Original Research Article

Heat Penetration Characteristics and Shelf Life of Ready to Serve Eel Curry in Retort Pouch

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A B S T R A C T

Ready to serve thermal processed eel fish curry was developed using eel steaks (*Mastacembalus armatus*). The eel curry was packed in an indigenously developed four layered laminated retortable pouch consisting of 12 micron polyester / 9 micron aluminium foil / 5 micron nylon / 70 micron cast polypropylene of size 150x 200 mm and processed in a steam air retort at 121°C. The curry and eel steaks were packed in 60:40 proportion. Time-temperature data from sealed samples was collected during heat processing using a 'Nano Vacq 1 Tc' data logger to record the data during processing. The product was processed for 2, 3 and 4 min at 121°C at the process value of 5.03, 12.89 and 16.75 min respectively. Further, product was analyzed for textural attributes like cohesiveness toughness, succulence and fibrosity and sensory analysis. Based on these analyses, it was observed that, the product processed for 3 min (F_0 value of 12.89 min) with total process time of 55min and cook value 97.65 min gave better textural and sensory characteristics and the product was commercially sterile. The product processed for 3 min was kept for storage to evaluate the shelf life for a period of 8 months. During storage at ambient temperature, biochemical parameters like pH, TVB-N and organoleptic characteristics like appearance, colour, taste, odour and overall acceptability were evaluated. During storage like pH value decreased from 6.7-5.8, whereas TVB-N values increased from 4.20 - 17.07 mg%. The sensory scores for all attributes were decreasing during storage. The product was acceptable for a period of 7 months at ambient temperature of $30\pm2^{\circ}$C.

Introduction

Thermal processing seems to be a good alternative to obtain a shelf-stable product with good nutritional value. Scarce information is available about the effects of thermal processing on the nutritional value of eel (*M. armatus*). There is an increasing consumer demand for high quality convenient ready-to-eat food products and has led to an increase in the commercial production of ready-to-eat products (Kumar *et al.,* 2013). Retort pouch processing technology has been widely recognized as one of the alternatives to metal cans for producing thermal processed shelf stable foods. Value addition and diversification to satisfy the ever changing and diverse demands from the importing countries as well as urban consumers at home are some of the major challenges faced by the Indian

fish processing industry (Manju *et al.,* 2004). Traditionally processed ready-to-eat foods packed in tin and aluminium cans have their own disadvantages like higher price of container, development of metallic flavour and discolouration in the product (Vijayan and Balachandran, 1986). Retort pouch is flexible, laminated package that can withstand thermal processing and has the advantages of cans as well as flexible packages. Thin profile containers like retort pouch facilitate larger surface area which helps to increase the rate of heat transfer into the food and reduce process time and maximize the retention of quality factors of the fish product (Bindu *et al.,* 2011).

Gopal *et al.,* (1986) have studied the suitability of flexible pouch for packing fish pickles. A new packaging medium namely curry was suggested as an alternative to the conventional brine and oil pack for different species of fish (Vijayan and Balachandran, 1986; Vijayan *et al.,* 1998). Bindu *et al.,* (2001) have studied thermal processing of ready to serve masmin curry from skipjack tuna in opaque retortable pouches.

Similar studies were also reported on standardization of ready-to-serve curry products in retort pouch by Gopal *et al.,* (2001) studied the ready-to-serve traditional Kerala style mackerel curry in retort pouch, Ravishankar *et al.,* (2002) have studied heat processing and storage of seer fish curry in retort pouches, Manju *et al.,* (2004) studied the suitability of retort pouches for seer fish moilee, Ravishankar *et al.,* (2008) studied the ready to serve Goan style mackerel curry in retort pouches, Dhanapal *et al.,* (2010) studied the quality of ready to serve tilapia fish curry with PUFA in retortable pouches, Mallick *et al.,* (2010) observed the instrumental and sensory characteristics of Indian white shrimp in curry medium in retort pouch, Bindu *et al.,* (2011) studied the heat penetration characteristics and shelf life of ready to serve

mahaseer curry in opaque retortable pouches and Dileep *et al.,* (2012) have studied the retortable pouch processed squid rings in curry medium, Majumdar *et al.,* (2014) have observed the instrumental and sensory characteristics of catla curry in retort pouch to optimize F_0 value.

One of the main features in appreciating seafood is the texture (Cheret *et al.,* 2005). Texture is rated as an important quality attribute of meat. The importance of texture on the overall acceptability of foods is well known and it directly affects the acceptance by consumers (Xavier *et al.,* 2013). It is also a structural, mechanical and surface properties of foods detected through the sense of vision, hearing, touch and kinesthetic (Szczesniak, 2002).

Present market trends are indicative of extensive demand for ready to cook or ready to serve convenience products processed out of a wide variety of fish and shell fish. One of the ready to serve products is fish curry.

Hence, attempts were made to develop a process for the preparation of eel curry in retort pouches and to study its shelf life and quality characteristics at ambient temperature.

Materials and Methods

Raw material

Fresh eel were obtained from the Ratnagiri fish market. Fishes were put in ice in the ratio of 1:1 (fish: ice) and transported to laboratory in insulated containers.

The fishes were washed thoroughly in potable water and cut into steaks of 4-5 cm size, using knife. In order to remove slime and blood and increase the firmness of fish muscle during thermal processing, these eel steaks were used for the preparation of eel in curry product.

Proximate composition of fresh eel fish meat

Proximate composition i.e. crude protein, crude fat, moisture and ash of the eel fish were analyzed by AOAC (2005) methods.

Preparation of eel curry

Eel curry was prepared following the recipe given in Table 1. The standardized recipe of curry medium was prepared according to Patange *et al.,* (2016). Air from the filled pouch was exhausted by steam flushing (Madhawaraj *et al.,* 1992) and sealed immediately using an impulse heat-sealing machine. These pouches were further processed in an overpressure retort.

Retort pouch

Laminated flexible pouch (4-ply), consisting of 12 micron polyester (outer layer), 9 micron aluminium foil and 15 micron nylon (middle layer) and 70 micron polypropylene (inner cast) was used for packing the fish curry. Pouches (150 x 200 mm) used in the present study were purchased from M/s. Pradeep Laminators Pvt. Ltd. Pune. Maharastra, India.

Overpressure retort

A steam air retort system (KVP Enterprise, TN) was used for the experiment. The retort was operated in the steam/air mixture mode during the sterilization cycle. For heat penetration studies pouches were fixed with thermocouple gland through which thermocouples were inserted. Thermocouple output was measured using 'Nano Vacq 1 Tc' data logger to record the data during processing. The retort temperature was maintained at 121 ^{o}C throughout the heating period. After processing the pouches to required F_0 value, they were cooled rapidly to prevent overcooking as well as survival of any

thermophiles (Ravishankar *et al.,* 2002) till the core temperature of the product reached 55°C by pumping water into the retort and re-circulating it. On completion of retorting wireless data logger was removed from pouch and recorded dada was analyzed by using software 'Qlever 2 lite' to calculate process value and process time.

Thermal process evaluation

Heat penetration data were plotted on a semi log paper with temperature deficit i.e. Retort temperature – Core temperature (RT-CT) on log scale against time. Slope of heating curve (f_h), time in minutes for sterilization at retort temperature (U), final temperature deficit (g) and cook value (Cg) were determined. The process time (B) was calculated by the formula method (Stumbo, 1973). Total process time was determined by adding process time (B) and the effective heating period during come up time i.e. 42% of come-up time of the product. The F_0 value is used as a basis for comparing heat sterilization procedures. It represents the total time-temperature combination received by a food. Among the three different durations (2, 3 and 4 min) tried, the product processed for 3 min was found to have better sensory attributes and textural property and hence samples processing at 121°C for 3 min was chosen for the studies.

Texture profile analysis

The texture profile analysis (TPA) was performed using a cylindrical probe of 5 mm diameter fitted with load cell. Eel steaks were cut into 2.5 cm block for analysis of texture profile. The textural characteristics such as; cohesiveness (ratio of energies expanded in the first and second cycles), toughness, succulence and fibrosity were evaluated after heat penetration study of eel in curry processed at three different durations of

processing for 2, 3 and 4 min. The product were analyzed based on compression of samples with Texture analyzer (Perten Instrument, Sweden; model TVT-300XP) with TexCal texture analyzer software (version 4.0.2.50), was used to objectively evaluate textural differences between treatments. Uniform size eel steaks samples from processed pouches were used for the analysis. The samples were compressed twice to 40% of their original height.

Commercial sterility test

Thermal processed pouches were tested for commercial sterility as per IS 2168:1971. About four pouches selected at random were incubated at 55°C for four days and another four were incubated at 37°C for 14 days. The incubated pouches were opened aseptically and samples were transferred into sterile thioglycollate broth (HiMedia) tubes. Then a layer of sterile liquid paraffin wax was poured in each test tube to create anaerobic conditions. The tubes were then incubated at 37°C for 48 h and observed for turbidity development, which indicates the survival of microorganisms. The tubes were further incubated for 48 h to ascertain sterility.

Sensory test

Sensory analysis was carried out by a 5 member trained sensory panel using a ten point hedonic scale (Vijayan, 1984).

Storage study

Storage characteristics of product were evaluated at ambient temperature at 30±2°C. The product was analyzed periodically every 30 days for changes in pH, TVB-N and sensory characteristics. pH value of the fish pieces was determined by AOAC (2005). TVB-N was determined according to Beatty and Gibbons (1936).The characteristics

covered under the taste panel was appearance, colour, taste, texture, odour and overall acceptability. A sensory score of 5 taken as the limit of acceptability.

Results and Discussion

Proximate composition of fresh eel fish meat

The proximate composition of fresh eel was 77±0.88 moisture, 20±0.5 crude protein, 1.6±0.13crude fat and 1.5±0.05% ash.

Standardization of thermal process parameters for eel steaks in curry in retort pouch

Heat penetration characteristics of eel in curry processed for 2, 3 and 4 min durations at 121°C (Table 2). In all the pouches, the filling weight was maintained at 250 g per pouch. The sterilization values (F_0) were estimated to be 5.03, 12.89 and 16.75 respectively. The F_0 value recommended for thermal processed fish products ranges from 5 to 20 (Pflug and Christensen, 1980; Frott and Lewis, 1994). The slope of heating curve (f_h) values for eel in curry for 2, 3 and 4 min were 8.88, 10.15 and 9.98 min respectively. The number of minutes required to sterilize at retort temperature (RT) (U) were 5.03, 12.89 and 16.75 min respectively. The ratio of slope of heating curve to the number of minutes required to sterilize at RT (i.e. f_h/U) values were 1.24, 0.81 and 0.49. The final temperature deficit (g) values for eel fish in curry were 0.60, 0.52 and 0.32 min respectively. The process time (B) taken to achieve thermal processing at 121°C for 2, 3 and 4 min were 20.20, 12.13 and 13.19 min. The total process time (TPT), which was found out by adding 42% of CUT to B varied significantly with change in sterilization value and it was 63.33, 56.66 and 69.00 min for eel in curry processed at 121°C for 2, 3 and 4 min

respectively. The cook value (Cg) increased significantly with F_0 value and was 70.17, 98.67 and 99.99 min respectively.

Texture profile analysis

The results of TPA of eel steaks in curry processed for 2, 3 and 4 min (Fig. 1). The toughness/hardness for F_0 values of 5.03, 12.89 and 16.75 min was 4.26 ± 0.34, 4.38±0.32and 4.07±0.29 J.m^{-3}. It is observed from the result that the toughness decreased as F0 values increased ($p>0.05$). This may be due to the effect of prolonged heat treatment on breakdown of connective tissue protein leading to softness of the muscle. The values obtained for cohesiveness for eel in curry were 0.42±0.06, 0.45±0.06 and 0.41±0.06 for 5.03, 12.89 and 16.75 min respectively and showed no significant difference ($p>0.05$) when F_0 increased. This value is an indication of internal bonding of the muscle cohesiveness in fish in curry. The succulence values obtained for eel in curry product for 5.19, 12.89 and 16.75 min for processing at 121°C were 3.54, 4.01 and 2.95 g/area respectively. In case of fibrosity, the values for different durations processed at 121°C were 7.99, 8.36 and 8.02 respectively. These decreasing trends of texture profiles were mainly due to the increase in the heat treatment (Majumdar *et al.,* 2015). Sreenath *et al.,* (2008) noted the decreasing in texture profile of shrimp curry processed for different F_0 values at 121°C. Majumdar *et al.,* (2015) observed the decreasing trend in texture profile of rohu curry processed at 121.1^{o}C. Mohan *et al.,* (2006) reported the decreasing trend in texture profile of 'Shrimp Kuruma' in retort pouch and aluminium cans.

Sensory analysis

The sensory scores observed in the present study, indicated that the overall acceptability scores for eel in curry processed for 12.89 min

gave higher values as compared to product processed for 5.19 and 16.75 min (Fig. 2). Significant effect was observed on colour of the product. The sensory scores for colour was 8.3 for 12.89 min which was higher than 5.19 (7.4) and 16.75 (7.5) min processed product.

Similarly, score given for test attribute by taste panel was 8.3 for 12.89 min which was higher than 5.19 min (score 7.8) and 16.75 min (7.6) processed product. The sensory scores for odour was 9.0 for 12.89 min which was also higher than 5.19 (8.5) and 16.75 (8.2) min. The scores for texture was 8.4 for 12.89 min which was higher than 5.19 (7.3) and 16.75 (7.2) min. Ravishankar *et al.,* (2008) carried out sensory evaluation of mackerel curry processed for different F_0 values i.e. 7, 8 and 9 min. Similarly, Dhanapal *et al.,* (2010) observed the sensory scores for tilapia fish paste processed for different F_0 values i.e. 6, 7, 8 and 9 min, Abhilash *et al.,* (2013) observed the sensory score of crab koftha processed for different F_0 values of 5, 6 and 7 min and sensory score for rohu curry processed for different F_0 values of 7, 8 and 9 as observed by Majumdar *et al.,* (2015).

Based on the commercial sterility, sensory evaluation and texture profile analysis, F_0 value of 12.89 min for 3 min duration was found satisfactory for the preparation of eel steaks in curry in retort pouches (Table 3 and Fig. 3). The product was kept for storage study to evaluate the shelf life at ambient temperature (30±2°C).

Storage studies of eel steaks in curry in retort pouch

Changes in biochemical characteristics

The change in the pH values of eel curry during storage at ambient temperature (Table 4). The pH values of eel steaks in curry decreased from 6.7 to 5.8 during storage.

Table.1 Recipe of standardized curry medium

Sr. No.	Ingredient	Quantity
1	Fresh eel	400 g
2	Raw coconut	¾ size
3	Green chilly	10 g
4	Dried whole red chilly	10 g
5	Garam masala mix	20 g
6	Turmeric powder	1 g
7	Coriander Seed	10 g
8	Onion	1 no.
9	Garlic, Ginger	6 pieces
10	Refined oil	100 ml
11	Salt	12 g
12	Semi-dried kokam (*Gracinia indica*)	4 pieces
13	Chirphal powder (*Zanthoxylum rhetsa*)	2 g
14	Fresh coriander leaves	2 g
15	Water	200

Table.2 Heat penetration characteristics of eel steaks in curry processed at 121°C

Sr. No.	Heat penetration characteristics	Processing duration		
		2 min	**3 min**	**4 min**
1	F_o	5.03 ± 0.07	**12.89± 0.79**	16.75 ± 1.33
2	f_h (min)	8.88 ± 0.36	**10.15± 0.50**	9.98 ± 0.37
3	U (min)	5.03± 0.71	**12.89± 0.79**	16.75± 1.33
4	f_h/U	1.24± 0.16	**0.81± 0.03**	0.49± 0.05
5	g ^{o}C	0.60± 0.04	**0.52± 0.02**	0.32± 0.05
6	Cg (min)	70.17± 0.53	**98.67 ± 2.13**	99.99± 2.53
7	B(min)	20.22± 0.60	**12.13 ± 0.41**	13.19± 0.29
8	CUT (min)	10.73± 0.29	**8.22± 0.17**	6.79± 0.32
9	TPT	63.33 ± 7.26	**56.66± 7.26**	69.00±4.58

(All values are expressed as mean ± standard error)
F_0- Sterilization value, fh- slope of heating curve, U- Time in min for sterilization at retort temperature, g- Final temperature, B- Process time, CUT- Come up time, Cg- Cook value, TPT- Total process time

Table.3 Heat penetration characteristics of eel in curry product processed for 3 min at 121°C

Sr. No.	Process parameters	Processed for 3 min duration
1	F_0	12.89
2	fh (min)	10.15
3	U	12.89
4	fh/U	0.81
5	g^{o}C	0.52
6	Cg (min)	98.67
7	B (min)	12.13
8	CUT	8.22
9	TPT	56.66

Table.4 Changes in pH values of eel in curry product during storage at ambient temperature

Storage period (Months)	pH
0	6.6 ± 0.1
1	6.4 ± 0.1
2	6.2 ± 0.1
3	6.1 ± 0.1
4	6.1 ± 0.1
5	6.0 ± 0.5
6	5.9± 0.1
7	5.8 ± 0.1
8	5.7 ± 0.1

Table.5 Changes in TVB-N content of eel in curry product during storage at ambient temperature

Storage period (Months)	TVB-N
0	4.20 ± 0.30
1	5.57 ± 0.06
2	6.12 ± 0.35
3	6.83 ± 0.13
4	7.68 ± 0.17
5	9.48 ± 0.53
6	12.03 ± 0.10
7	14.03 ± 0.71
8	17.07 ± 0.17

Fig.1 Texture profile attributes of eel steaks in curry processed for 2, 3 and 4 min at 121°C
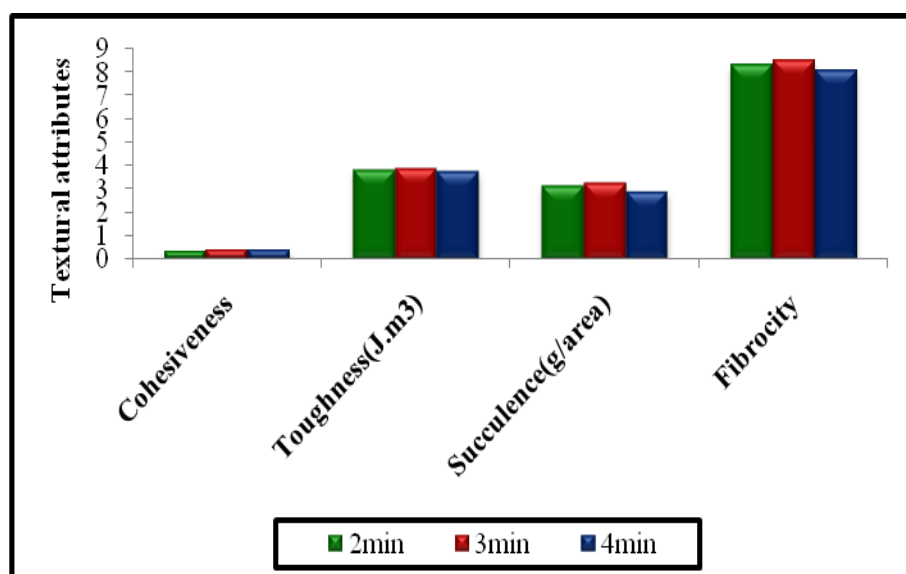
Fig.2 Sensory characteristics of eel steaks in curry processed for 2, 3 and 4 min at 121°C
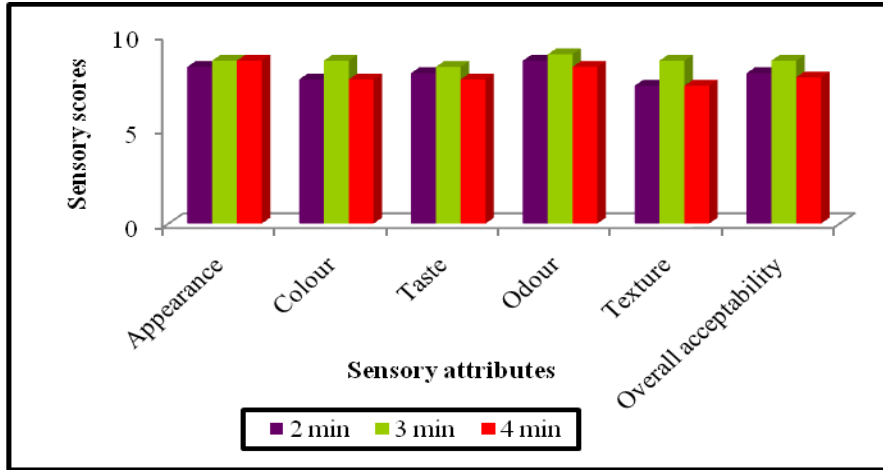

Fig.3 Heat penetration characteristics of eel steaks in curry processed for 3 min
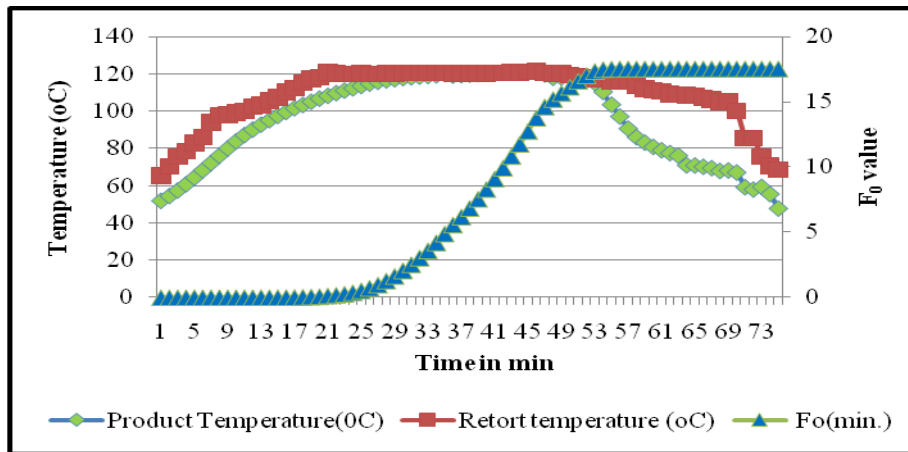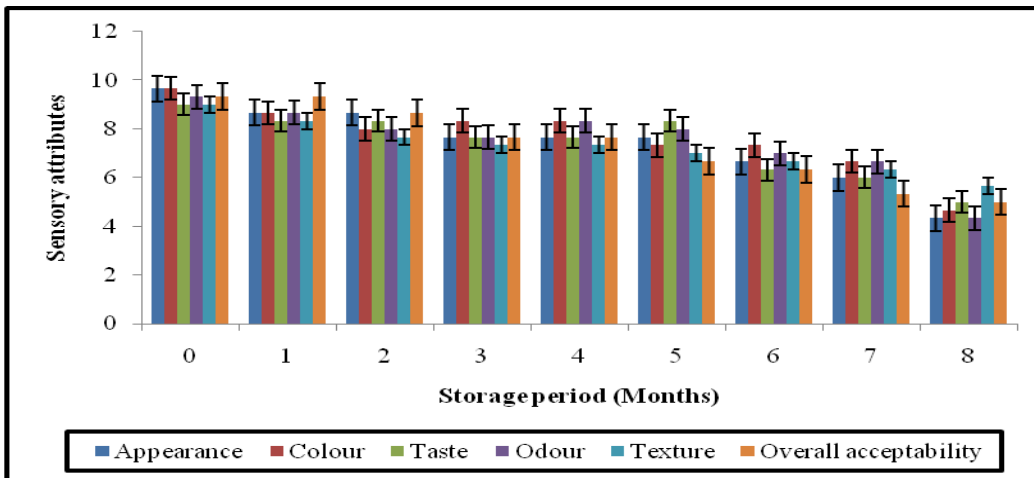

Fig.4 Changes in sensory score of eel steaks in curry during storage at ambient temperature

The commonly observed decrease in pH might be due to degradation of proteins and liberation of free amino acids (Rajan *et al.,* 2011). The results are in accordance with the studies conducted by Mohan *et al.,* (2006) has reported a slight reduction in the pH of shrimp kuruma upon storage in both retort pouch and aluminium cans.In case of mackerel curry packed in retort pouch, Mallick *et al.,* (2006) observed decrease in pH values from 5.8 to 5.43 at room temperature and 5.65 to 5.55 at 37°C during 6 months storage of rohu in curry medium using polyester-coated tin free steel cans. Similarly Ravishankar *et al.,* (2008) and Tribuzi *et al.,* (2015) observed decreasing trend in pH values from 5.5 to 5.25 and 6.72 to 6.63 during 12 months storage of Goan style mackerel curry in retort pouch and 52 weeks storage of chopped mussel meat in retort pouch respectively.

The TVB-N values of eel steaks in curry increased progressively from initial values of 4.2 to 17.07 mg% at the end of 8 months of storage at ambient temperature (Table 5). This may be attributed to the breakdown of proteins, amino acids and other nitrogenous compounds during thermal processing (Kovalchuk, 1954). Dileep *et al.,* (2012) observed increase in TVB-N content from 20 to 24.3 mg% in thermal processed squid rings in curry medium during 90 days at ambient temperature. Akande and Faturoti (2009) also noted increase in TVB-N content from 25.94 to 45.63 mg% and 22.17 to 42.37 mg% in canned Bonga in oil and also in tomato sauce respectively during 36 months of storage in cans. Chandra *et al.,* (2012) observed the increase in TVB-N content of ribbon fish in TFS cans from 4.55 to 20.18 mg% during 5 months of storage. Dinakaran *et al.,* (2017) reported increase in TVB-N values of mackerel curry in semi rigid containers from 14 mg% in the 1st month to 34.7 mg% in the 14th month of storage.

Changes in sensory characteristics

Sensory evaluation of eel in curry processed for 3 min of F_0 value of 12.89 at 121°C was carried out at an interval of 30 days (Fig. 4) The score for appearance decreased from 9.67 to 4.33 at the end of 8 months of storage. The score for colour decreased from 9.67 to 5.78 at the end of storage. The score given for taste also decreased from 9.00 to 5.00 at the end of storage. Sensory score for odour was lowered from 9.33 to 4.33 at the end of storage. The score for texture decreased gradually from 9.00 to 5.67 at the end of storage. The sensory score for overall acceptability decreased from 9.67 to 5.00 at the end of storage. The visual observations of the product revealed that, colour of the product did not change and texturally the fish steaks were intact up to 6th month of storage, after that the colour of the curry faded out towards the end of the storage. These observations were reflected in the colour score of the product as the colour score decreased drastically towards the 8th month of the storage. Moreover, there was disintegration of the fish steaks towards the end of the storage which was observed in the 7th month of storage in the eel in curry packs. Decreasing trend in sensory scores during storage of thermal processed product have been reported by Gopal *et al.,* (2001) for traditional style mackerel curry, Mallick *et al.,* (2006) in rohu cury, Bindu *et al.,* (2007) in clam meat and Ravishankar *et al.,* (2008) in Goan style mackerel curry. Dileep *et al.,* (2012) noted the sensory analysis for squid ring in curry in retort pouch and showed a marginal decrease in all attributes after a period of 90 days of storage.

The retort pouches are suitable for packing eel curry. The biochemical and sensory characteristics of the product were satisfactory during storage. Eel curry processed for 3 min duration with an F_0 value of 12.89 min was found to be ideal with

respect to all the parameters. The product was found to have storage stability at ambient temperature (30 ± 2°C) with desirable organoleptic characteristics.

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