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STUDIES ON MINCED FISH - STORAGE AND QUALITY IMPROVEMENT*

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ABSTRACT

Mince from different fishes was prepared, frozen at —35 to—40°C and stored at —20±1°C and yields were worked out. Shelf life assessments were made on mince from threadfin bream (*Nemipterus japonicus*), lizardfish (*Saurida gracilis*) and catfish (*Tachysurus* sp.). Washing the mince improves the quality as well as shelf life. Washed and unwashed minces have a shelf life respectively of 24 and more than 32 weeks for catfish. Addition of 0.2% clove in the mince prevented the development of rancidity upto 35 weeks and improves the quality.

INTRODUCTION

LARGE quantities of low priced fishes are caught during shrimp trawling. One way of profitably using this fish is to produce minces which can serve as a base for several culinary preparations. Fish mince can be frozen and stored, but the shelf life is short compared to fillets. Minces from many species have dark appearance. The colour of the mince can be improved by washing (Grantham, 1981 ; Rodger *et al.*, 1980 ; Miyauchi *et al.*, 1975 ; Joseph and Perigreen, 1986), which also enhances jellying properties, storage stability and reduces fat degradation. However, development of rancidity is a limiting factor in shelf life. Many spices like clove contain components with antioxident properties. These may be incorporated in the mince to enhance the storage stability as also improve flavour.

Yield of mince, effect of washing mince on its yield, chemical composition and storage stability, effect of cloves on fat stabilisation of mince and shelf life of forzen mince are reported in this paper.

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MATERIALS AND METHODS

Minces were prepared from headed, gutted, split open and washed fresh catfish (*Tachysurus* sp.), ribbonfish (*Trichiurus* spp.), sciaenids (*Johnius* spp.), silverbelly (*Leiognathus* spp.) horse mackerel (*Megalaspis cordyla*), threadfin bream (*Nemipterus japonicus*), lactarius (*Lactarius lactarius*), lizardfish (*Saurida gracillis*) and shark (*Scoliodon sorrakowah*) procured from the local fish market, using a meat picking machine. Minces from threadfin bream, lizardfish and catfish were packed in waxed cartons (500 g) lined inside with 150 gauge polythene sheet and quick frozen in a contact plate freezer at —35 to —40°C.

In another series of studies, minces from catfish, threadfin bream and lizardfish were washed in chilled water at 2 to 5°C. For every kg of fish mince 5 litres of water were used. The fish mince kept in chilled water for 15 min with occasional stirring was filtered through anylon net and pressed to remove excess water and packed and frozen as above.

Powdered clove (2g/kg minced fish) was mixed thoroughly with mince from horse mackerel and packed and frozen as above. All samples were stored at —20±1°C.

TABLE 1. *Percentage yield of fish mince and its proximate composition*

Fish	% yield	Chemical composition			
		Moisture	Fat	Protein	Ash
Catfish ..	34	78.2	1.4	17.8	1. 1
Ribbonfish ..	50	80.1	0.91	19.9	0.89
Sciaenids ..	51	75.75	3.25	19.5	1.25
Silverbelly ..	40	77.2	2.10	20.1	1.12
Horse mackerel ..	43	76.48	2.82	20.25	0.95
Threadfin bream ..	46	80.24	0.72	18.13	0.85
Lactarius ..	49	76.88	1.61	19.3	1.45
Lizardfish ..	50	79.5	0.92	18.6	1.21

The samples were drawn periodically for analysis. The frozen samples were sealed in a polythene bag and kept in running water for 60 to 70 min for thawing and drained over a wire mesh for 10 min and analysed. Moisture, fat, total nitrogen, non-protein nitrogen (NPN) and ash were determined by the method of AOAC (1975) and peroxide value by the method of Lea (1952). The changes in extractability of protein were followed by the method of Dyer *et al.* (1950). Total volatile basic nitrogen (TVBN) was determined by the method of Conway (1947). The method of Tarladgis *et al.* (1960) was used for the determination of thiobarbituric acid (TBA) value. Organoleptic studies were conducted as described by Joseph and Perigreen 1(983).

RESULTS AND DISCUSSION

Table 1 gives the yields of mince from different fishes and their proximate composition. Except for catfish the yield varied from 40-50%. The moisture varied with fat and the percentage of protein was about 18-20.

The changes in PV during frozen storage of fish mince from catfish, threadfin bream and lizardfish are given in Table 2. In general the peroxide values of stored mince increased rapidly in the early stages and the increase was more in catfish, while it was the least in threadfin bream. The PV of minced catfish reached 38.9 meg/1000 gm by 34 weeks storage, while it was 28.0 and 30.2 meg/1000 gm for threadfin

TABLE 2. *Changes in PV of fish mince from threadfin bream, lizardfish and catfish during frozen storage*

No. of weeks	PV meg/1000 g fat		
	Catfish	Threadfin bream	Lizardfish
0 ..	9.8	7.8	8.5
4 ..	14.2	12.5	13.2
10 ..	23.4	13.4	17.9
16 ..	27.9	18.1	16.2
22 ..	35.8	23.5	21.8
28 ..	39.2	26.4	29.3
34 ..	38.9	28.0	30.2

TABLE 3. *Changes in protein extractability during frozen storage*

No. of weeks	SSN % to TN		
	Catfish	Threadfin bream	Lizardfish
0 ..	72.8	74.8	69.3
4 ..	60.0	58.8	41.8
10 ..	42.8	49.7	34.2
16 ..	36.4	43.5	32.8
22 ..	34.2	40.9	31.9
28 ..	33.5	38.2	29.8
34 ..	35.9	37.3	31.2

bream and lizardfish respectively. As seen from the results the fat stability is low in frozen fish mince. It is reported that fish mince contains high levels of long chain polyunsaturates (Ackman *et al.*, 1976) and they are highly susceptible to enzyme hydrolysis and non-enzyme oxidation, because the mincing process accelerates these reactions through physical surface effects (Lall *et al.*, 1975) and through the dispersion of catalytic contaminants (Howgate, 1976 ; Silberstein and Lillard, 1978).

The changes in protein extractability of minces during frozen storage are given in Table 3. The decrease in protein extractability varied considerably with the species of fish. The mince from lizardfish showed a rapid decrease in extractability which reached the lowest value by 10 to 14 weeks. The catfish showed a gradual decrease in the extractability though it was more in the early stages of storage. The protein from minced threadfin bream was more stable against protein insolubilization in salt solution. The high rate of protein

TABLE 4. *Average sensory score of fish mince during frozen storage*

No. of weeks	Sensory score Catfish	Threadfin bream	Lizardfish
0 ..	7.5	8.0	8.0
4 ..	6.4	6.5	6.0
10 ..	5.5	5.0	5.3
16 ..	4.6	4.6	4.4
22 ..	4.1	4.8	4.2
28 ..	3.0	4.2	3.7
34 ..	—	3.7	3.8

insolubilization of minces might be attributed to the accelerated deconformation, aggregation and cross linking of myofibrillar protein of the frozen stored fish mince (Laird *et al.*, 1980).

The average sensory score obtained by a trained taste panel is given in Table 4. Minced catfish is judged to have a storage life of 22 weeks. By this time it became rancid, the intensity of which increased on further storage. Fish mince from threadfin bream was found acceptable for more than 28 weeks. There was a decrease in textural qualities and the product became fibrous with poor water holding capacity in 22 weeks. Minced lizardfish had a shelf life of 22 weeks as shown by sensory studies. There was no detectable rancidity in the product. Fibrosity, granularity and chewiness increased on frozen storage of all the samples, but the rate and extent of these changes varied with species.

Certain properties like jellying, colour, storage stability, etc. were increased by washing the mince, but significant solid loss was reported. Table 5 gives an account of the

TABLE 5. *Weight loss on washing of minces from different species*

Fish	% weight loss	Remarks
Catfish ..	19	Colour is improved.
Threadfin bream	22	Colour pinkish white, no significant improvement
Shark ..	28	Muscle becomes fibrous.
Lizardfish ..	23	Slight improvement in colour, Muscle becomes fibrous.

loss of solids during washing the minces and their sensory changes. Minced shark showed the maximum loss (28%) while it was around 20% for the other fishes. Significant improvement of the colour was noticed on washing the minced catfish, probably due to loss of blood and coloured pigments. Colour did not improve in threadfin bream. Minced shark and lizardfish became fibrous and a little improvement in colour of minced lizardfish was noticed.

TABLE 6. *Effect of washing on certain chemicals component*

Fish		Moisture %		Fat		NPN		TVBN	
		BW	AW	BW	AW	BW	AW	BW	AW
Catfish	..	78.2	81.1	1.4	0.8	340	150	12.0	3.5
Threadfin bream	..	80.3	83.5	0.72	0.6	318	162	10.9	3.2
Lizardfish	..	79.5	82.3	1.18	0.87	325	146	8.6	2.9

BW=Before Washing ; AW=After Washing

The changes in moisture, fat, NPN and TVBN of washed mince are given in Table 6. There was about 3% increase of moisture in minced catfish, threadfin bream and lizardfish. A reduction in the amount of fat was noticed in all the samples. 43% loss of fat occurred in catfish while it was 24% in lizardfish and 14% in threadfin bream. Significant decrease in NPN, TVBN were found in all the samples ranging from 50-55%, while the loss in TVBN was 65-70%. The washed meat has a bland taste perhaps due to the loss of flavour bearing components.

As seen from Table 7 washing improved the shelf life and it was more pronounced with catfish than threadfin bream. Significant loss of soluble components like enzymes and fat may be the reasons for enhancing the shelf life. Similar observations were made by Shimizu and Fujita (1985) who reported that when minces were washed, stability to freezing were increased although the extent of the increase was different with fish species and storage period.

TABLE 7. *Average sensory score of washed samples during frozen storage*

Weeks		Catfish Control	Catfish Washed	Threadfin bream Control	Threadfin bream Washed
0	..	7.0	7.5	7.5	7.0
8	..	5.5	6.5	5.0	5.5
16	..	4.5	6.0	4.5	5.0
24	..	3.9	5.2	4.6	4.8
32	..	3.0	4.5	4.0	4.4

Table 8 shows the effect of cloves on PV, TBA and sensory score of minced horse

TABLE 8. *Changes in the chemical properties and sensory scores of spiced mince and control prepared from horse mackerel during storage at —20°C*

Weeks		PV		TBA		Sensory scores	
		C	S	C	S	C	S
0	..	12.8	—	1.02	—	7.2± 0.9	—
3	..	22.7	13.8	2.92	0.554	5.5± 0.8	7.0± 1.12
21	..	47.3	21.2	3.2	0.48	4.1 ±0.65	6.4± 0.5
35	..	58.2	27.9	2.80	0.67	3.3±0.92	4.8± 1.2

C=Control ; S=Spiced

mackerel treated in comparison with control. Considerable difference in PV and TBA were noticed between spiced mince and control. After 35 weeks' storage the PV were 58.2 and 27.9 and TBA values 2.8 and 0.67 for control and spiced mince respectively. A corresponding improvement in the sensory properties was also noticed. The spiced mince did not become rancid in 35 weeks, while the control became rancid in 21 weeks. Cloves contain high amount of eugenol which is a good antioxidant. Besides antioxidants a number of flavour enhancing components are present in cloves. These might improve the organoleptic acceptability of the product. Thus addition of cloves was found to reduce rancidity and enhance organoleptic acceptability.

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A METHOD OF CORRECTION FOR DIEL EFFECTS ON OBSERVATIONS, IN ASSESSING THE ANNUAL VARIATIONS OF A PARAMETER*

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ABSTRACT

The ship-survey data, especially those controlled by solar heating during day and nocturnal cooling during night, necessitate diel corrections in their observed values for accurate seasonal variations. Based on harmonic analysis, an analytic method is envisaged and worked out for seasono-diel variations applicable for assessing more accurately the annual variations of a parameter in the Indian region.

INTRODUCTION

CERTAIN parameters in oceanography, meteorology and marine biology, especially those which are governed by solar radiation and nocturnal cooling, like the sea surface temperature, barometric pressure and so on exhibit clearly systematic variations in a day (diel variations) superimposed on their sesonal variations. As practised by India Meteorological Department, if observations are made in fixed hour of the day, it is easy to get the mean value of the parameter for the month and henceforth its seasonal (month to month) variations. However, such monthly mean value does not take care of the entire diurnal variations. Information based on ship-survey is much more restricted from the synoptic point of view, as it is impossible to vist a particular station or region always at a particular hour of the day in the regular surveys by research vessels. It is inevitable to involve different hours of the day in such data of observations over a year.

As the curve of seasonal variations of the parameter proceeds from month to month in its annual march, the dirunal oscillations bring changes in the actual observations made. Therefore observations conducted at different times of the day require correction for the study of their seasonal variations, the amount of correction being dependent upon the actual time (hr) of observing the parameter.

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TECHNIQUE OF CORRECTION FOR DIEL OSCILLATIONS

Let a parameter Y in a month T be represented by Y_T (monthly mean) in its annual march and Y_t the diel fluctuation value at the hour t of the day and $Y_{T,t}$ the actual observation at the hour t in the same month T. Then,

$$Y_{T,t} = Y_T + Y_t \text{ or}$$
$$Y_{T,t} - Y_t = Y_T \quad (1)$$

Therefore $-Y_t$ is the required diel correction to be applied to the actual observation $Y_{T,t}$ in order to get the annual march Y_T of the parameter Y.

Y_T is constant for a given value of T and Y_t oscillates on Y_T with a duration of 24 hrs.

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The mean diel cycle for each month is prepared by pooling up the data of the month taken at different hours. Of all the diel oscillations, the diurnal and semidiurnal waves are important. Therefore, eq. 1 can be represented as

$$Y_{T,t} - \left(+ \sum_{p=1}^{2} a_p \cos p \frac{2\pi t}{24} + \sum_{p=1}^{2} b_p \sin p \frac{2\pi t}{24} \right) = Y_T \quad (2)$$

where a and b are harmonic coefficients. Over 24 hrs, the diel oscillations will get nullified. It is therefore clear that

$$Y_T = \frac{1}{24} \sum_{t=0}^{23} (Y_{T,t}) \quad (3)$$

which is the mean value of $Y_{T,t}$ for the 24 hrs of the day.

16-*ordinate scheme for diel variations*

The hour-wise mean value of the parameter for 24 hrs is prepared for each month by pooling up the available data of observations of the parameters for the month. The primary period (24 hr) is divided into 16 equal parts starting from t=0 (mid night) and the corresponding 16 ordinates are chosen. Let the ordinates in the order be Y_0, Y_1, Y_2,.... Y_{14} and Y_{15}. As the 16-ordinate scheme brings out the diurnal wave and semi-diurnal wave effectively from the diel variations, it is the best suited for treatment of the diel variations (Murty, 1987). The scheme is as follows :

Arrange the Y series as

	Y_0	Y_1	Y_2	Y_3	Y_4	Y_5	Y_6	Y_7	Y_8
		Y_{15}	Y_{14}	Y_{13}	Y_{12}	Y_{11}	Y_{10}	Y_9	
Sum	P_0	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8
Diff.		q_1	q_2	q_3	q_4	q_5	q_6	q_7	

Rearrange p and q series as

p_0	p_1	p_2	p_3	p_4		q_1	q_2	q_3	q_4
p_8	p_7	p_6	p_5			q_7	q_6	q_5	
r_0	r_1	r_2	r_3	r_4	Sum	m_0	m_1	m_2	m_3
s_0	s_1	s_2	s_3		Diff.	n_0	n_1	n_2	

and the r series as

	r_0	r_1	r_2
	r_4	r_3	
Sum	v_0	v_1	v_2
Diff.	w_0	w_1	

Tabulate the results as follows :—

TABLE 1. *Summary of coefficients for diel variations*

Multiplier					
0.383	..	s_3		m_0	
0.707	..	s_2	w_1	m_1	n_0+n_2
0.924	..	s_1		m_2	
1	..	s_0	w_0	m_3	n_1
sum =	..	$8a_1$	$8a_2$	$8b_1$	$8b_2$

If each set of the diurnal waves and semidiurnal waves for the twelve months of the year show reasonable closeness in their respective amplitudes and phases which could be determined by the closeness of each of the corresponding coefficients a_1, a_2, b_1 and b_2 for the twelve months, then the diel correction for the entire year can be represented by a single expression. In case there is significant disparity in the values of the diel coefficients from month to month, it is required to consider the diel oscillation for each month or at least for each season. In either case, the parameter $Y_{T,t}$ observed at time t (hr) in the month T would become, after diel correction, Y_T as expressed by equation 2.

SEASONAL VARIATIONS

As Y_T is the mean value of the parameter for the month, its variations from month to month are considered for the study of seasonal variations of the parameter. From the climatic view-point of the waters around India, the period of the year may be broadly divided into three main seasons, namely, the monsoon season from June to September, the winter season from October to January followed by the hot-weather season from February to May. The annual variations of Y_T may be represented by the first three harmonics which are determinable from the variations of Y_T during the the year.

$$\therefore \; Y_T = A_0 + \sum_{n=1}^{3} A_n \cos n \frac{2\pi T}{12} + \sum_{n=1}^{3} B_n \sin n \frac{2\pi T}{12} \qquad (4)$$

where A_1, A_2, A_3, B_1, B_2 and B_3 are coefficients of harmonics. T is in months (T=0 or 12 refers to December so that the digital counting of months follows the conventional rule)

$$A_0 = \frac{1}{12} \sum_{T=0}^{11} Y_T \qquad (5)$$

which is the annual mean of Y_T for the 12 months of the year.

12-ordinate scheme for seasonal variations

The 12 values of Y_T, each representing a particular month of the year, constitute the 12 ordinates required for the scheme to express the seasonal variations in the form of the first three harmonics.

Arrange the twelve Y_T values as

	Y_0	Y_1	Y_2	Y_3	Y_4	Y_5
	Y_6	Y_7	Y_8	Y_9	Y_{10}	Y_{11}
Sum	p_0	p_1	p_2	p_3	p_4	p_5
Diff.	q_0	q_1	q_2	q_3	q_4	q_5

Arrange p series as

	p_0	p_1	p_2
	p_3	p_4	p_5
Diff.	r_0	r_1	r_2

Arrange q series as

	q_0	q_1	q_2
	q_3	q_4	q_5
Sum	s_0	s_1	s_2
Diff.	t_0	t_1	t_2

Rearrange r, s and t series as

	r_0	r_1	s_0	s_1	t_0	t_1
		r_2		s_2		t_2
Sum	u_0	u_1	w_0	w_1	m_0	m_1
Diff.		v_1		l_1		n_1

Arrange the terms in the following Table 2.

TABLE 2. *Summary of coefficients for seasonal variations*

Multiplier						
0.5	$-l_1+m_1$	v_1		w_1+n_1		
0.865	l_1+m_1			w_1-n_1	u_1	
1	w_0+m_0	u_0	$w_0+m_0+l_1-m_1$	w_0-m_0		$w_1+n_1-w_0+m_0$
Sum=	$12A_1$	$6A_2$	$12A_3$	$12B_1$	$6B_2$	$12B_3$

From the above Table and from eq. 5, the values of the harmonic coefficiencts A_1, A_2, A_3, B_1, B_3 and A_0 required for eq. 4 are determined.

The total seasono-diel effects on the observed parameter can be rewritten, by combining eq. 2 and 4 as,

$$Y_{T,t} - \left[a_1 \cos\left(\frac{2\pi t}{24}\right) + a_2 \cos 2\left(\frac{2\pi t}{24}\right) + b_1 \sin\left(\frac{2\pi t}{24}\right) + b_2 \sin 2\left(\frac{2\pi t}{24}\right) \right]$$
$$= A_0 + A_1 \cos\left(\frac{2\pi T}{12}\right) + A_2 \cos 2\left(\frac{2\pi T}{12}\right) + A_3 \cos 3\left(\frac{2\pi T}{12}\right) + B_1 \sin\left(\frac{2\pi T}{12}\right) + B_2 \sin 2\left(\frac{2\pi T}{12}\right) + B_3 \sin 3\left(\frac{2\pi T}{12}\right) \quad \ldots (6)$$

their mean value is treated to represent the value at 0700 hrs. The mean diel cycle is prepared for each month.

Taking the mean diel cycle for December (0=T=12), for example, the 16-ordinate scheme for diel variations worked out as described below :

The ordinates are

Y_0	Y_1	Y_2	Y_3	Y_4
77.95	77.90	77.70	77.70	77.60
Y_5	Y_6	Y_7	Y_8	Y_9
77.64	78.10	78.62	79.20	79.61
Y_{10}	Y_{11}	Y_{12}	Y_{13}	Y_{14}
79.70	79.25	78.90	78.65	78.50
and	Y_{15}			
	78.05			

Arranging the ordinates

	77.95	77.90	77.70	77.70	77.60	77.64	78.10	78.62	79
		78.05	78.50	78.65	78.90	79.25	79.70	79.61	
p	77.95	155.95	156.20	156.35	156.50	156.89	157.80	158.23	79
q		—0.15	—0.80	—0.95	—1.30	—1.61	—1.60	—0.99	

EXAMPLE

To cite as an example, data on surface temperature (°F) of the nearshore waters at Waltair for the period from February 1960 to January 1961 from a Ph.D. thesis (Murty, 1965) are utilised here, as the coverage of the same in terms of diurnal cycles was excellent. One hundred and fifteen diel cycles in all, with not less than five diel cycles in any month were covered in those observations which were taken at alternate hours of the day starting from 0700 hrs and ending by 0700 hrs the next day in each cycle. As the initial and final readings of each diel cycle are clubbed together,

Rearranging p series

	77.95	155.95	156.20	156.35	156.50
	79.20	158.23	157.80	156.89	
r	157.15	314.18	314.00	313.24	156.50
s	—1.25	—2.28	—1.60	—0.54	

Rearranging q series

	—0.15	—0.80	—0.95	—1.30
	—0.99	—1.60	—1.61	
m	—1.14	—2.40	—2.56	—1.30
n	0.84	0.80	0.66	

Rearranging r series

157.15	314.18	314.00
156.50	313.24	
313.65	627.42	314.00
0.65	0.94	

Tabulating the results

Multiplier				
0.383	—0.54		—1.14	
0.707	—1.60	0.94	—2.40	0.84+0.66
0.924	—2.28		—2.56	
1	—1.25	0.65	—1.30	0.80
Sum=	—4.6847	1.3146	—5.7989	1.8605
	$8a_1$	$8a_2$	$8b_1$	$8b_2$

$a_1=-0.586$; $a_2=+0.164$; $b_1=-0.725$; $b_2=+0.233$

Therefore for December (T=12 or 0), the diel correction ($-Y_t$) for the observed surface temperature (in °F) at any hour t of the day is given by

$$-Y_t = +0.586 \cos\left(\frac{2\pi t}{24}\right) - 0.164 \cos 2\left(\frac{2\pi t}{24}\right) + 0.725 \sin\left(\frac{2\pi t}{24}\right) - 0.233 \sin 2\left(\frac{2\pi t}{24}\right) \quad \ldots (7)$$

Applying the procedure for dirunal and semidiurnal waves of the mean diel cycle for each month, the coefficients thereby obtained are enlisted in the following Table 3.

The coefficients a_1, a_2, b_1 and b_2 are the required constants for each month for estimating the diel fluctuation Yt at any hour t of the day in the respective month.

TABLE 3. *Coefficients of diel variations in all the 12 months*

Month		a_1	a_2	b_1	b_2
0/12	..	—0.586	0.164	—0.725	0.233
1	..	—0.532	0.185	—0.817	0.249
2	..	—0.749	0.176	—1.171	0.325
3	..	—0.962	0.258	—1.286	0.167
4	..	—1.143	0.254	—1.511	0.333
5	..	—0.741	—0.076	—0.633	0.154
6	..	—0.613	0.078	—0.626	—0.144
7	..	—0.648	0.323	—0.826	0.231
8	..	—0.377	0.191	—0.532	0.206
9	..	—0.278	0.163	—0.557	0.305
10	..	—0.633	0.221	—0.373	0.091
11	..	—0.659	0.320	—0.529	0.165

The diel fluctuations for the three distinct seasons as in Table 4 (monsoon, winter and hot weather season) are obtained from the mean values of each of the coefficients a_1, a_2, b_1 and b_2 for the months corresponding to the respectives easons from Table 3.

From the values presented in above Table.

$$Y_{t\,(m)} = -0.479 \cos \frac{2\pi t}{24} + 0.189 \cos 2\frac{2\pi t}{24} - 0.635 \sin \frac{2\pi t}{24} + 0.150 \sin 2\frac{2\pi t}{24} \quad ..8\,(a)$$

$$Y_{t\,(w)} = -0.603 \cos \frac{2\pi t}{24} + 0.223 \cos 2\frac{2\pi t}{24} - 0.611 \sin \frac{2\pi t}{24} + 0.185 \sin 2\frac{2\pi t}{24} \quad ..8\,(b)$$

$$Y_{t(h)} = -0.899 \cos \frac{2\pi t}{24} + 0.153 \cos 2 \frac{2\pi t}{24} - 1.150 \sin \frac{2\pi t}{24} + 0.254 \sin 2 \frac{2\pi t}{24} \quad ..8\ (c)$$

where $Y_{t\,(m)}$, $Y_{t\,(w)}$ and $Y_{t\,(h)}$ are the amounts of fluctuations at hour t in the monsoon, winter and hot weather seasons respectively. The diel fluctuation coefficients of the Table 4

TABLE 4. *Seasonal mean coefficients of diel variations*

coef. / Season	a_1	a_2	b_1	b_2
Monsoon .. (June-Sept.)	—0.479	+0.189	—0.635	+0.150
Winter .. (Oct.-Jan.)	—0.603	+0.223	—0.611	+0.185
Hot weather .. (Feb.-May)	—0.899	+0.153	—1.150	+0.245

or the equation 8 provide means for diel correction in the observed surface temperature (°F) of the nearshore waters of Waltair.

SEASONAL VARIATIONS

The average of the monthly mean values is 81.297 ($=A_0$). Proceeding with 12-ordinate scheme on the monthly mean values which are equal to Y_T values (°F) as shown at the bottom.

Arranging p series

	160.96	159.62	162.55
	165.63	164.50	162.30
r	—4.67	—4.88	+0.25

Arranging q series

	—4.08	—3.96	—3.89
	—4.33	—4.24	+1.16
s	—8.41	—8.20	—2.73
t	+0.25	+0.28	—5.05

Arranging r series

	—4.67	—4.88
		+0.25
u	—4.67	—4.63
v		—5.13

T (month)	0	1	2	3	4	5	6	7	8	9	10	11
Y_T	78.44	77.83	79.33	80.65	80.13	81.73	82.52	81.79	83.22	84.98	8 84.37	80.57

Arranging the 12 ordinates

	78.44	77.83	79.33	80.65	80.13	81.73
	82.52	81.79	83.22	84.98	84.37	80.57
p	160.96	159.62	162.55	165.63	164.50	162.30
q	—4.08	—3.96	—3.89	—4.33	—4.24	+1.16

Arranging s series

	−8.41	−8.20
		−2.73
w	−8.41	−10.93
l		−5.47

Arranging t series

	+0.25	+0.28
		−5.05
m	+0.25	−4.77
n		+5.33

The tabular form corresponding to Table 2 is

Multiplier						
0.5	5.47−4.77	−5.13		−10.93+5.33		
0.866	−5.47−4.77			−10.93−5.33	−4.63	
1	−8.41+0.25	−4.67	−8.41+0.25	−8.41−0.25		−10.93+5.3
			−5.47+4.77			+8.41+0.25
Sum =	−16.6778	−7.235	−8.86	−25.5412	−4.0096	+3.06
	$12A_1$	$6A_2$	$12A_3$	$12B_1$	$6B_2$	$12B_3$

from which

$A_1=-1.390$; $A_2=-1.206$; $A_3=-0.738$
$B_1=-2.128$; $B_2=-0.668$; $B_3=+0.255$

The annual variations (monthly means) are given by

$$Y_T = 81.297-1.393 \cos \frac{2\pi T}{12} -1.206 \cos 2 \frac{2\pi T}{12} - 0.738 \cos 3\frac{2\pi T}{12} -2.128 \sin \frac{2\pi T}{12} - 0.668 \sin 2\frac{2\pi T}{12} + 0.255 \sin 3\frac{3\pi T}{12} \quad ..(9)$$

Assuming that the diel fluctuations are the same in each month of the same season, eqs. 8 b, c provide correction factors ($-Y_t$) for the observed values ($Y_{T,,t}$) at the hour t in the month T.

From eqs 8 and 9, for monsoon months

$$Y_{T,t} - \left(-0.479 \cos \frac{2\pi t}{24} + 0.189 \cos 2\frac{2\pi t}{24} - 0.635 \sin \frac{2\pi t}{24} + 0.150 \sin 2\frac{2\pi t}{23}\right)$$

$$= 81.297 - 1.390 \cos \frac{2\pi T}{12} - 1.206 \cos 2\frac{2\pi T}{12} - 0.738 \cos 3\frac{2\pi T}{12} - 2.128 \sin \frac{2\pi T}{12} - 0.668 \sin 2\frac{2\pi T}{12} + 0.255 \sin 3\frac{2\pi T}{12} \quad ..(10a)$$

for winter months

$$Y_{T,t} - \left(-0.603 \cos \frac{2\pi t}{24} + 0.223 \cos 2\frac{2\pi t}{24} - 0.611 \sin \frac{2\pi t}{24}\right.$$

$$+ 0.185 \sin 2 \frac{2\pi t}{24} \Big)$$

$$= 81.297 - 1.390 \cos \frac{2\pi T}{12}$$

$$- 1.206 \cos 2 \frac{2\pi T}{12}$$

$$- 0.738 \cos 3 \frac{2\pi T}{12} - 2.128 \sin \frac{2\pi T}{12}$$

$$- 0.668 \sin 2 \frac{2\pi T}{12}$$

$$+ 0.255 \sin 3 \frac{2\pi T}{12} \quad ..(10b)$$

$$\cos 2 \frac{2\pi T}{12} - 0.738 \cos 3 \frac{2\pi T}{12}$$

$$- 2.128 \sin \frac{2\pi T}{12}$$

$$- 0.668 \sin 2 \frac{2\pi T}{12}$$

$$+ 0.255 \sin 3 \frac{2\pi T}{12} \quad ..(10c)$$

In order to realise the significance of diel corrections, let us consider Y_{Tt} for t=0100 hr. In this case, the diel correction (from eq. 10 will become +0.336, 0.414 and +0.826 for monsoon, winter and hot weather seasons respectively. The annual march of the concerned parameter (surface temperature in °F) for 0100 hr before and after correction for diel effects and the monthly mean values of the parameter are shown in Table 5 for comparison.

The closeness of the corrected figures with the corresponding monthly mean values (Table 5) indicates that the diel correction

TABLE 5. *Comparison of the annual march of surface temperature (°F) with the mean 0100 hr observation*

Month T	Value of $Y_{T,t}$ for t=0100 hr. (without correction for diel effects)	Value of $Y_{T,t}$ for t=0100 hr with diel correction (adopting the seasonal corection)	(adopting the monthly correction)	Monthly mean value Y_t
0/12	78.0	78.41	78.45	78.44
1	77.3	77.71	77.69	77.83
2	78.7	79.52	79.34	79.33
3	79.4	80.22	80.23	80.65
4	78.9	79.72	79.90	80.13
5	81.0	81.82	81.85	81.73
6	81.9	82.23	82.55	82.52
7	81.4	81.73	81.78	81.79
8	83.0	83.33	83.19	83.22
9	84.9	85.23	85.01	84.98
10	83.9	84.31	84.34	84.37
11	80.1	80.51	80.47	80.57

and for hot weather season

$$Y_{T,t} - \Big(- 0.899 \cos \frac{2\pi t}{24}$$

$$+ 0.153 \cos 2 \frac{2\pi t}{24} - 1.150 \sin \frac{2\pi t}{24}$$

$$+ 0.245 \sin 2 \frac{2\pi t}{24} \Big)$$

$$= 81.297 - 1.390 \cos \frac{2\pi T}{12} - 1.206$$

method is very effective in bringing out the seasonal character of variation of the parameter.

CONCLUSIONS

Even though the methodology of diel corrections (eq. 2 or 6) is the same for any region, the actual values of the coefficients differ from region to region and from parameter to parameter. The split-up of seasons is made in such a manner, in the example, that seasonwise determined coefficients are more suited for tropical areas dominated by monsoon system. The diel correction coefficients evaluated in the example (eq. 10) are applicable only for the surface temperature of the nearshore waters off Waltair (Visakapatnam). Evidently, the more the number of observations with uniform spread over hours and months, the more accurate would be the evaluated constants involved in the expression of seasono-diel variations of a chosen parameter in a region.

It may be said that the expression for seasono-diel variatons serves a useful purpose for time-series analysis of environmental parameters in general and in the field of oceanography in particular. It provides a correction factor for observations made at different times of the day (day and night) in the study of seasonal variations of a parameter in a chosen region. Different sets of constants are required for different regions, if their characters differ.

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