. The quantities of salt and citric acid can be reduced if the product requires no protection during the curing process, as may happen under conditions giving a rapid hygienic cure. The minimum amounts would be, salt sufficient to saturate and citric acid equivalent to 2% of the final moisture content in the cured fish.

A rough marketing test on this product in a polythene wrap showed that it appealed more to the educated group (clerks etc.) than to the working class group. The appeal lay primarily in the hygienic appearance of the product while the complaint against it was that it lacked the flavour of dried fish sold in the market. The flavour of market dried fish is largely due to decomposition during curing. As far as the local consumer was concerned, our dried fish was different from the market varieties with which he is familiar and therefore had to be accepted on its own merit as a new product.

DISCUSSION

Based on the experiments described, an improved method for the manufacture of dried fish may be suggested. This method involves brining, air-drying and the use of citric acid as a preservative. The main advantage of the process is the stability of the product during manufacture and storage. Further, as was earlier noted, slow air-drying can be practised only if the product can be protected from spoilage during this period. The incorporation of citric acid provides a process which is independent of weather conditions. This stability and protection are achieved by the increased rate of salt penetration, the bactericidal action of the citric acid in the presence of salt and the preservative action of the salt itself.

The entry of the salt into the flesh is essentially osmotic in nature. When salt penetrates, it causes the precipitation of the proteins and the saturation of the residual water in the cell. Penetration of the salt ceases when a saturation value of 27% w/w is reached inside the cell. Values observed above this ratio in our experiments sugge st that salt is also absorbed by various cell constituents, probably the protein reticulum. Citric acid in common with other

organic acids influences the entry of salts by increasing the permeability of the cell membrane. The time taken for the salt inside the cell to reach a sufficient concentration is thus lessened.

The antibacterial effect of the salt-citric acid is thought to be due to the enhanced activity of the salt in the presence of acids. It has been shown by Nunheimer and Fabian (1940) that in the case of food poisoning *Staphylocci*, the addition of acid reduces by 50% the amount of sodium chloride necessary for germicidal action. It has also been reported that certain groups of bacteria including aerobic and anaerobic spore-bearers are inhibited by concentrations of salt that permit the growth of lactic acid bacteria which produce sufficient lactic acid to supplement the inhibitory action of salt (Jacobs, 1944). The susceptibility to salt in acid is even greater in the case of proteolytic and peptolytic bacteria (Ericson and Fabian, 1942).

In addition to the effect of the hydrogen ion, Nunheimer and Fabian (1940) have reported that the germicidal and antiseptic properties of acids are also due to the un-ionised molecule itself or the anion or both. Hess and Gibbons (1942) in similar observations have noted that citric acid and lactic acid were more effective than acetic acid, although this is a stronger acid. Our experiments also suggest that while acids affect the activity of salt as a preservative, the citrate radicle is also of significance in this connection.

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