ISSN 2321–340X

Journal of Aquatic Biology & Fisheries | Vol. 6 | 2018 | pp. 150-158

STUDY ON CRISPY AND CRUNCHY COOKIES ENRICHED WITH SOLAR DRIED INDIAN ANCHOVY *STOLEPHORUS COMMERSONII*

Jeyanth Allwin, S.I., Hermina Giftson, Saritha, K., Jamila Patterson* and Immaculate, J.K.

Suganthi Devadason Marine Research Institute, 44 Beach Road, Tuticorin, Tamil Nadu 28001,India
(Affiliated to Manonmaniam Sundaranar University, Abishekapatti, Tirunelveli - 627012. Tamilnadu, India)
**Email: jamilapat@sdmri.in*

The aim of the present study is to enrich cookies with the Indian anchovy *Stolephorus commersonii* and to determine their nutritive value for human consumption. The following contents were examined in the enriched cookies: moisture, protein, lipid, carbohydrate, ash, pH,trimethylamine-N oxide (TMA-N), Total volatile base-Nitrogen (TVB-N), Peroxide value (PV), Thiobarbituric acid (TBA), Free fatty acid (FFA), Total viable count (TVC) and Total fungal count (TFC) and organoleptic qualities. Additionally the shelf-life of the seafood cookies was analyzed and found to be within the limits of edibility under ambient storage up to 20 days. The seafood cookies received the unanimous approbation of the members of the panel who appraised the cookies. These cookies are delicious and nutritious snacks for all the age groups of people, and are safe for consumption.

Key words: *Stolephorus commersonii*, seafood cookies, shelf-life, quality analysis

INTRODUCTION

Diets of people vary significantly according to regional, seasonal, and socio-economic dfferences, and also depending on the urban-rural division. The basic reason for this variation in diet is the disparity in income; and the variation influences the nature and incidence of nutritional problems. Furthermore, incorrect food selection, improper cooking methods and substandard storage systems cause serious problems of nutrition (Yagmur and Gunes, 2011). In recent years, worldwide, there is an increased consumption of fish and fish products. This has been brought about by the increased awareness of the nutritional value of seafood as published by USFDA department of health in their dietary guidelines (Wang *et al.*, 2010). There is scope to increase the consumption of protein-rich snacks in preference to snacks rich in carbohydrates. Highly nutritious cookies, in one form or another, are consumed by almost all. For centuries carbohydrates were considered an excellent source of energy and hence formed an essential part of human diet (Ryan, 2005). The main physical characteristic of the cookies are the solid form and the golden brown colour; chemically they contain carbohydrate and fat in large proportions, and vitamins, mineral and protein in smaller proportions. The deficiency of these latter nutrients is a cause of malnutrition, whose severity is different in different areas (Adebooye, 1996). When people consume baked products without any nutrient supplement they suffer from malnutrition. Therefore there is a need to enrich or fortify cookies in order to improve their nutritional value. Fortification consists in the addition to food of one or more essential nutrients that are not commonly found (Brekkan, 1996).

Value added fish products such as fish balls and fish cakes originated in China where fresh fish is used as a raw material. Nowadays people in other Asian regions also consume fish-based products. Since the early 1980s the number of industrial entities engaged in the production of value-added fish products has been growing in countries like Singapore, Malaysia, China and Thailand. They focus on the export of frozen fish balls and cuttlefish balls to countries like Australia, Japan, and the United States. Several countries have also invested and established overseas factories for fishery by-products (Morrissey and Tan,

2000). According to the FAO reports fish balls are marketed and consumed around the world, but in India this industry is in the nascent stage only (FAO, 2003).

In general anchovies are considered to be the small marine fish growing up to 20 Cm, seen in the warmer waters around the world. The Indian anchovy (*Stolephorus commersonii*) constitutes approximately 40% of the total fish production in Tamil Nadu (Kumaraguru *et al.*, 2010). The catch of 79,127 tons of anchovies in India in 2010 (CMFRI, 2009) shows a high potential and this low-value fish has a high demand among the coastal populations. The landing of *Stolephorus* in India is 61,571 tons in 2016 (CMFRI, 2017). In Tuticorin people consider anchovy as a protein resource and also as basic food because it is cheaper. Ready-to-cook and ready-to-eat products are in great demand because of the changes in lifestyle and the altered social conditions, brought about by the advancement in technology and also by the increase in the number of working women. The present study proposes to examine the enriching of cookies with *Stolephorus commersonii*, and to determine its nutritive value for human consumption. Anchovy-enriched cookies can be used to alleviate protein deficiency and malnutrition especially among school children. Hence it is imperative to test the cookies for their chemical and biological acceptability, apart from studying their savoriness and determining their shelf-life period.

MATERIALS AND METHODS

Source of raw materials

The Indian anchovy (*Stolephorus commersonii*) of about 15 to 18 cm long were collected and brought to the laboratory in an ice box. The raw materials were washed and degutted by removing head, scales and visceral parts. They were again washed and dried with a solar dryer at 60°C for 8 hours and then powdered and used for further study.

Preparation of fish cookies

The seafood cookies were prepared using 50% dried fish meat powder, 30% finely milled, refined and bleached wheat flour (maida),10% butter, 15% sugar, 5% vanilla essence and 1% salt. Powdered sugar was mixed with butter, salt and vanilla essences and made into a paste. Then maida and fish powder were added to the sugar paste and made into dough and allowed to ferment for one hour at 27° C. The fermented dough was made into small balls and then spread by a gentle pressing with the palms. Then it was kept on baking pans rubbed with oil and baked in an oven at 180°C for about 30 minutes. The baked cookies (Fig.1) were cooled to prevent moisture formation. Then the cookies were packed in polypropylene pouches and stored at room temperature for further analysis.

Proximate composition

Proximate composition of the fresh fish was analyzed. The moisture content was determined by drying the samples at 105°C to constant weight; the Lowry's method was used to determine the crude protein content (Lowry, 1951). The crude fat content was determined following the method of Folch *et al*., (1957). Total carbohydrate was estimated by the Anthrone method (Hedge and Hofreiter, 1962). Ash content was determined according to AOAC (1995) by placing the sample in a muffle furnace at 525° C to incinerate until the sample was completely free from carbon particles. The dish was then placed in desiccators to cool before weighing.

Quality analysis of seafood cookies

The composition value of the following contents of the seafood cookies were determined: moisture, protein, lipid, carbohydrate, ash, pH, Trimethylamine-N oxide (TMA-N), Total volatile base-Nitrogen (TVB-N), Peroxide value (PV), Thiobarbituric acid (TBA), Free fatty acid (FFA), Total viable count (TVC) and Total fungal count (TFC). The pH values of the samples were determined with the help of a pH meter (AOAC, 2002). TVB-N and TMA-N were determined according to the procedure of Beatty and Gibbons (1937) by using Conway micro diffusion unit and the results were expressed in terms of nitrogen mg N/100 g. Oxidative stability of seafood cookies was also measured using titrimetric determination of the amount of peroxide or hydro peroxide groups, the initial product of lipid oxidation (peroxide value). The peroxide value (PV) was expressed as milli equivalent of O2/kg fat AOAC (2005). TBA number was determined with the help of Tarladgis's (1960) method. Free fatty acid (FFA) value was determined as per AOAC, (2005) and expressed as percent (%) of oleic acid. Microbial analysis such as Total viable count (TVC) and Total fungal count (TFC) of the seafood cookies was

Fig.1. Baked seafood cookies

quantified by using spread plate technique (APHA, 1984).

Textural analysis of cookies

The hardness of the cookies was determined by Texture Analyzer TA–XT2i (Stable Micro system) with a load cell of 2 kg weight (AACC, 2000).

Organoleptic quality

Cookies sample were subject to a sensorial examination also. For this purpose, to quantify the sensorial characters of the samples, a scale of 1 to 5 points was used. The products were described by a panel of 10 members, who examined the colour, odour, texture, appearance and taste of the cookies. The scoring was: 1 = very bad, 2 = bad, 3 = Normal, 4 = good and 5 = very good. The organoleptic character was studied by comparing the results of the analysis of immediately prepared cookies with the results of the analysis of those stored for 10 to 20 days. The overall savoriness was determined by the panel using hedonic scale (Amerine *et al*., 1965).

Storage study

The seafood cookies were packed and sealed in 200 gauge polythene bags, sealed and kept in an air tight jar at room temperature (37ºC). The storage studies were carried out for every two days up to 20 days to determine the quality and shelf life of the seafood cookies. The quality characteristics such as pH, TVB-N, TBA and TMA-N, which might occur in the products under ambient storage conditions, were observed using standard methods. Sensorial triplicate analyses were conducted every two days and chemical triplicate analyses were conducted every ten days during the storage for determining quality and shelf life of the seafood cookies.

STATISTICAL ANALYSIS

One way ANOVA was performed to analysis the variation between effect of days and different quality parameters. In addition, variations of storage times in the shelf life of products by different sensory factors were tested with the One way ANOVA.

RESULTS AND DISCUSSION

Consumption of fish in diet is very important for health. Unaware of the importance of balanced diet, people depend on new products. Processed sea food products have become available as a result of technological developments. The objective of the present study is to make fish enriched seafood cookies. It is an innovative ready-to-eat sweet product enriched with Indian anchovy, *Stolephorus commersonii*, dried with solar drier. The proximate composition of the fish varies from species to species mainly due to the availability of food and feeding habitat of the species and their seasonal distribution. Initially the nutritive value of the raw material was assessed and the results were presented in Table 1. One way ANOVA was performed to estimate the different biochemical parameters in the experimental fish and no significant variation was observed in the parameters. According to Palani Kumar *et al*., (2014) a slight variation was reported in moisture, protein, lipid, ash and carbohydrate content of *S. commersonii* in Tuticorin coastal water and the findings are more or less similar to the present findings in the same fish. Vaishnavi *et al*., (2015) reported the percentage of protein content of *Stolephorus commersonnii* as 24.54% in raw and 43.21% in dry fish from Nagapattinam coastal water. This fish of high nutritive value is available throughout the year; and it is a preferred type of seafood to all consumers. This is the chief reason for the selection of this species for the innovative cookies development programme. After preparation the cookies were assessed for the appearance and texture properties. The textural

Table 1. Proximate composition of *Stolephorus commersonii*

Parameter	Composition (%)
Moisture	72.33 ± 0.66
Protein	18.75 ± 0.21
Lipid	3.72 ± 0.17
Ash	2.99 ± 0.30
Carbohydrate	0.213 ± 0.06

properties were good, and appearance was also good because cookie flours hold less water (Faridi *et al.*, 1994). The main hydrophilic components of a cookie formula are flour and sugar. Lower water absorption by flour raises the water absorption by sugar and thus decreases dough viscosity during baking. This allows the dough to spread more forming cookies of larger diameter (Slade and Levine, 1994). Damaged starch absorbs more water than the intact one and leads to stiffness of cookie dough, to decreased cookie diameter and to lower spread. Moreover, a higher percentage of damaged starch makes the starch more susceptible to enzyme attack which results in smaller cookies too. In the present study the quality of the cookie was not adversely affected by the inclusion of seafood and other materials; only taste and nutritive value have been increased with the addition of seafood.

Table 2 presents the proximate composition, spoilage indicators and microbiological quality of the seafood cookies. In sea food cookies the proximate composition was found to be more or less than the raw fish. Osibona *et al*., (2009) reported the nutritive value of deep fried fish cake made from shrimp by catch. Adeleke and Odedeji (2010) reported seafood bread prepared by fortification of wheat flour with Tilapia fish protein. Ayse *et al*., (2011) reported the proximate composition of anchovy cakes. Nikheel and Asif (2013) reported the nutritive value of pangasius fish cutlet. The results of the present study reveal that protein, lipid and carbohydrate were higher in the cookies than the raw materials, which can be attributed to the addition of the other ingredients in cookies.

The pH is determined in the products for their stability (Azad, 2001). The pH of the seafood cookies were neutral (6.96) because fresh fish of prime quality were used. Total Volatile Nitrogen (TVB-N) and Trimethylamine nitrogen (TMA-N) relate to protein breakdown, and hence are widely used as spoilage indicators of fish (Chakrabarti, 1984). The freshly prepared seafood cookies had volatile amine nitrogen no TMA-N content indicating that the cookies were free from deterioration. Depending on the TMA-N amounts the product can be classified as good up to 4 mg/100 g; as marketable up to 10 mg/100 g; and as decayed beyond 12 mg/100 g (Ludorf and Meyer, 1973). A measure of the hydro peroxides contained in the oil is considered as peroxide value and it is the first product of oxidation. Peroxide values of 20 to 22 meq0_2/kg (milliequivalent/kg) of lipid correspond to noticeable rancid taste. In this study, seafood cookies had a peroxide value of 0.02 meq0_2/kg with no noticeable rancid taste. TBA is widely used for the assessment of the degree of secondary lipid oxidation and the values of 3 to 4 mg of malonalydehyde/kg indicate quality loss in the fish products (Scott *et al*., 1992). Results of the present study showed the absence of TBA which reveals that the oxidative rancidity remained relatively low in the samples denoting the fact that the products did not undergo any kind of lipid oxidation. If the FFA in the lipid content of the product increases due to the

Table 2. Nutritive value of cookies enriched with *Stolephorus commersonii*

Parameter	Seafood cookies
Chemical quality	
Moisture (%)	3.11 ± 0.02
Protein (%)	18 ± 1.23
Lipid (%)	5.26 ± 4.78
Carbohydrate (%)	6.49 ± 0.12
Ash (%)	3.2 ± 2.23
pH	6.96 ± 0.09
TMA-N (mg N/100g)	-
TVB-N (mg N/100g)	0.8 ± 0.11
PV (mEq02/kg)	0.02 ± 0.19
TBA (mg malonaldehyde/kg)	-
Free fatty acid (% of oleic acid)	-
Microbial quality	
TVC(CFU/g)	5 ± 1.26
TFC (CFU/g)	Nil

action of lipases, the quality of freshness of the product gets reduced (Reddy *et al*., 2012). In the present study Free Fatty Acid calculated as Oleic acid were 0% indicating the freshness of the product. Our results for quality indicator of freshly prepared value-added product were in accordance with the results of Boran and Albayrak (2010).

In general, the muscles of freshly caught fish from healthy waters are sterile. Microorganisms exist generally in skin, gills and intestines. After the catch, however, microorganisms may spread over muscles from gills and intestines depending on the processes employed in catching. As a result, the nature of fish degradation depends on microorganism present in the species, and the consumers of such fishes may contract infection or suffer from toxicity. Therefore, with regard to health of the consumer, and for the storage method to be used the information about the number and species of the microorganisms existing in the muscle of fish is very important (Gram and Huss, 1996). In the present study low microbial count was noticed in the seafood cookies immediately after preparation. The bacterial count was around 5 CFU/ g, which was within the acceptable limits proposed by (ICMSF, 2005). Absence of fungal colonies in the product was observed during the study. This could be due to the fact that the cookies were fresh, that the processing was hygienic, and that the raw materials were fresh (Young and Romero, 1979). Osibona *et al*., (2009) observed too low microbes in shrimp by catch fish cake.

A low pH and moisture content of the products may be the adverse conditions that induce microbial build up in the seafood cookies. The storage characteristics were studied for every 2 to 20 days. Table 3 shows the chemical characters (pH, TMA-N, TVB-N and TBA number) of seafood cookies under storage of 10 and 20 days at room temperature (27°C). There is a growing interest in the production of readymade seafood such as fish balls, fish cakes, fish cutlets and studies have been conducted to investigate the quality changes of the products. Only a very much limited study had been carried out on the fish bread product and on the experimental seafood-based product stored in ambient temperature. A decrease in the moisture content from 3.11 to 2.97% was observed in seafood cookies stored at ambient temperature for 20 days. Moisture content of the cookies between twenty days showed that it is statistically not significant (One way ANOVA, df=32; F=0.777; P=0.469; Sig=p>0.05). The enzymatic degradation of fish muscle may be caused by the increase of pH (Love, 1992). In the present study during the storage period at ambient temperature (27°C) from 1 to 20 days the seafood cookies showed slight increase in pH from 6.50 to 6.79. The cutlet made from cattla fish showed increasing trend of pH from 6.50 to 6.79 when stored at -2 to -4°C (Pawar, 2011). The pH content of the cookies between initial to twenty days showed that it is statistically not significant (One way ANOVA, df=32; F=0.158; P=0.855; Sig=p>0.05). The most commonly used chemical method for assessing fish quality is Trimethylamine N-oxide (TMAO) which is generally present in marine fishes (Magnusson and Martinsdottir, 1995). The decomposition of TMAO due to bacterial spoilage and enzymatic activity results in the production of TMA (Serdaroglu and Deniz, 2001). The levels of acceptability for human consumption are generally in the range of 10 - 15 mg TMA-N/100 g (Huss, 1988). One of the most frequently used analyses of freshness of the product is TMA-N analysis because it is considered as a good indicator for bacterial contamination of the product. According to Ludorf and Meyer (1973) the product decayed beyond 12 mgN/100 g. In the present study at the initial stage the TMA-N value was not detected in seafood cookies and it slightly found (3.5 mg N / 100 g) in the 20 days of storage. The present results agreed with the results of Ayse *et al*., (2011). In the present study the finding did not exceed the acceptable limit even at the end of storage period. According to the report of Muhammet Boran and Sevim Kose (2007) based on TMA of fried fish balls made from raw whiting (*Merlangius merlangus euxinus*) the product became unfit for consumption by the 10th day, while the products made from precooked whiting were consumable up to 14 days of storage in ambient temperature. TMA-N content of the cookies between 20 days showed that it is statistically not significant (One way ANOVA, df=32; F=0.004; P=0.996; Sig=p>0.05).

When cookies were prepared using good raw materials the TVB-N levels were low in the beginning of the storage period but during storage it increased.

Huss (1995) reported TVB-N amount in the newly caught fresh fish ranged between 5 to 20 mg/100g and the values for fresh fish were between 30 to 40 mg/100g. In the present study TVB-N value of seafood cookies stored for 20 days was 10.84 mg/ 100g and it indicates the freshness of the product and it also shows that there is no volatile amine production during the storage. However, in the baked products lower TVB-N values were observed (Kose and Erdem, 2001). Therefore, it can be concluded that baking may affect the TVB-N development of the products. Oxidation of fat gives bitter taste and a yellow-brown colour to the products. TVB-N content of the cookies between initial to twenty days showed that it is statistically not significant (One way ANOVA, df=32; F=0.00; P=1.000; Sig=p>0.05). Thiobarbituric acid number is used for expressing the fat oxidation. According to researchers, in a very good material the TBA number should be less than 3 mg MDA/kg and in a good material it should not exceed 5 mg MDA/kg. The limit of palatability ranges between 7 and 8 mg MDA/kg (Varlik *et al.*, 1993). In the present study the levels of TBA in seafood cookies increased throughout the entire storage period (20 days) and ranged from 0 to 0.43 mg MDA/kg, and it was within the good material class. The reason for the presence of low TBA amounts may be due to the baking process which might have removed some of the products of lipid oxidation (Osibona *et al*., 2009). Present study shows that oxidative rancidity remained relatively low in all samples throughout the storage period. TBA content of the cookies between 0 to 20 days showed that it is statistically not significant (One way ANOVA, df=32; F=0.254; P=0.777; Sig=p>0.05). The results obtained from the present study are similar to the findings from Bertagnolli *et al.,* (2014). The authors reported that guava peel flour cookies have moisture content ranging from 2.7 to 4.9%. According to Bertagnolli *et al.* (2014), cookies with low moisture content will have longer shelf life conditions if they are stored under the control conditions such as appropriate packaging, either gas storage or normal storage with in dry and cool place. So far cookies have not been prepared from seafood, and this was the first attempt and it has resulted in a good nutritive value added product. Cookies made with seafood has higher nutritive value than the vegetable incorporated cookies (Cauvain and Young, 2000; Bertagnolli *et al.*, 2014; Bala *et al.*, 2015; Chia and Chong, 2015). In the present study the seafood cookies have withstood a shelf life of 20 days without showing any noticeable change in ambient temperature (27^{o}C) in traditional packing using low density polythene bags. Many researchers in different countries have studied about value added products using different fish species. Adeleke and Odedeji (2010) reported lower shelf life for bread fortified with Tilapia flour which showed good organoleptic score.

The results of sensorial analysis of the seafood cookies are presented in Table 4. It has been reported that the most important criterion for designating product quality in food storage is the result of sensorial analysis; and products which fail to satisfy the sensorial criteria cannot be eaten. For this analysis, triplicate samples from each of the three different lots were taken at regular intervals. Each assessment was carried out by well-trained persons with 10 years experience in sensory analysis. The odour, taste and texture were evaluated using an acceptability scale of 1 – 5. Samples scoring 3 or above were considered acceptable for human consumption. Average score of the value represents the mean of three samples. The panelists liked the seafood cookies, which was prepared for our study. Based on the panel's score the sensory properties of the baked seafood cookies were acceptable according to the panel's evaluation, both initially and after 10 to 20 days of storage. No changes in taste or texture, i.e. the sensorial criteria, were detected up to the twentieth day of storage in ambient temperature. One way ANOVA was carried out for different sensory factors and for different number of days; and no significant variation was observed (p>0.05). Rancidity was not observed until 20 days. Higher rate of lipid oxidation causes rancidity, which consequently affects the flavor and general acceptability. In the present study lipid oxidation does not affect the quality of the seafood cookies stored at ambient temperature and so the panelists favorably considered the seafood cookies. In this study the results of sensory evaluation were supported by the results of chemical analysis. Ayse *et al*. (2011) reported anchovy cake was acceptable

Table 3. Storage quality characteristics of seafood cookies

Sampling Days	Moisture (%)	pH	TMA-N (mg/100g)	TVB-N (mgN/100g)	TBA (mgMDA/kg)
0	3.11 ± 0.10	6.96 ± 0.13	-	0.8 ± 0.07	-
2	3.11 ± 0.02	6.63 ± 0.09	-	0.8 ± 0.03	-
4	3.09 ± 0.03	6.84 ± 0.14	2.3 ± 0.20	1.4 ± 0.06	-
6	3.02 ± 0.03	6.95 ± 0.39	2.1 ± 0.05	2.6 ± 0.10	0.04 ± 0.01
8	3.01 ± 0.02	6.99 ± 0.01	2.4 ± 0.12	2.9 ± 0.10	0.07 ± 0.01
10	3.01 ± 0.02	6.98 ± 0.07	2.7 ± 0.10	3.1 ± 0.02	0.1 ± 0.01
12	3 ± 0.02	6.98 ± 0.07	2.9 ± 0.08	3.8 ± 0.08	0.3 ± 0.10
14	2.99 ± 0.04	6.99 ± 0.02	3.08 ± 0.06	5.25 ± 0.36	0.35 ± 0.05
16	2.97 ± 0.05	7.04 ± 0.05	3.4 ± 0.10	8.9 ± 0.11	0.39 ±0.12
18	2.97 ± 0.10 7.	7.1 ± 0.03	3.5 ± 0.09	9.88 ± 0.08	0.42 ±0.03
20	2.97 ± 0.09	7.1 ± 0.15	3.5 ± 0.09 10.	84 ± 0.15	0.43 ± 0.04
One way ANOVA	Sig=p>0.05	*Sig=p>0.05*	*Sig=p>0.05*	Sig=p>0.05	Sig=p>0.05

Table 4. Sensory evaluation of seafood cookies

Quality factor	Storage period in days		
	0	10	20
Colour	5.00 ± 0.00	4.30 ± 0.12	4.00 ± 1.22
Odour	5.00 ± 0.00	3.60 ± 0.15	3.40 ± 0.02
Texture	5.00 ± 0.00	4.10 ± 0.78	4.10 ± 0.06
Appearance	5.00 ± 0.00	4.20 ± 1.23	3.50 ± 0.13
Taste	5.00 ± 0.00	4.00 ± 0.07	3.50 ± 0.25

as fresh up to 6 days at cold storage (4°C). The organoleptic properties of the deep-fried cakes made from shrimp by catch were acceptable up to six weeks of storage in ambient temperature (Osibona *et al*., 2009). The organoleptic evaluation of cutlet stored at -15 to -18° C was not in acceptable condition for 16 days (Nikheel and Asif, 2013). In the case of seafood cookies, the score was >3 during the storage period. The results revealed that the ambient temperature storage slows down the process of deterioration while maintaining better nutritional quality for the consumers.

CONCLUSION

The processing of fish meat into value added snack as seafood cookies is an innovative attempt at providing good nutritive value to the consumers. Indian anchovy is an excellent fortifier in cookies as well as other bakery products and this will lead the way to the fishery by-product industries. The shelf life of the seafood cookies is 20 days in the ambient temperature (27°C). Apart from the traditional package such other methods as modified atmosphere packaging (MAP) and Controlled Atmosphere Packaging (CAP) will be experimentally assessed to commercialize the product.

ACKNOWLEDGEMENTS

The authors wish to acknowledge their indebtedness to the Department of Biotechnology (Government of India) for the financial support, and to the Director of Suganthi Devadason Marine Research institute (SDMRI) for providing all the facilities for carrying out this work.

REFERENCES

Adebooye OC 1996. Proximate composition and nutrient analysis of six selected leafy vegetables of South West Nigeria. Ife J. Agric., 18: 56-63.

Adeleke RO and Odedeji JO 2010. Acceptability Studies on Bread Fortified with Tilapia Fish Flour.Pakistan Journal of Nutrition 9 (6): 531-534.

Amerine MA Pangborn RM and Roessler EB 1965.Principles of Sensory Evaluation of Food, pp. 46–

65, Academic Press, NewYork, NY.

AOAC 1995. Official methods of analysis. Association of Official Analytical Chemists, Inc., Washington, DC, USA.

AOAC 2002. pH 981.12. Official Methods of Analysis (17th ed.). Gaithersburg, Maryland.

AOAC 2005. Official Methods of Analysis of the Association of Official Analytical Chemists International. Editors: Horwitz , W., 18th Edition (AOAC, Washington DC).

APHA 1984. Compendium of Methods for the Microbiological Examination of Foods, 2nd ed. American Public Health Association, Washington, DC

Ayse GI , Nermin K and Ozlem EC 2011. Sensorial, chemical and microbiological quality of anchovy cake .African Journal of Biotechnology, 10(48): 9870-9874.

Azad AK 2001. Formulation and development of fish burger and fish stick from silver carp and their quality evaluation. M. S. Thesis, Department of Fisheries Technology, Bangladesh Agricultural University, Mymensingh, Bangladesh.

Beatty SA. and Gibbons NE 1937. The measurement of spoilage in fish. Journal of Biology Biodiversity Canada, 3 : 77-91.

Boran G and Albayrak N.2010. Regional anchovies foods of the black sea region and seasonal change on proximate composition of anchovy http:// www.biriz.biz/rize/hamsi/mevsimsel degisimler.pdf. (in Turkish).

Brekkan 1996. Fish protein concentrate. Advance in Fish Science and Technology. Pg. Google Website.

Chakraborty R.1984. Changes in the muscle of three IMC during frozen storage. Fish Technol. 21:91-93.

CMFRI 2010. Annual report, 2009-2010. Innovation is the key sustainability and enhanced productivity in any production system. Monograph-Technical report. URI: http://eprints.cmfri.org.in/id/eprint/6344

CMFRI 2017.Marine fish landings in India.Booklet 6/ 2017.

FAO 2003. Fisheries Statistics. http://www.fao.org /fi/ statist/summtab/default.asp.

Folch J, Lees M and Sloane Stanley GH 1957. A simple method for the iso-lation and purification of total lipid from animal tissue. J.Biol.Chem. 226: 497-509.

Gram L. and Huss HH 1996. Microbiological spoilage of fish and fish products. Int. J. Food Microbiol. 33: 121-137.

Hedge JE and Hofreiter BT 1962. Determination of reducing sugars, methods in carbohydrate chemistry, M.L Academy press, New York, 1: 388-389.

Huss HH 1995. Quality and Quality Changes in Fresh Fish. Food and Agriculture Organization Fisheries Technical Paper -348, Food Agric. Organization United Nations, Roma, p. 132.

ICMSF 2005. Microorganisms in Foods 6: Microbial Ecology of Food Commodities, 2nd edition. New York: Kluwer Academic/Plenum Publishers.

Kose S. and Erdem ME 2001. Quality changes of whiting (*Merlangius merlangus euxinus* N., 1840) stored at ambient and refrigerated temperatures. Turkish Journal of Fisheries and Aquatic Sciences, 1: 59-67.

Kumaraguru AK , Kannan R and Sundaramahalingam A 2010. Studies on socioeconomics ofcoral reef resource users in the gulf of mannar coast, South India. No: 015012/29/98/SER. Dt. 7/30, 2010.

Love, R.M. 1992. Biochemical dynamics and the quality of fresh and frozen fish. Fish Processing Technology, Editors: Hall GM, (Chapman and Hall) 1-30.

Lowry OH, Rosenbrough NJ, Farr A and Randall RJ 1951. Protein measurement with the Folin phenol reagent. J Biol Chem 193:265-75.

Ludorf V and Meyer M 1973. Fish and fishery products. Paul Parey- Verlag Berlin and Hamburg, p. 309.

Magnusson H. and Martinsdottir E. 1995. Storage quality of fresh and frozen-thawed fish in ice. Journal of Food Science, 60: 273-278.

Morrissey MT and Tan SM 2000. World resources of surimi. In: J. Park (Ed.), Surimi and Surimi Seafood, Marckel Decker Inc., New York: 1-21.

Muhammet Boran M and Sevim Köse K 2007. Storage Properties of Three Types of Fried Whiting Balls at Refrigerated Temperatures. Turkish Journal of Fisheries and Aquatic Sciences, 7: 65-70.

Nikheel R and Asif P 2013. Biochemical and sensory quality changes of fish cutlets made from Pangasianodon hypophthalmas during storage in refrigerated display unit at -15 to -18oC. International journal of Food, agriculture and veterinary sciences, 3(1), pp. 1-8.

Osibona AO, Akinwande AT, Ozor P and Akande RG 2009. The nutritional composition, sensory evaluation and microbiological studies of fish cake made from shrimp by catch.African Journal of Food Science Vol. 3(7). pp. 177-183.

Palani kumar M, Ruba Annathai A, Jeya Shakila R and Shanmugam SA 2014. Proximate and major mineral composition of 23 medium sized marine fin fishes landed in the Thoothukudi Coast of India. J Nutr Food Sci, 4:1.

Pawar PP 2011. Preparation of battered and breaded product from freshwater fish (*Catla catla*). M.F.Sc thesis submitted to Konkan Krishi Vidyapeeth, Dapoli, Maharashtra state, India

Reddy MA, Elavarasan A , Reddy DA and Bhandary MH

2012. Suitability of reef cod (*Epinephelus diacanthus*) minced meat for preparation of ready to serve product. Advances in Applied Science Research 3(3): 1513-1517.

Ryan, Nacy Ross Bread Microsoft (R) Encarta (R), 2006. (CD) Redmond W.A: Microsoft Corporation, 2005.

Scott DN, Fletcher GC, Charles JC and Wong RJ 1992. Spoilage changes in deep water fish, smooth Oreo dory during storage in ice. International Journal of Food Science and Technology, 27 (5): 577-588.

Serdaroðlu M and Deniz EE 2001. Factors affecting the formation of trimethylamine and dimethylamine in fishes and some fisheries. EU Water Products Magazine, 18: 575- 581.

Tarladgis BG, Watts BM, Younathan MT and Dugan LR 1960. A distillation method for the quantative determination of malonaldehyde in rancid foods. J. Am. Oil Chemist's Soc., 37: 44-48.

Vaishnavi T, Dhanalakshmi B and Chitra, G 2015. Quality attribute of fresh and dry marine edible species from Nagapattinam District, Tamil Nadu, India, Trends in Fisheries Research, 4(1): 2319 - 4758.

Varlýk C 1994. In cold stored sardines determination of histamine level. Food Technology 19: 119- 124.

Wang T, Zhang J and Zhang X 2010. Fish quality evaluation based on temperature monitoring in cold chain. African Journal of Biotechnology. 9(37): 6146-6151.

Yagmur C and Gunes E 2011. http://www.zmo.org.tr/resimler/ekler/ 95f15384c2a79ce_ek.pdf (in Turkish).

Young RH and Romero JM 1979. Variability in the yield and composition of by-catch recovered from Gulf of California Shrimping Vessels. Tropical Sci. 21: 249-264.