THE PROBLEM OF LEACHING IN ICED FISH

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Introduction

Fish is probably the most easily perishable of human food materials, deterioration being caused by bacterial, enzymatic and oxidative changes in its body, all of which set in immediately after the fish dies. Ambient temperatures exert a remarkable influence on the course of these deteriorative changes which are progressively accelerated as the temperatures rise. Tropical countries like ours are most affected in this respect as they have got the highest atmospheric temperature conditions. The maximum time limit up to which fish can keep really fresh at our temperatures is four hours after which distinct spoilage sets in which can be detected organoleptically as well as by the usual chemical indices of spoilage[1]. When once spoilage starts, it is rapid and in the course of nine to twelve hours at room temperature, the fish is rendered almost inedible. The easiest way of delaying or controlling such deteriorative changes is to reduce the temperature of the material as low as possible either by icing or mechanical refrigeration. The former, being cheaper, is most widely resorted to.

Circumstances demanding icing of Fish

The amount of fish which can be distributed in the fresh condition and the area which can be covered in this manner are very much limited. India is a country having a coast line of 4,800 KM, some of the potential fish consuming centres lying as far interior from the fish landing places. In order to make maximum use of our fish landings and to let this cheap source of protein reach as wide a cross section of our population as possible, fish has to be transported in the fresh condition to such places, for which icing is an unavoidable step.

Fish has also to be transported to the processing factories which may be sometimes hundreds of kilometres away from the landing places. Such transportation involves a few hours to a couple of days at times, when due to poor landings, the catch may have to be held over to accumulate sufficient quantity for a truck load. After arriving at the factories, the fish may be either processed immediately or further held over for convenience in both of which cases the material has to be preserved by icing.

In the case of deep sea fishing, vessels which do not have processing facilities on board and which have to stay out in the sea for long periods like a fortnight or three weeks, the catches are generally preserved by a combination of icing and mechanical refrigeration. Hence, icing of fish is an integral part of the fish processing industry, the method generally followed being to mix the cleaned fish intimately with crushed ice, the quantity of which has to be varied depending upon the period of preservation anticipated. Such icing procedures are invariably accompanied by several changes in the composition of the edible fish muscle, some of which are proposed to be reviewed briefly hereunder.

Icing and Chemical Composition

Ice lowers the temperature of the fish to round about its melting point and in doing so retards the proliferation and acti-

TABLE 1. *Proximate composition of edible fish muscle*

Group of fish	T.P. (OWB) % (N×6.25)	W.E.P. % (OWB) (N×6.25)	W.E.N.P.N.: mg N % (OWB)	Free α-amino N: mg N % (OWB)
Elasmobranch	16.72—19.89	2.31—3.48	973—1487	22.6—129.8
Teleosts	16.31—20.45	1.61—4.08	237— 399	9.1— 59 7
Crustacea	14.38—17.53	1.58—4.84	447— 914	197.8—394.2
Mollusca	12.47—15.51	1.25—3.11	188— 790	41.5—349.4
Reptilia	15.33	2.79	402	68.8

T.P.—Total Protein. W.E.P.—Water Extractable Protein.

W.E.N.P.N.—Water Extractable Non-Protein Nitrogen. OWB—Original Weight Basis.

vities of micro-organisms and controls enzymatic and oxidative changes to a large extent. But a very important event that takes place in iced fish and which has passed unnoticed till recently is the leaching out of the water soluble constituents from the fish muscle. The extent to which this phenomenon affects the quality and composition of the iced fish is determined to a large extent by the chemical constitution of the fish muscle, especially their contents of water soluble/extractable constituents. Velankar and Govindan[2] have reported the proximate composition of the edible portion of a large number of food fishes which appears to be interesting in this context and which can be summarised as in Table 1.

As seen from the table, among the different groups maximum proportions of water extractable proteins are encountered in the crustacea with fairly high levels of water extractable non-protein compounds in which latter, this group ranks only second in abundance. As such, maximum extents of leaching losses during ice storage can be reasonably expected to occur in this group.

Leaching Losses

Probably the earliest report of leaching losses of soluble constituents in iced fish was that of Dyer and Dyer[3]. They observed heavy losses of soluble proteins and free amino acids in iced gutted cod. Their observations are summarised in Table 2.

TABLE 2. *Leaching losses in gutted cod iced at 65°F*

	Initial amount present: g N per fish	Per cent leached out after		
		6 days	12 days	15 days
Proteins	39	1.8	3.3	3.8
Amino acids	4.7	28.0	49.0	60.0

It may be pointed out that the amounts of materials leached out are dependent upon the quantity of water made available for the purpose from melting ice and the length of holding in ice. The former depends upon the quantity of ice used and the temperature of storage. The higher the temperature of storage, the higher is the amount of ice melted. Ambient temperatures being the maximum in tropical countries, the problem of leaching losses in iced fish is most serious in such climatic conditions. The results of a comparative study made under Indian conditions in which whole prawns were stored in crushed ice (with contact) as well as the same sealed in thin tin cans and surrounded by crushed ice (Govindan, unpublished data) are summarised in Table 3.

The differences between the values for the sealed and exposed samples of prawns are very striking as seen from the table and indicate the magnitudes of the leaching losses that occur in prawns iced at our temperatures. The losses are found to be

Table 3. *Comparative analytical values of whole prawns stored in and out of contact with ice*

Duration of storage in ice days	Total solids %		Total nitrogen mg % (OWB)		W.E.N. mg % (OWB)		N.P.N. mg % (OWB)	
	Sealed	Exposed	Sealed	Exposed	Sealed	Exposed	Sealed	Exposed
0	22.8	22.8	3358	3358	1445	1445	747	747
2	22.7	19.7	3298	2693	1542	1177	702	547
4	21.5	17.1	3220	2435	1646	980	740	456
6	21.3	16.1	3208	2397	1617	783	723	368
8	21.5	16.7	3200	2483	1625	698	730	290
10	22.3	15.3	3194	2168	1615	590	754	238
12	22.3	15.0	3324	2152	1599	464	752	181
14	22.3	14.7	3394	2159	1592	414	753	125

minimum when the prawns are stored in round condition, more in headless and most in peeled and deveined. The losses also increase with decreasing size of the prawns[4]. This is attributable to the increasing surface areas exposed to the action of melting ice.

Leaching losses occurring in oil sardines (*Sardinella longiceps*) during holding in ice are shown in Table 4 (Govindan, unpublished data).

Table 4. *Leaching losses in oil sardine held in ice*

Duration of storage days	Water soluble nitrogen	Non-protein nitrogen	Free α-amino nitrogen
	(mg N %, moisture and fat free basis)		
0	3053	1675	428.5
1	...	1570	389.8
3	2610	1459	397.3
6	2165	1299	386.7
9	1846	1074	343.0

Leaching and Quality Assessment

The total nitrogen, water soluble nitrogen and non-protein nitrogen values of the prawn muscle which are sufficiently high in the fresh state and which show rapid fall on storage in ice as a result of the combined effect of leaching out of the soluble constituents and simultaneous absorption of moisture by the muscle can be used as indices of quality of the material because particular levels of these values can be associated with definite periods of holding in ice[5]. In a similar manner, free α-amino acid nitrogen and inorganic phosphorus in the muscle also show rapid falls in iced (in contact) prawns. The commonly used indices of quality for fish, viz., trimethylamine, total volatile nitrogen, volatile acid number and total bacterial plate count, all of which show progressive increases as spoilage advances, really decrease during holding in contact with ice. The figures

Table 5. *Chemical changes in prawn muscle stored in contact with ice*

Days of holding in ice	Bact. count (multiply by 10^6)	Volatile acid number	Trimethylamine	Total volatile N	α-amino N	Inorganic phosphorus mg P % OWB
			(mg N % OWB)			
0	1.3	2.3	0	13.5	286	172
3	0.5	1.9	0	11.8	202	120
6	0.4	1.9	0	8.6	138	91
11	0.1	1.1	0	7.3	59	47
17	1.7	0.9	0	3.7	28	38
21	...	5.4	0	5.7	19	36
25	...	7.7	0	6.2	7	38

TABLE 6. *Chemical changes in prawn muscle stored out of contact with ice*

Days of holding in ice	Bact. count (multiply by 10^4)	Volatile acid number	Trimethyl-amine (mg N % OWB)	Total volatile N (mg N % OWB)	∝-amino N (mg N % OWB)	Inorganic phos-phorus mg P % (OWB)
0	4.7	8.6	0	16.7	271	184
1	0.6	8.7	1.7	19.0	276	190
3	0.3	10.7	1.2	21.2	258	170
5	0.4	9.2	1.6	19.4	252	176
7	0.4	9.6	1.2	23.7	275	170
10	2.2	8.1	1.9	24.2	278	154
15	10.9	9.6	2.2	23.8	265	154
19	3.9	9.8	2.0	26.5	270	146
22	20.5	5.3	2.1	27.8	272	145

presented in tables 5 and 6 (Govindan, unpublished data) appear interesting in this context.

A comparison of the figures in the two tables shows the rapid rate of washing out of these products of spoilage. Such rapid falls in free ∝-amino acid nitrogen contents and inorganic phosphorus in prawns stored in contact with ice have been reported earlier by Velankar and Govindan[6]. These observations have been later on confirmed by Susamma *et al*[7] and Nayar *et al*[8].

Similar results obtained in an experiment with a teleost fish, *Synagris japonicus* (Govindan, unpublished data), are shown in Table 7.

Govindan[9], taking advantage of this rapid fall in free ∝-amino acids and soluble nitrogenous constituents in ice-stored prawns, has developed a colour test using ninhydrin. Aqueous extracts of the muscle gave a blue colour with ninhydrin, the

TABLE 7. *Chemical changes in 'Synagris japonicus' stored in contact with ice*

Days of holding in ice	Volatile acid number	Trimethyl-amine (mg N % OWB)	Total volatile N (mg N % OWB)	∝-amino N (mg N % OWB)	Inorganic phos-phorus mg P % (OWB)
0	2.8	1.6	13.2	18.4	219
5	1.7	1.3	9.0	14.4	171
12	1.7	0	4.8	11.6	103
19	0.7	0	4.4	6.8	68
27	6.3	0	1.5	3.8	58

intensity of which decreased as the period of storage increased. The characteristic shrimp flavour was also progressively lost with advancing period of storage in ice due to leaching out of the flavour bearing compounds. After a critical period of storage determined by the size and mode of holding in ice i.e., whole, headless or peeled and deveined, the prawn meat assumes a flat flavour.

Economic Significance of Leaching

At least in the case of prawns stored in ice, leaching out of the soluble nitrogenous constituents has a very significant effect on the economics of the process. The loss in weight due to leaching is made good by absorption of water and in practice, a net increase in weight of the muscle is observed during holding in ice as shown by the figures in Table 8[4].

Even a storage for two days in ice of the peeled meat causes a loss of 15 per cent of the solids which progresses up to 30 per cent with increase in storage period. As this loss is accompanied by a simultaneous increase in weight, the primary processor (at the raw material stage) does not lose; but on the contrary, gains to the extent of the

TABLE 8. *Losses in solids and nitrogen, gain in weight and changes in moisture contents in prawn muscle stored in ice*

Days of holding in ice	Moisture %	Increase in weight %	Solids lost: % of original weight (Original moisture basis)	Total nitrogen in leach water: mg N % (Original weight basis)
0	76.78	...	...	...
2	80.85	14.2	14.95	470
5	83.77	12.4	22.89	685
8	84.05	14.1	26.08	776
12	84.96	11.9	25.41	750
14	84.01	12.6	29.85	929
16	85.04	12.6	28.48	918

increase in weight, even though the food value of the material suffers due to the loss of the protein matter. As the moisture levels in the raw material are not affected to any appreciable extents during the processes of freezing and subsequent frozen storage [10], such losses do not affect the economics of the freezing industry much. But the conditions are far different in the canning and dehydration industries. Irrespective of the initial levels of moisture in the raw material, the first step in the canning process, viz., blanching brings down the moisture contents of the meat to round about 70 per cent. It is this blanched meat that is subsequently filled in cans and processed. Hence, if 100 kg of fresh (uniced) prawn meat (moisture content: 75 per cent) are blanched, we get $\frac{25\times100}{30}$ =83.3 kg of blanched meat of moisture content 70 per cent. If the prawn meat is blanched after a period of holding in ice when the moisture levels have reached 85 per cent, 100 kg of the material will yield only $\frac{15\times100}{30}$ = 50 kg of blanched meat (moisture level: 70 per cent). These figures are based on theoretical calculations and under practical conditions they would be considerably affected by the amounts of soluble materials that go out into the blanching brine. In the dehydration industry also, this phenomenon causes heavy losses, because iced materials with high moisture levels give much smaller yields than fresh materials with lower moisture levels.

Conclusions

Leaching losses in iced fish are heavy especially in those containing higher levels of water extractable protein and non-protein compounds like the groups of crustacea and mollusca. This problem deserves special consideration under our conditions as our country has a flourishing prawn processing industry and meltage of ice is maximum in a tropical country like ours. Taking into consideration the tremendous losses in solids and hence nutritive values during preservation of prawns in ice, the processor must reduce the pre-process storage period in ice to the minimum so as to retain the maximum nutrients and flavour bearing compounds and thereby to maintain high overall quality of the processed product. This is all the more important from the economic point of view especially in the canning and dehydration industries where the yields go down considerably as the period of storage in ice increases. This phenomenon also interferes with the application of the routine and traditional spoilage indices like trimethylamine, total volatile nitrogen, volatile acid number and total bacterial plate counts to such fishes, because the first three constituents being highly miscible with water are easily washed away by melting ice and the micro-organisms are partly destroyed/inactivated by the low temperatures and partly washed away in the above manner. This leaves us with only organoleptic characteristics and some other indices resulting from the phenomenon of leaching for determining the quality of such material.

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