STUDIES ON THE CURING AND PRESERVATION OF "CHOODAI"

I. Some Aspects of Dry Salting

By V. Krishna Pillai, A. P. Valsan and M. Rajendranathan Nayar

(Central Marine Fisheries Research Station, Mandapam Camp)

Introduction

The methods adopted in India for the curing of "Choodai" (*Sardinella* spp.) in places where this fish constitutes a major portion of the fishery can be broadly classified into the following, *viz.*, sun-drying, dry-salting, wet-salting and pit-curing. A specialised method known as the 'Colombo method of curing' is practised on a commercial scale in some places on the West Coast (Nicholson, 1930). The choice of the method adopted by the fishermen seems to be based more on convenience rather than on convention. When there is heavy fishing the fishermen invariably resort to sun drying and often spread the fish on the sandy beach itself for drying. The product thus obtained will not be wholesome and may contain, besides sand, other materials from the mud. The fish is sometimes washed in sea-water before being spread for drying, but this practice also is not strictly followed anywhere. In the dry salting and wet salting processes also many such unhygienic practices are often met with. Immediately after catch, the fish is mixed with salt without washing and removal of the slimy matter (the quantity of salt being a matter of approximation in places where Government fish-curing yards are not available) and left in some containers until a good market is found for the fish. No strict time limit is followed for the salting process and as such the products can either be under-salted or over-salted. As regards pit-curing it can be considered to be the most unhygienic method practised in the curing of "Choodai". The fish without washing is mixed with salt, generally in excess, and put in pits lined on the inside with palmyrah leaves, covered with palmyrah leaf mats with earth above and tramped upon to give pressure (Nicholson, 1930). The product obtained is often in a disintegrated form with a viciating smell and mixed with a very high percentage of sand.

It became, therefore, necessary to get a clear idea of the details of the methods practised in the country for the curing of this fish and to study the physical and chemical properties of the products produced in each area by

the different methods and that of the material which goes to the markets for distribution, before starting experimental work in the laboratory.

Samples of cured "Choodai" were accordingly collected from a number of fish-curing yards along the coast and from two of the fish markets which are among the major dry-fish distributing centres in the country. These samples included various local sardines, *Sardinella gibbosa*, *S. fimbriata*, etc., cured by the processes of sun-drying, dry-salting and wet-salting. Unfortunately no representative sample of pit-cured sardines could be obtained during these collection trips and hence was not studied in detail. The samples were analysed for their moisture, salt, total volatile nitrogen and total mineral matter contents.

Ash and salt were estimated by the method recommended by the A.O.A.C. (1950, p. 295) while the total volatile nitrogen was estimated by the method of Beatty and Gibbons (1937). Potassium carbonate was used and the volatile nitrogen was distilled off from the fish sample in a microkjeldahl under reduced pressure, the bases absorbed in 2% boric acid and finally titrated against N/70 sulphuric acid using Tashiro's indicator. The results of analysis of the samples obtained from different centres are tabulated in Table I.

TABLE I

Analyses of cured samples collected from different fish-curing centres in India

Source	Method of Processing	Moisture %	Ash %	NaCl %	T.V.N. mg./100 g.	Sand %
Paramakudi market ..	Sun-dried	28·0	17·6	7·20	165·0	..
Dhanushkodi ..	,,	13·8	15·7	3·00	274·0	2·7
Manapad ..	,,	22·7	10·9	0·75	287·0	1·8
Alleppey	Wet-cured (*Sardinella* sp.)	46·2	19·1	14·25	115·5	..
Cape Comerin ..	Wet-cured (*Sardinella* sp.)	42·2	18·4	12·24	188·2	0·30
Cape Comerin ..	Dry-salted	38·8	19·6	17·20	275·5	..
Bingi	Dry-salted (*S. fimbriata*)	36·4	15·2	14·25	196·6	..

The data presented in the table show that the samples collected from the different regions do not conform to any set standards of quality and purity. They

seem to differ widely in all the essential characteristics. In the sun-dried samples, even though the moisture content is kept low, the total volatile nitrogen remains very high. Added to this the low moisture content has obvious disadvantages in that the fish flesh loses its softness and becomes brittle. When the fish contains a good percentage of salt, as is the case with samples cured by the wet-salting and dry-salting processes, the moisture content is seen to be above 35%. In the sun-dried samples the moisture content varies with samples and the average value remains below 20%, the lowest value recorded being 13·8% for samples collected from Dhanushkodi. The salt content too shows wide degree of variations in the sun-dried samples (between 0·75% and 7·2%). This variation can only be ascribed to the defects in the method adopted by the fishermen in the drying process. Sometimes the fish is dried on the beach sand which is salty and, therefore, is a source of salt to the drying fish. In other cases the fish are spread on platforms used for drying salted fish or the dried material is kept in bags or mats used for keeping salted fish or salt itself. Although the analyses of the fish are done on the flesh devoid of the skeleton, skin and scales, thus avoiding a large percentage of calcium compounds from the material, it is seen that there is considerable difference between the total mineral matter and the salt contents of the samples. This indicates that a lot of silicious matter has accumulated in the sun-dried samples. The total volatile nitrogen content also shows high variations indicating that the samples are of different degrees of spoilage.

In the dry-salted and wet-salted samples the percentage of salt varies considerably as also the moisture content. It is noted that the total volatile nitrogen values are much less than in the sun-dried samples. Almost all the dry-and wet-salted samples were collected fresh from the fish-curing yards while the sun-dried samples were collected mostly from materials stocked for indefinite periods in the fish markets.

Experimental

Sun-drying.—Samples of *Sardinella gibbosa* measuring between 12·0 cm. and 14·0 cm. were collected from Kundugal Point in the Rameswaram Island and brought to the laboratory for experimental curing. The interval between the actual fishing and the arrival at the laboratory usually varies between 6 and 8 hours during which period the fish may undergo a certain amount of spoilage. Therefore it cannot strictly be said that the experiments were conducted on fresh fish.

The samples were thoroughly washed in salt water and then sun-dried by spreading them on palmyrah leaves. In order to study the optimum moisture content desirable for sun-dried sardines a series of experiments were conducted in which the samples after washing were dried for different periods separately to varying moisture content. These were packed in paper and kept for spoilage studies. At regular intervals representative

samples taken from each lot were analysed for their total volatile nitrogen contents, and their general appearance noted. A few investigations were also conducted on the use of common preservatives like sodium nitrite and ammonia in the keeping quality of the sun-dried fish. Table II gives the progressive reduction in the moisture content of the fish in 4 different treatments from one lot [(1) control, (2) treated with 0·02% of sodium nitrite, (3) treated with a light solution (1%) of ammonia and (4) treated with a solution of ammonia containing 0·02% of sodium nitrite] after drying for different periods. The initial moisture and T.V.N. contents of the fish are found to be 78·8% and 62·4 mg./100 g. respectively from an analysis of a representative sample.

TABLE II

Changes in the moisture and T.V.N. values during different periods of drying of sardines

No.	Fresh Fish		After 8 hrs. drying		After 16 hrs. drying		After 24 hrs. drying		After 32 hrs. drying	
	H_2O %	T.V.N. mg./100g.	H_2O %	T.V.N. mg./100 g.	H_2O %	T.V.N. mg./100 g.	H_2O %	T.V.N. mg./100 g	H_2O %	T.V.N. mg./100 g.
1	78·8	62·4	57·3	184·0	40·9	277·7	34·2	325·8	19·2	338·2
2	do	do	60·7	133·2	35·8	189·8	30·3	158·7	18·8	224·0
3	do	do	64·3	184·1	44·0	243·3	26·0	249·3	20·5	264·0
4	do	do	62·7	112·5	46·4	175·1	33·0	198·3	23·3	294·0

In regard to the keeping qualities of the samples having different moisture content it was observed that the samples kept after 8 hours drying with a moisture content of 60% and above showed signs of mould attack by the third day. Samples with a moisture content of above 40% kept well for nearly 6 days while those kept after 24 hours drying (within the course of 3 days) with a moisture content of over 30% kept for over a fortnight before being similarly attacked. This observation was true irrespective of whether the fish was treated with preservatives like sodium nitrite, ammonia, etc., or not. But the samples kept after 32 hours drying with a moisture content below 25% were found to keep well for more than 3 months. By this time almost all the samples including those treated with ammonia and ammonia along with sodium nitrite developed a rancid odour, with the surface of the fish acquiring a deep brown colouration. The sardine samples treated with sodium nitrite (0·02%) were however not affected during this period and these remained in very good condition for over 6 months.

Salting experiments.—In the sun-drying as in the salting processes the fish is used as a whole without gutting. In actual practice this is found to be the only practical process as the sardines of commercial catches are generally small and obtained in very large quantities during the fishing seasons. However this brings in a definite disadvantage in the salting process, quite unlike in the case of big fishes where they are gutted and sometimes sliced before salting, in that the salt penetration into the body of the fish is very slow. As a natural consequence a good deal of time is taken before optimum penetration of salt is effected. During this long period the fish undergoes a fair amount of spoilage.

Proportion of salt to be used.—In order to study the optimum salt concentration required for the efficient curing of sardines the two common species, *viz.*, *S. gibbosa* and *S. albella* were taken up for laboratory trials. These were salted with different proportions of salt (1 : 3; 1 : 4; 1 : 5; 1 : 6; 1 : 7 and 1 : 8 by weight of salt to fish) in triplicate series. The amount of salt penetrated during different periods extending to over 30 hours in each of the treatments was estimated by taking representative samples at periodic intervals and analysing them. The results are tabulated in Tables III and IV.

TABLE III

Rate of penetration of salt under normal condition of salting in S. albella

(NaCl expressed as percentage of original material)

Proportion of salt	Initial	2 hours	8 hours	14 hours	20 hours	26 hours	32 hours	38 hours
1 : 3	0·70	1·64	4·56	6·72	8·07	9·56	10·88	13·75
1 : 4	0·70	1·58	4·68	6·63	7·82	9·18	12·87	13·10
1 : 5	0·94	1·40	4·40	5·85	6·78	9·52	11·70	12·00
1 : 6	0·88	1·35	5·85	6·98	7·60	8·50	10·88	11·85
1 : 7	0·88	1·34	4·20	5·13	5·85	7·90	9·12	9·27
1 : 8	1·05	1·46	3·18	4·40	5·33	7·15	8·00	8·40

In these series of experiments it was observed that the self-brine formed during the salting process was too little even after 24 hours to cover the entire

fish in the salting vessel. As a result of this the top layers of fish always remained exposed resulting in uneven distribution of salt between the different layers.

TABLE IV

Rate of penetration of salt under normal conditions of salting in S. gibbosa

(NaCl expressed as percentage of original material)

Proportion of salt used	Initial	3 hours	9 hours	12 hours	15 hours	20 hours	25 hours	30 hours
1:4	0·78	1·8	5·1	6·3	7·2	8·8	11·9	13·9
1:5	0·78	1·6	4·2	5·6	7·0	8·8	11·7	14·0
1:6	0·78	1·7	4·0	5·7	7·3	8·5	11·4	12·9
1:7	0·78	1·4	4·0	5·3	6·8	7·4	10·5	11·0
1:8	0·78	1·4	4·2	5·0	6·8	7·2	9·3	9·8

To overcome this difficulty experienced in the salting of sardines a series of experiments was conducted to study the effect of applying pressure on the salt penetration and the production of self-brine. The fish in the salting vessel after the addition of the required quantity of salt is covered with a loosely fitting wooden sheet over the centre of which is placed a small weight enough to make the fish press tightly against each other. Pressure can even be applied by manipulation of a mechanical screw arrangement.

It was observed that when pressure is applied, as described above, enough self-brine is formed within 4 to 6 hours of salting to cover the entire fish in the vessel, thus facilitating uniform penetration of salt throughout the different layers. It was also observed that the rate of penetration of salt is quicker in this case and the optimum salt penetration effected in lesser time than in the normal techniques. The rate of penetration of salt at different intervals when pressure is applied to the fish has been worked out in the case of a number of treatments and compared with the corresponding treatment without the application of pressure. The values obtained for the salt content and T.V.N. at various intervals in the different treatments are tabulated in Tables V and VI respectively.

During these experiments it was noticed that uniform penetration of salt can be achieved by even raising the level of the self-brine in the salting

vessel to the top of the fish. The extent of salt penetration obtained with this method when salt was used in the proportion 1 : 6 is seen in Table V. But one disadvantage noticed is the greater time taken for the penetration of salt. When water is added it dissolves most of the salt in the vessel, resulting in the formation of an unsaturated solution from which absorption becomes slow. However, this is found to be a convenient alternative where pressure could not be applied. If saturated brine is used instead of sea-water in making up the level, it may work as satisfactorily as in the case of application of pressure.

TABLE V

Amount of salt penetration during different salting periods under different treatment conditions

Details of treatment	14 hours		24 hours		41 hours	
	Moisture %	Salt %	Moisture %	Salt %	Moisture %	Salt %
1 : 7 unwashed ..	68·9	3·74	61·3	8·43	50·6	12·00
1 : 7 washed	69·9	3·00	64·0	7·93	61·1	9·20
1 : 7 (P) unwashed ..	66·5	6·00	62·0	8·10	62·5	10·30
1 : 7 (P) washed ..	68·8	4·50	63·5	8·26	62·9	10·10
1 : 8 (P) unwashed ..	68·7	5·26	65·3	7·30	67·5	7·60
1 : 8 (P) washed ..	69·6	4·50	66·6	6·45	67·0	7·20
1 : 8 washed	64·7	2·50	63·6	5·40	64·0	7·20
1 : 8 unwashed ..	69·2	2·25	64·8	6·30	63·0	7·80
1 : 5 (P) washed ..	59·3	9·38	57·6	11·00	57·2	12·17
1 : 5 washed	60·4	8·21	57·3	12·28	56·6	12·40
1 : 5 (P) unwashed ..	58·3	10·10	55·5	11·12	53·2	13·82
1 : 5 unwashed ..	60·4	8·15	57·6	10·65	56·9	11·70
1 : 6 (P) washed ..	61·5	9·35	58·7	10·30	58·9	11·70
1 : 6 washed	62·3	7·86	56·2	9·59	55·9	10·98
1 : 6 (P) unwashed ..	62·0	9·00	57·9	9·84	57·8	11·15
1 : 6 unwashed ..	61·8	7·53	61·1	10·40	56·9	11·23
1 : 5 gutted and washed ..	59·4	10·21	53·5	14·15	54·0	15·09
1 : 6 gutted and washed ..	61·5	9·30	58·3	12·75	57·2	13·21
1 : 6 level raised by adding sea-water	69·3	5·21	65·6	7·8	62·2	9·36

P = Pressure.

TABLE VI

Changes in the T.V.N. values of sardines during salting under different experimental conditions

(Values expressed as mg./100 g. original material)

Treatment details	Initial	18 hours	24 hours	41 hours
1 : 7 unwashed	18·56	112	123	173
1 : 7 washed	18·56	115	108	142
1 : 7 (P) unwashed	18·56	94	104	162
1 : 7 (P) washed	18·56	80	85	136
1 : 8 (P) unwashed	18·56	135	128	190
1 : 8 (P) washed	18·56	104	98	166
1 : 8 washed	18·56	118	126	190
1 : 8 unwashed	18·56	139	153	182
1 : 5 (P) washed	13·44	84	..	89
1 : 5 washed	13·44	87	..	98
1 : 5 (P) unwashed	13·44	118	..	168
1 : 5 unwashed	13·44	84	..	112
1 : 6 (P) washed	13·44	78	..	115
1 : 6 washed	13·44	..	..	118
1 : 6 (P) unwashed	13·44	78	..	118
1 : 6 unwashed	13·44	98	..	106
1 : 5 gutted—washed	13·44	49	..	56
1 : 6 gutted—washed	13·44	41	..	47

P = Pressure.

Keeping quality of the salted sardines obtained by the different treatments.— The samples obtained from the various treatments were dried to a moisture content below 40%. In drying of the fish the effect of putting the samples in the direct sun as well as in the shade was studied in detail. The results obtained with one particular series are given in Table VII.

TABLE VII

Effect of drying salted sardines in direct sun as well as in shade

(salting period 41 hours)

Details of treatment	Direct Sun			Shade		
	Moisture %	T.V.N. mg./100 g.	NaCl %	Moisture %	T.V.N. mg./100 g.	NaCl %
1 : 7 unwashed ..	44·68	134·4	15·56	35·72	145·6	18·07
1 : 7 washed ..	39·12	154·0	13·33	36·88	190·4	13·82
1 : 7 (P) washed	35·70	151·2	13·79	31·46	215·6	14·70
1 : 7 (P) unwashed	40·40	84·0	12·27	36·36	162·4	13·11
1 : 8 (P) unwashed	37·52	131·6	14·80	37·98	137·2	14·76
1 : 8 (P) washed	40·88	100·8	11·79	35·22	191·8	12·83
1 : 8 washed ..	39·82	126·0	8·40	36·62	103·6	9·06
1 : 8 unwashed ..	44·70	120·4	13·99	31·14	89·6	17·42

TABLE VIII

Changes in the total volatile nitrogen during storage

(Values expressed as mg. N/100 g. of original material)

Details of treatment	Initial	1 month	3 months
1 : 7 (P) 18 hours	120·4	..	224·0
1 : 7 18 ,, ...	145·6	174·0	224·0
1 : 7 (P) 41 ,, ...	179·2	193·5	249·2
1 : 7 41 ,, ...	126·0	152·0	184·8
1 : 8 (P) 18 ,, ...	218·4	107·2	257·6
1 : 8 18 ,, ...	154·0	172·8	266·0
1 : 8 (P) 41 ,, ...	170·8	200·0	252·0
1 : 8 41 ,, ...	156·8	..	173·0
1 : 8 gutted	107·2	106·0	112·0
1 : 7 ,, ...	86·8	91·0	114·8
1 : 5 (P) 24 hours	137·2	120·8	140·0
1 : 5 24 ,, ...	152·6	..	168·0
1 : 6 (P) 24 ,, ...	135·8	142·3	162·4
1 : 5 : (P) gutted—24 hours ..	116·0	108·0	123·2
1 : 5 ,, 24 ,, ..	92·4	..	100·8
1 : 6 (P) gutted—24 hours ..	106·4	118·2	140·0
1 : 6 ,, 24 ,, ..	96·0	100·2	126·0
1 : 5 (P) 17 hours	95·2	134·4	134·4
1 : 5 17 ,, ...	75·6	145·6	162·0
1 : 5 (P) + $NaNO_2$	98·0	156·8	159·6
1 : 5 ,, ...	92·4	134·4	159·6
1 : 6 (P) 17 hours	89·6	172·4	173·6
1 : 6 $NaNO_2$—17 hours ..	103·6	156·8	179·2
1 : 6 (P) + $NaNO_2$—17 hours ..	123·2	156·8	168·0
1 : 6 + $NaNO_2$—24 hours ..	84·0	140·0	162·4

P=Pressure. The figures given in hours indicate the salting period.

The samples after drying were packed in paper and kept for the study of their keeping qualities. At periodic intervals the total volatile nitrogen and the peroxide values were estimated. The changes in the total volatile nitrogen contents of the samples are given in Table VIII.

TABLE IX

Changes in the peroxide value of the fish during spoilage

(Values expressed as ml. 0·002 N $Na_2S_2O_3$ per gram of fat)

Details of treatments	Initial	1½ months	2 months	2½ months	3 months	4 months
1:4	11·5	..	23·8	..	47·0	51·7
1:3	19·6	..	27·4	..	37·8	44·8
1:4	4·8	..	14·9	24·0	29·0	..
1:4	4·2	..	15·7	22·8	33·1	..
1:5 (P) 18 hours	4·0	..	34·3	..	..	..
1:5 18 ,, ...	4·7	..	32·3	..	..	..
1:6 (P) 18 ,, ...	3·2	..	32·8	..	..	..
1:6 18 ,, ...	5·2	..	..	..	..	..
1:5 (P) 18 ,, —gutted ..	3·7	..	30·2	..	..	..
1:5 18 ,, ,, ..	4·2	..	37·4	..	..	..
1:6 (P) 18 ,, ,, ..	2·8	..	48·8	..	..	..
1:6 18 ,, ,, ..	5·6	..	34·2	..	..	..
1:5 (P) 24 hours	3·7	25·7	37·4	..	..	..
1:5 24 ,, ...	4·5	36·8	43·2	..	..	..
1:5 (P) 24 ,, + $NaNO_2$	4·1	34·2	36·6	..	..	..
1:5 24 ,, ,, ..	4·7	37·0	45·6	..	..	..
1:6 (P) 24 ,, ...	1·2	38·6	42·7	..	..	..
1:6 24 ,, ...	4·9	37·0	45·6	..	..	..
1:6 (P) 24 ,, + $NaNO_2$	7·0	37·0	40·7	..	..	..
1:6 24 ,, ,, ..	5·8	46·0	49·2	..	..	..
1:7 (P) 17 ,, ...	3·4	20·2	..	32·4	..	..
1:7 17 ,, ...	7·2	16·6	..	22·1	..	..
1:7 (P) 41 ,, ...	13·2	25·4	..	30·0	..	..
1:7 41 ,, ...	10·4	29·4	..	41·7	..	..
1:8 (P) 17 hours	18·7	53·4	..	78·2	..	..
1:8 17 ,, ...	21·4	65·8	..	89·7	..	..
1:8 (P) 17 hours	19·2	61·2	..	90·2	..	..
1:8 41 ,, ...	16·2	60·9	..	112·5	..	..
1:8 17 ,, —gutted ..	2·0	13·1	..	24·4	..	..
1:7 17 ,, ,, ..	5·3	17·4	..	26·0	..	..

P=Pressure. The figures given in hours indicate the salting period.

The peroxide values of the samples were estimated by the method of Stansby and Lemon (1941) and expressed as millilitre of 0·002 N sodium thiosulphate per gram of fat. The results obtained on samples cured with

different proportions of salt (1:4; 1:5; 1:6; 1:7 and 1:8 with both gutted and ungutted fish) and kept for a period of three months are tabulated in Table IX.

Discussion of Results

The main defect with the present system of sun-drying of 'Choodai' is that various impurities enter the product during handling. Further, the samples show very high proportions of volatile nitrogenous substances indicating a high degree of spoilage. Table II reveals one of the factors that contribute to this high volatile nitrogen content. The data show that if the drying of the fish during the initial periods (first day) is not effective in bringing down the moisture content to a minimum, the volatile nitrogen content increases appreciably. The moisture content of the fish after the first day's drying on a palmyrah leaf mat was around 60%. This is too high and the samples, when kept overnight at this moisture content, undergo spoilage, and this is reflected in the increased T.V.N. values. It is also seen that after two days drying when the moisture content has come down to 40% the increase in the T.V.N. is not so great (the T.V.N. values to be therefore, converted to moisture-free basis and compared). The only possible remedy, seems to be the quick drying of the fish during the first day so that the moisture content remains below 40%. This may be possible if the fish are dried on cement platforms, which get heated up quickly and this facilitates drying of the fish from the lower surface also. It may be mentioned that when the fish are spread on the beach sand also drying is quicker as the hot sand dries up the fish from below; but the disadvantage is the mixing of the sand and other unwanted materials with the fish.

Tables III and IV indicate the rate of penetration of salt in the two species of sardines, *viz.*, *S. albella* and *S. gibbosa* respectively, for various proportions of salt used, under normal salting conditions. In these experiments care was taken to use the same salt and almost the same size of fish in all the different series. From the tables it may be observed that, as the proportion of salt used in the experiment diminishes, there is a progressive reduction in the amount of salt that gets into the fish within 36 hours. Taking the optimum salt content of salted sardines to be between 15 and 20% of the dry matter as suggested by Venkataraman, Vasavan and Valsan (private communication) it may be observed that, when salt is added in the proportion 1:3 to 1:6, the optimum salt penetration is brought about within 20 to 26 hours in the case of *S. albella* and within 20 hours in the case of *S. gibbosa*. In the case of lower proportions of salt the corresponding time limit seems to be higher. The same tables indicate that higher proportions of

salt are not necessary and have no extra advantage. In these experiments only one layer of fish was used in the salting vessel to ensure uniform penetration of salt throughout. But in practice when a large number of layers of fish are used, as under normal conditions of salting, the rate of penetration is not found to be uniform in the different layers of the fish.

Effect of drying salted sardines in shade.—Sardines cured with two different proportions of salt (1 : 7 and 1 : 8) were divided into two groups one set being dried in the sun and the other in an airy room. It was observed that the former took two days to dry to a moisture content of 40% while the latter took over 4 days. The total volatile nitrogen contents of the samples from the two groups (Table VII) indicate higher values with almost all the samples dried in the shade. Though drying of salted fish is recommended to be carried out in shade in a current of air (Jarvis, 1945) in the case of sardines there is every likelihood of it undergoing slow spoilage when the drying period is extended; and what is required seems to be quick drying since the fish is used as a whole without gutting.

Effect of pressure.—It is thus apparent that for the better curing of sardines at least three important steps have to be taken besides adherence to strict hygienic conditions. These are (1) effecting quick dehydration and salt penetration allowing only the minimum salting period, (2) allowing uniform penetration of salt into the different layers of fish and (3) quick drying of the fish. Table V gives the details of a number of treatments on *S. gibbosa* in which the proportion of salt is varied in experiments with and without the use of pressure. The moisture and salt contents of the samples from each series at various stages of salting are also tabulated in the above table. The effect of gutting the fish and raising the level of the self-brine after 6 hours to the top layer of the fish with sea-water is also studied. The data presented in Table V indicate that, when pressure is applied, there is greater penetration of salt during the initial periods. The water that is squeezed out of the fish dissolves the salt to form a saturated solution which, probably, facilitates quicker penetration of salt into the body of the fish. For example in the series using 1 : 7 and 1 : 8 salt, the NaCl content varies between 2·25 to 3·7% (about 6 to 8% on the dry basis) in 14 hours when pressure is not applied while it varies between 4·5 to 6% (between 12 to 15% on the dry basis) when pressure is applied. A similar variation may be seen with treatments where the proportion of salt is raised to 1 : 5 and 1 : 6. The table also shows that when the fish is gutted the optimum salt penetration is effected more quickly than in the ungutted fish even though pressure is applied in the latter case. However, the minimum salting period with res-

pect to gutted sardines has not been worked out in the present paper. The data further reveal that 14 hours is the maximum period that needs be allowed for the optimum penetration of salt in sardines if pressure is applied from the surface of the fish, when salt is used in the proportion 1 : 6 and 1 : 7. When a lower ratio of salt is used the period of salting has to be extended, but, in any case, the salting period need not be more than 18 hours. In cases where proportions higher than 1 : 6 of salt are used, penetration is seen to be still more quick, but this involves unnecessary wastage of salt as there is always a limit to the amount of salt that the fish can absorb.

The observations made in the preceding paragraphs are confirmed to a very great extent when the values for the total volatile nitrogen content of the fish during the various stages of salting under different conditions are considered (Table VI). When a higher proportion of salt (1 : 5 or 1 : 6) is used the T.V.N. values keep very low usually varying between 20 and 80 mg./100 g. of fish after 18 hours salting during which optimum penetration of salt is attained. Even after 24 hours this continues to be the case. But subsequent values obtained with the same series after 41 hours salting show a substantial increase in the T.V.N., indicating, probably, that further spoilage has taken place during the latter period (between 24 and 41 hours). Unfortunately similar values corresponding to smaller proportions of salt are not available; but it may safely be assumed that the same phenomenon happens in such instances also. All these indicate that the time of salting shall not be increased, in any case, beyond a maximum of 24 hours with respect to ungutted sardines. The data collected indicate that the safest limit is 14 hours or even less during which optimum penetration of salt is effected.

Changes in the T.V.N. values during storage.—The samples obtained from the various treatments were kept for the study of their keeping qualities. The total volatile nitrogen contents of these samples were estimated at periodic intervals and the values are tabulated in Table VIII. It may be seen that when lower proportions of salt were used the samples showed very high initial values for T.V.N. followed by substantial increase during storage; and in many cases the T.V.N. goes above 250 mg./100 g. of fish. When higher proportions of salt are used the initial vlaues of T.V.N. remain well below 100 mg./100 g. excepting in one series where the fish used for the experiment was in the spoiling condition. But in all these cases it is noted that the T.V.N. values do not increase much in the course of 3 months. A similar correlation may be seen between the period of salting and the T.V.N. values. When comparing treatments where only the period of salting is

altered it may be seen that the T.V.N. values of those samples salted or longer time are higher.

Changes in the peroxide value during storage.—To study the decomposition of the fish samples obtained from the different treatments in full, the peroxide value, as an index of oxidation of fat, was also estimated periodically. The results are tabulated in Table IX. The values clearly show that with very high proportions of salt (1 : 3 and 1 : 4) the variation of peroxide value is only within narrow limits during the period of observation. The values do not seem to depend either on the period of salting or on the application of pressure. The values obtained with respect to the treatments where sodium nitrite was used are interesting. They are invariably higher than the corresponding treatments where the preservative was not added. This is in agreement with the observation made by Tarr ('947) that sodium nitrite when used along with sodium chloride promoted fat oxidation.

Summary and Conclusions

The paper deals with the studies conducted on different aspects of curing of sardines. Data have been presented on the changes in the moisture and total volatile nitrogen contents of the fish during drying in the sun for different periods under different experimental conditions. It is observed that in sun-dried sardines the moisture content of the fish has to be kept below 25% in order that it may keep for a sufficiently long period without undergoing spoilage.

The rate of penetration of salt in the case of *S. gibbosa* and *S. albella* at different intervals during dry-salting with different proportions of salt was studied. It is observed that, under normal conditions, optimum salt penetration takes place within 20 hours in the case of the former and 26 hours in the case of the latter when salt is used in the proportion 1 : 3 to 1 : 6. With less amount of salt the period of salting is found to increase. It is further observed that the T.V.N. values of these samples kept for long periods for salting are found to be comparatively very high.

In cases where pressure is applied on the fish while salting, the period required for optimum salt penetration is found to be less, thus minimising the chances of too much spoilage during salting. The water from the fish is squeezed out quickly when pressure is applied and this probably helps in quciker and uniform curing.

The T.V.N. and peroxide values of the stored samples were estimated at monthly intervals. The results indicate that when a sufficiently high proportion of salt, up to 1 : 6 by weight of fresh fish, is used the increase in the T.V.N. values is comparatively small.

Acknowledgement

We are indebted to Dr. N. K. Panikkar, Chief Research Officer, Central Marine Fisheries Research Station, Mandapam Camp, for the keen interest he has taken during the course of this work.

REFERENCES

Beatty, S. A. & Gibbons, N. E. 1937 — Measurement of spoilage in fish. *J. Biol. Bd. Canada*, 3 (1), 77–91.

Jarvis, N. D. 1945 .. Home preservation of fishery products. *U.S. Fish and Wild Life Service, Fish. Leaflet*, 18.

Nicholson, F. A. 1930 .. *The Preservation and Processing of Fish*, Government Press, Madras.

Stansby, M. E. & Lemon. 1941 — Studies on the handling of fresh mackerel. *U.S. Fish and Wild Life Service, Research Report*, Part I, 1–46.

Tarr, H. L. A. 1947 .. Control of rancidity in fish flesh. *J. Fish. Res. Bd., Canada*, 7 (3), 138–54.