

**STUDIES ON THERMAL PROCESSING OF TUNA-A COMPARATIVE
STUDY IN TIN AND TIN-FREE STEEL CANS**

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ABSTRACT

Tin-free steel can is an ideal alternative to open top sanitary tin cans (OTS) for thermal processing of little tuna (*Ethynnus affinis*) in curry used as filling media. Effect of heat penetration on physical, biochemical and sensory characteristics of canned tuna product were studied. The chemical analysis of raw tuna fish showed a protein content of 24.20 % and a lipid content of 1.37%. Comparatively, tuna used in the present study is more suitable for canning due to the presence of more protein and less fat in its flesh. Precooking is an important step in general canning process as it serves to reduce moisture content along with inhibiting enzymatic reaction, decreasing microbial load and cleansing the meat. The protein content of precooked tuna was 2.92% more than raw tuna due to relative concentration of moisture content decreases due to precooking. The percentage of yield of light meat and dark meat was 36.58% and 10.18% from whole cooked tuna and the same for dark and white meat was 28.40%. Tuna in curry packed in two metal containers subjected to thermal processing at 115⁰C for 70 minutes. The F₀ (slowest heating point) values for canned tuna in curry packed in TFS and Tin cans obtained were 10.13 and 10.23 minutes and cook values were 145.5 minutes & 153.6 minutes respectively. During the storage period, the total volatile base nitrogen, trimethyleamine nitrogen, free fatty acid values were found to increase, while thiobarbituric acid value decreased and pH was slightly acidic. There was no significant difference (p<0.05) in appearance, colour, odour, taste, flavour, texture, overall quality of the raw tuna and final products. However, both canned products were acceptable even after storage of 5 months at ambient temperature and also, the product remained commercially sterile. It was concluded that according to quality of the product and heat penetration studies, tin-free steel container can be used as alternative to the open top sanitary tin cans for canning tuna meat.

Key words: Cooking, Curry, Quality, Shelf-life, Storage

INTRODUCTION

Canning is an art of preserving foods and the industry expanded based on trial and error basis and skill of individual canners. During the 1990's, this method received much scientific scrutiny and has now developed into a sound and established technology to produce commercially sterilized safe foods having an almost infinite shelf life.

Tuna contains higher biological protein than beef and is one of the best sources of dietary amino acids. Further, tuna flesh contains substantial quantities of vitamins B₁₂, A and D and is also a rich source of phosphorous, iodine and fluorine [1]. Canned fish may be considered an excellent source of vitamin D [2].

The use of tin-free-steel (TFS) cans for thermal processed foods is one of the most recent developments in the fish canning industry. Tin-free steel can is an alternative to open top sanitary tin cans (OTS) and aluminium cans, which have disadvantages like high price of the container, imperfect lacquer coating, discolouration of the product, dissolution of metals in the food upon storage and resultant development of metallic taste in the product. The health problems associated with ingestion of food contaminated with metals and the components leaching out of the epoxy resinous coating like bisphenol-A are well documented [3, 4, 5]. The higher container cost in the case of tin cans is due to the limited geographical distribution of tin resources, which raise the cost of the container [6]. The higher price of container has resulted in the collapse of the fish canning industry in developing countries like India. Hence, the chromium coated steel plate acts as an alternative to tin plate for canning of seafood products and has gained prominence [7]. Tin-free-steel cans have easy to open ends and are coated inside with a polymer that does not react with products [8].

At present, value addition is of utmost importance in the fish processing industry because of the realization of high unit value of such products. Thermal processing of fish in curry medium has been attempted by several workers. Ready to eat foods were traditionally processed in rigid containers like tin and aluminium cans [9, 10]. The shelf life of formulated fish curry packed in a retort pouch at room temperature was recorded as around 12 months [11]. Also, the North Indian style curry medium for packing of rohu in tin-free-steel cans was standardized [8]. Mohan *et al.* [12] had developed a thermal processed shrimp kuruma in retort pouch [12]. Moreover, ready-to-eat squid masala packed in locally made coated tin-free-steel cans also exists in South India [13].

The present investigation work was aimed at standardizing the canning process for little tuna, packed in two different metal containers (tin and TFS cans) using curry as a filling medium. The cans underwent a vacuum seaming process and then thermally processed at 115⁰C for 70 min after which a comparative heat penetration study was carried out between the two canned products. Both canned products were stored at room temperature (28 ± 2⁰ C) and sensory, biochemical and microbiological analyses were performed on monthly basis for a period of 5 months.

MATERIALS AND METHODS

Raw materials

Little tuna (*Euthynnus affinis*) procured from Mangalore fish landing centre and caught from the Arabian Sea along the west coast of India, was brought to the laboratory in iced condition. After removing head and viscera, it was kept in running water for removal of blood.

Containers

The containers used for packing the products were Open Top Sanitary (OTS) 8 oz tin cans with SR- lacquer manufactured and supplied by M/S Poysha Industries, Ltd., India and two piece Easy Open End 6 oz TFS cans were obtained from AM-Tech pack, Mysore, India.

The TFS can is made up of Electrolytic Chromium Coated Steel (ECCS) plate with clear Polyethylene Terephthalate (PET) coating on either side of the finished plate has a thickness of 0.19 mm. Both the cans were washed thoroughly by using soap detergent solution as well as fresh water to remove the adhering impurities and dried well to remove the traces of water.

Heat penetration assembly

Before filling the cans, Ellab SSA – 12050-G700-TS stainless steel electrode was fixed at the geometric centre of the TFS and tin cans. The product was packed into the cans, exhausted and sealed with a vacuum seamer.

The time-temperature measurement during the sterilization process was carried out using Ellab CTF 84 data recorder connected to printer. The heat penetration data included retort temperature, product temperature, F_0 value and cook value at the time of one min during thermal processing at 115° C for 70 minutes.

Curry preparation

Three different types of curry recipe were prepared as the filling media and analysed by a panel of 8-10 judges based on the sensory scores (Appendix I). One among the recipes was selected as a filling medium based on the above sensory scores. The curry was prepared as per the method given by Mallick *et al.* [8]. The contents of the recipe are given in Table.1.

Precooking of dressed tuna

Dressed fish was precooked in steam pressure of 10 psi for 60 minutes to attain a temperature of 90-92⁰C at central bone surface to soften the fish muscle for separation of dark meat from the whole tuna and kept at 4-6⁰ C in a refrigerator overnight [14]. The skin was separated off from the precooked tuna and was split dorsoventrally along the lateral line to get loins. Red meat, lying along the lateral line was removed manually and white meat was carefully separated from the cooked tuna loins.

Preparation of cans for thermal processing

The thermal processing study was carried out at Central Institute of Fishery Technology, Cochin, India. To prepare test cans for the heat penetration study, can body was perforated by means of a punching tool for side entry and the packing gland was tightly screwed into the can body with a rubber gasket so as to make the joint air proof. The position of the perforation was such that the thermocouple tip would be at the predetermined cold spot to record the core temperature, F_0 value and cook value of the canned tuna in curry product. With the standard operation achieved by the above experiment, final canned products were prepared for the storage study. Separated light meat of precooked tuna pieces about 110 g was filled in TFS and tin cans with standardized hot curry (90°C) weighing about 60 g. Both cans were maintained with a uniform net weight of 170 g and vacuum sealed with an automatic vacuum seamer and subsequently subjected to thermal processing. Canning procedure for tuna is given in figure 1.

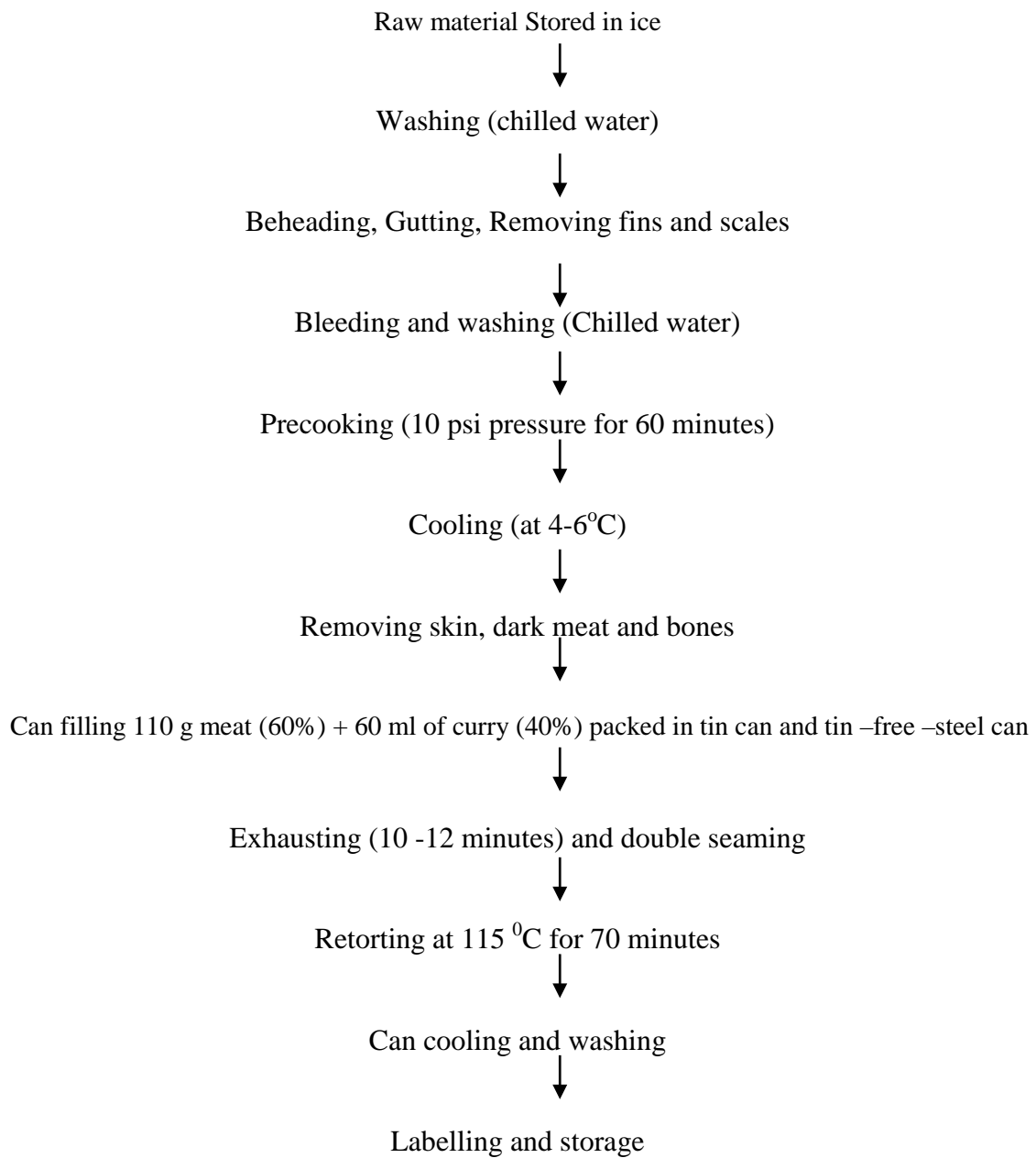


Figure 1: Tuna canning in curry packed in tin and TFS containers

Biochemical analysis of sample

Moisture content of the fresh and final products of tuna was determined according to AOAC method [15]. Crude protein was determined by following the method suggested by Kjeldhal [15]. Crude fat content of the sample was determined according to the procedure described by Bligh and Dyer [16]. Ash content was determined by heating the sample at 550°C for 4-6 hrs using a muffle furnace [15]. Determination of TVB-N (Total volatile base nitrogen) and TMA-N (Trimethylamine nitrogen) was made by following the Conway diffusion method [17]. Free Fatty acid in the lipid extract was determined by the improved titrimetric method [18]. Thiobarbuteric acid value of fish sample was determined spectrophotometrically [19], while pH of the sample was measured according to the method given by Suzuki [20].

Sensory evaluation

The sensory analysis of fresh cooked little tuna as well as finished products were carried out using a 10-point hedonic scale by 8-10 trained taste panellists [21]. The scoring of the product was done based on the scorecard given in Appendix I.

EXPERIMENTAL RESULTS

Physical, biochemical, microbiological and sensory characteristics of raw tuna

The physical, biochemical and sensory characteristics of raw tuna are given in Table 2. The fish used had an average total length of 40.45 cm, average standard length of 34.95cm and average weight of 1.01kg. Organoleptic scores of raw tuna based on a 10 point hedonic scale were 8.9 for appearance, 8.5 for colour, 8.65 for taste, 8.25 for texture, 8.75 for odour and 8.5 for overall acceptability.

The biochemical parameters of TVB-N and TMA-N of fresh tuna were found to be 6.10 mg% and 2.5 mg% respectively. The pH of the fish meat was 6.02, FFA and TBA contents were 3.5% as oleic acid and 0.10 mg of melonaldehyde/kg, respectively. Total plate count found in the fresh fish was 4.45×10^4 cfu/g.

Yield at different stages of processing

The yield of dressed tuna meat (after removal of head, viscera and fins) from the whole round tuna was 69.2% and pre-cooking yield of dressed tuna meat was 50.36%. The separated dark and white meat yield was 10.18% and 36.58%, respectively (Table 3).

Proximate composition of raw tuna and precooked tuna

Moisture and ash contents of the fresh raw tuna were 73.10% and 1.43%, respectively. The fish had a high protein content of 24.20% and low fat content of 1.37% indicating that the fish is a lean variety. In precooked tuna, moisture content decreased to 69.98% and protein increased to 27.12%. Fat and ash contents of precooked tuna were 1.50% and 1.40%, respectively. Proximate composition of raw and precooked tuna are given in the Table 4.

Standardization of Thermal processing

The tuna meat in curry, packed in TFS and OTS tin cans were processed at 115°C for 70 minutes to study the rate of heat penetration characteristics. The results of the study such as retort temperature, product temperature, F₀ value and cook value were recorded at an interval of 1 minute and heat penetration profile of these parameters are presented in figures 2A, 2B, 3A, 3B.

Canned tuna in curry medium and packed in TFS and OTS tin cans had a F₀ value of 10.23 minutes and 10.13 minutes, respectively. The F₀ value was calculated using Ball and Olson formula method and also by Patashnik method [22]. The heat penetration characteristics with reference to cook value (C_g) were found to be 145.5 minutes for tuna in curry medium packed in TFS can and 153.6 minutes for tuna in curry medium and packed in tin can (figures 2A, 2B, 3A, 3B).

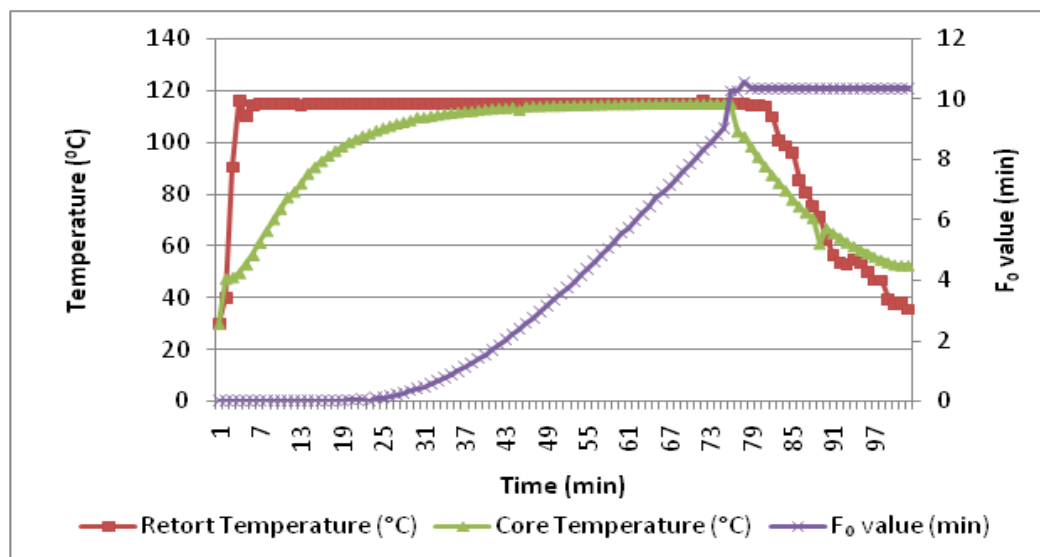


Figure 2A: Heat penetration characteristics with respect to F₀ value of canned tuna in curry in TFS can

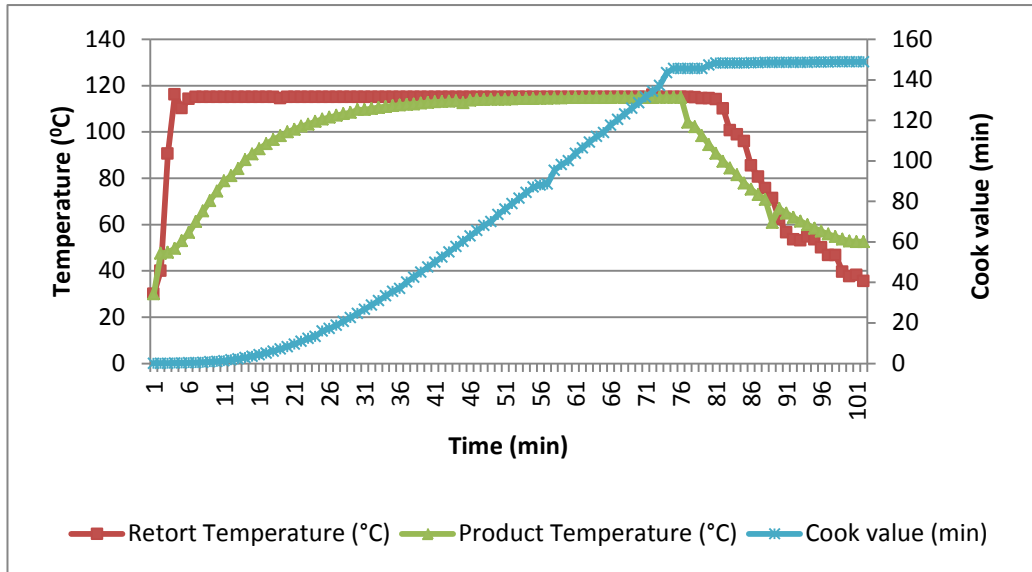


Figure 2B: Heat penetration characteristics with respect to cook value of canned tuna in curry in TFS can

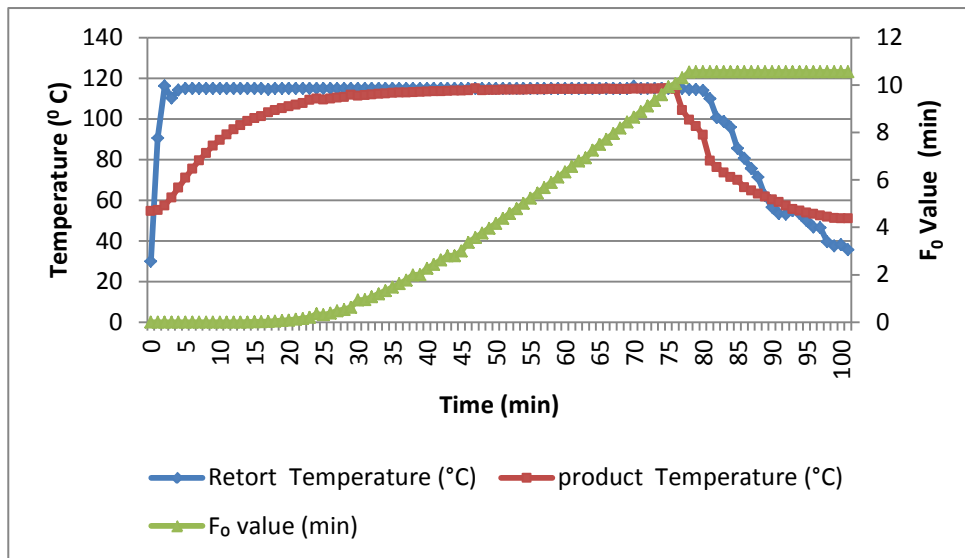


Figure 3A: Heat penetration characteristics with respect to F₀ value of canned tuna in curry packed in tin can

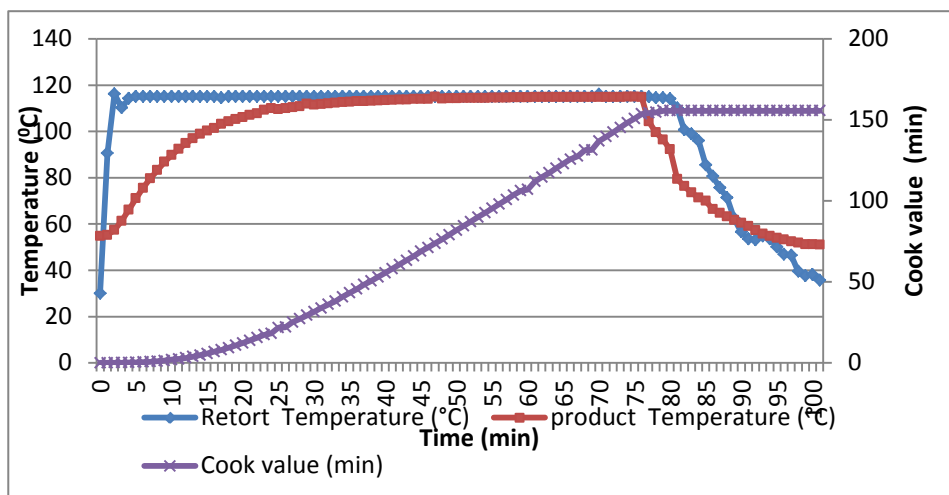


Figure 3B: Heat penetration characteristics with respect to cook value of canned tuna in curry in tin can

Evaluation of quality characteristics of canned tuna products after processing and during storage

Proximate composition

Changes in chemical and biochemical characteristics of canned tuna during storage period are presented in the Table 5. Initially the moisture, protein, fat and ash contents of freshly prepared tuna in curry packed in TFS cans were 72.39%, 24.29%, 1.50% and 1.82% of ash, respectively, and the respective contents observed were 72.90%, 24.10%, 1.46% and 1.54% at the end of 5 months of storage period. Proximate composition of tuna samples in curry packed in OTS tin cans were 71.10% of moisture, 25.64% of protein, 2.02% of fat and 1.23 % of ash which at the end of 5 months storage period were found to be 69.53%, 26.32%, 2.40% and 1.75, respectively.

Biochemical characteristics of canned tuna

The results of TVB-N and TMA-N analysis were presented in the Table 5. Initial TVB-N & TMA-N values of tuna in curry medium and packed in TFS can were 21.8 mg% and 7.26 mg% which increased up to 27.3 mg% and 12.3 mg %, respectively. Similarly, the TVB-N & TMA-N values for Tuna in curry medium and packed in Tin can were 20.5 mg% and 8.5 mg%, which increased up to 26.95 mg% and 11.6 mg% respectively at the end of 5 months of storage period.

The initial FFA content of freshly prepared canned tuna in curry packed in TFS and OTS tin cans were 3.07% and 3.57% of oleic acid and increased to 6.50% and 7.2% of oleic acid. The TBA values of canned tuna showed a slightly decreasing trend upon storage period (Table 5). Thiobarbuteric acid value of freshly prepared canned tuna in curry packed in TFS and OTS tin containers were 0.315mg and 0.329 mg of

melonaldehyde/kg of sample, and decreased to 0.239 and 0.243 mg of melonaldehyde/kg of sample respectively at the end of 5 months of storage period.

Changes in pH

The changes in the pH of the canned tuna are presented in the Table 6. pH of the freshly prepared canned tuna in curry packed in TFS and tin containers were 5.98 and 5.91, which decreased to 5.38 and 5.41, respectively at the end of 5 months.

Changes in organoleptic characteristics of canned tuna

Table 7 gives mean panel scores of canned tuna in curry packed in TFS and tin can. It was observed that mean panel scores for appearance, colour, odour, taste, texture and overall quality decreased slightly during 5 months of storage period in both cans. However, scores for all these characteristics can be considered as good for all the products at the end of 5 months of storage period. Among the organoleptic attributes, there was not much difference between the tuna in curry packed in TFS and tin can.

DISCUSSION

The length of little tuna used in the present study was 40.45 cm which is lower than 52 cm [23]. The yield of dressed meat in the present study was 69.2%, when compared to the yield obtained by the author who reported a dressed meat yield of 83.6% and dark meat yield of 20% in cooked skipjack tuna [24]. However, the white meat yield 36.4% reported was almost comparable to the present study.

Biochemical composition of fresh tuna sample

The proximate composition of fish and shellfish depends on several factors like diet, size, physiological state of fish and ecological conditions [25]. The results of the present investigation on proximate composition of fresh little tuna (*Euthynnus affinis*) agreed with earlier work carried out on proximate composition of the same species [23]. Tuna meat is high in biological value protein [24]. The variation of fat content can be attributed to species difference, food and feeding habit and season of harvest [26].

The value of 30 mg% for TVB-N and 15 mg% for TMA-N is considered as the limit for acceptability of freshness of fish [25]. As the values obtained in the present study are much less than acceptable limits for freshness of fish, the raw material used in the study can be considered of prime quality.

F₀ value and Cook value of canned tuna products

For the attainment of microbiologically stable state, the amount of heat received by the product during thermal processing needs to be verified. This is determined by the temperature profile within the product during thermal processing. The recommended F₀ values for fish and fishery products range from 5 to 20 minutes [27]. In smoked tuna canned in brine and oil used as the filling media and packed in retort pouches, heat penetration was faster in the brine pack compared to the oil pack [28]. In case of rohu (*Labeo rohita*) in curry packed in TFS cans have obtained an F₀ value of 8.79 minutes and the authors opined that the thermal process was adequate [8]. In the

present study, the obtained F_0 value was satisfactory for both the canned tuna products with reference to sensory attributes and commercial sterility. The F_0 value of 10 min obtained showed not much difference between the tuna in curry packed in TFS can and tin can.

Cook value is the measure of heat treatment with respect to nutrient degradation and textural changes during processing. Cook value is determined by measuring the extent of cooking and nutritional loss during processing in a manner similar to the D value, except that the reference temperature is 100°C instead of 121°C and Z value is 33°C [29, 30].

Biochemical changes in the canned tuna products during storage period

Canned tuna in brine, oil and tomato sauce packed in tin cans did not show any difference in their proximate composition even after one year of storage [24]. The moisture content of rohu (*Labeo rohita*) in curry was almost the same throughout the storage period [8].

Thermal processing caused an increase in TVB-N and TMA-N values in both the canned tuna products during the present investigation. The increase could be due to the breakdown of proteins, amino acids and other nitrogenous compounds such as trimethylamine oxide, nucleic acids and amines present in the foods which received thermal processing [31]. Changes in TVB-N and TMA-N during canning of albacore (*Thunnus alalunga*) tuna and reported that increase in total volatile base nitrogen and loss of trimethylamine oxide [32]. Several authors are of the opinion that heat processing in general increases FFA content on storage [33, 34]. Mathews *et al.* [35] conducted a comparative study of ground-nut oil packed in TFS and in tin containers; they found no significant difference in FFA value and quality of oil between the two containers [35]. A significant formation of free fatty acids occurred during the sterilization of different muscle zones of albacore tuna as reported by Aubourg *et al.* [36]. A decreasing trend in TBA value has been reported in canned fish [37, 38]. The decrease in TBA value of canned fish meat might be due to dilution of secondary oxidation product by the fill oils, or their extraction from the meat to the fill oils [36]. However, in case of canned tuna products, the decreasing trend in TBA content may be due to the dilution of secondary oxidation product by the filling medium (curry). The pH decreased slightly in rohu curry packed in TFS container and this effect was due to the acidic compounds present in tomato and spices used in the curry preparation [8]. Similarly in the present study, the decreased pH of tuna in curry packed in tin and TFS cans may be attributed to the same acidic compounds present in the curry ingredients.

In the present investigation, there was not much difference in biochemical characteristics of canned tuna in curry packed in TFS can and OTS tin cans. Hence, both the canned tuna curry products did not show marked changes in the quality during the storage period. Therefore, it can be concluded that there was no effect of containers on the final product.

Sensory characteristics

Thermally processed rohu curry in TFS cans was acceptable even after one year of storage with respect to sensory and biochemical parameters [8]. The quality of mackerel in brine with respect to organoleptic quality was acceptable when packed in TFS cans for up to 12 months of storage at 37⁰C [39]. In the present study, the organoleptic quality of canned tuna products was good as judged by sensory evaluation. There was no significant difference in the appearance, colour, odour, taste, texture, overall quality ($p < 0.05$) of product in the tin can and in the TFS can during storage. The organoleptic quality of both the canned tuna products was good even after storage of 5 months at room temperature.

CONCLUSION

There was not much difference between OTS tin can and TFS can products, taking into consideration the heat penetration studies and quality of the final product even after storage of 5 months at room temperature. Therefore, canners can adapt the Easy Open End TFS cans as an alternative to the high priced tin container for canning tuna. With this adoption, the fish canning industry may look forward to the use of the TFS cans for revival of the canning industry in India. Also, it may increase the demand for ready-to-serve canned tuna in curry products as well as the developments of diversified canned products for the domestic market.

ACKNOWLEDGMENT

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Table 1: Standardized tuna curry recipe

Ingredients	Quantity (g)
Dressed fish	1000
Onion	50
Garlic	15
Ginger	25
Coriander powder	30
Chilli powder	60
Turmeric powder	4
Mustard	2
Oil	50
Salt	20
Cumin	4
Pepper	4
Tomato	150
Water	1000ml

Table 2: Biochemical, microbiological and sensory characteristics of raw tuna

Biochemical characteristics		Sensory characteristics	
Parameters	Fresh Raw material	Sample characteristics	Score (out of 10)
TVBN (mg%)	6.10	Appearance	8.9
TMAN (mg %)	2.5	Colour	8.5
pH	6.02	Taste	8.65
Free fatty acid value (% of oleic acid)	3.5	Texture	8.25
TBA mg (melonaldehyde/kg)	0.10	Odour	8.75
Total plate count (cfu/gm of meat)	4.45 X 10 ⁴	Overall acceptability	8.50

Table 3: Yield of the different parts of tuna as a percentage of starting raw tuna fish

Materials	Weight (kg)	Percentage (%)
Whole fish	10	100
Dressed meat waste	0.674	6.7
Dressed meat yield	6.92	69.2
Pre-cooked fish	5.036	50.36
Dark meat	1.018	10.18
White meat	3.658	36.58

Table 4: Proximate composition of raw and precooked tuna

Parameters	Raw tuna meat	Pre cooked tuna
Moisture (%)	73.10	69.98
Protein (%)	24.20	27.12
Fat (%)	1.37	1.50
Ash (%)	1.43	1.40

Table 5: Changes in proximate composition during storage of canned tuna in curry packed in TFS and tin can

Parameter/storage	Product name	Months					
		0	1	2	3	4	5
Moisture (%)	TCTFS	72.39	73.01	72.35	73.01	72.15	72.90
	TCT	71.10	73.50	70.95	71.25	70.20	69.53
Protein (%)	TCTFS	24.29	24.30	24.10	24.35	24.92	24.10
	TCT	25.64	25.03	24.50	24.95	25.95	26.32
Fat (%)	TCTFS	1.50	1.49	1.91	1.41	1.30	1.46
	TCT	2.02	2.15	2.80	2.39	2.99	2.40
Ash (%)	TCTFS	1.82	1.20	1.65	1.33	1.23	1.54
	TCT	1.23	1.50	1.55	1.41	1.86	1.75

TCTFS: Tuna in curry in TFS can

TCT: Tuna in curry in Tin can

Table 6: Changes in biochemical characteristics of stored canned tuna

Parameter	Products name	Months					
		0	1	2	3	4	5
TVB-N (%)	TCTFS	21.80	20.7	22.4	25.2	25.7	27.3
	TCT	20.5	22.6	22.55	23.95	24.32	26.95
TMA-N (%)	TCTFS	7.26	8.4	9.0	10.2	11.6	12.3
	TCT	8.5	8.8	9.56	10.5	10.98	11.60
FFA % as oleic acid	TCTFS	3.07	3.69	4.15	4.68	4.98	6.50
	TCT	3.57	4.02	4.56	5.5	6.5	7.2
TBA mg of melonaldehyde/kg of sample	TCTFS	0.315	0.291	0.275	0.253	0.235	0.239
	TCT	0.329	0.312	0.287	0.265	0.256	0.243
pH	TCTFS	5.98	5.65	5.63	5.54	5.37	5.38
	TCT	5.91	5.79	5.63	5.56	5.44	5.41

TCTFS: Tuna in curry in TFS can; **TCT:** Tuna in curry in Tin can

Table7: Organoleptic scores of canned tuna in curry in TFS and tin can

Parameter	Type of cans	Months					
		0	1	2	3	4	5
A	TCTFS	8.5	8.03	8.8	7.89	8.2	7.8
	TCT	8.66	8.41	8.3	8.5	8.0	8.1
Colour	TCTFS	8.03	8.50	8.26	8.05	7.5	7.1
	TCT	8.5	8.66	8.45	8.05	7.9	7.8
Odour	TCTFS	8.13	8.61	8.35	8.45	7.9	7.89
	TCT	8.16	8.50	7.91	7.56	8.15	8.1
Taste	TCTFS	8.06	8.15	8.33	8.41	8.2	7.82
	TCT	8.16	8.30	8.56	8.3	8.41	7.9
Texture	TCTFS	8.56	8.39	8.16	8.21	8.05	7.98
	TCT	8.66	8.45	8.26	8.35	8.15	8.62
Overall Quality	TCTFS	8.56	8.25	8.53	8.42	8.37	8.21
	TCT	8.30	8.45	8.35	8.21	8.1	7.65

TCTFS- Tuna in curry packed in TFS can

TCT-Tuna in curry packed in Tin can

Appendix 1

Scorecard for sensory evaluation canned tuna in curry packed in tin and TFS cans

Assessor: -----

Date:

Sample number:

Attribute description	Attribute Score
Excellent	10
Very good	9
Good	8
Moderately good	7
Neither good nor bad	6
Slightly rancid, bitter or other off flavours	5
Moderately rancid, bitter or other off flavours	4
Strong rancid, bitter or other off flavours	3
Very strong rancid, bitter or other off flavours	2
Extremely rancid, totally unacceptable	1

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