An investigation on the quality and handling practices of skipjack tuna (*Katsuwonus pelamis*) along the main commercial distribution channels of Beruwala fishery harbour

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Abstract

Beruwala fishery harbour is one of the main fish-landing sites in Kalutara district in the southwestern coast of Sri Lanka. Skipjack tuna (*Katsuwonus pelamis*) is one of the major constituents of the catch of multi-day boats (MDBs) operated from this harbour. The marine fish catch landed in this district in 2001 was around 32110 mt. Recent studies based on sensory evaluation have shown that the post harvest loss of skipjack tuna at Beruwala fishery harbour is around 27±11.5%. Main objective of this study was to investigate the quality deterioration of skipjack tuna at different handling stages along the main commercial distribution channel starting from MDBs operating from Beruwala fishery harbour to final retailing stage that ends up at Matugama and Horana and to suggest remedial measures to reduce the quality deterioration along the handling chain. Mean Aerobic Plate Count (APC) of skinned fish from MDBs and pier were log 5.20±1.10 cfu/g and log 5.35±1.20 cfu/g respectively. APC of fish from transport vehicle, fish stall and retailed stage along Matugama channel were log 6.16±0.94 cfu/g, log 7.08±0.96 cfu/g and log 6.96±0.46 cfu/g respectively. In Horana distribution channel mean APC were log 5.14±0.71 cfu/g, log 6.13±0.49 cfu/g and log 6.40±0.15 cfu/g in fish from vehicle, stall and retailed stage respectively. *E.coli* were positive (>10 cfu) in 17%, 43%, 50%, 87% and 100% of flesh (skinned) samples of skipjack tuna in MDB, at pier, in transport vehicle, at stall and retailed stage respectively. *E.coli* were found in skin-on samples

from all stages and the range detected was 10^2 - 10^3 cfu/g. The average ambient temperature recorded on board of the MDB during fishing trip was 29.8°C with a variation of $\pm 3.7^\circ\text{C}$. Core temperature of fish stored in fish hold in MDB, at pier, inside transport vehicle and stall in market were $2.7\pm 2.1^\circ\text{C}$, $6.3\pm 4.1^\circ\text{C}$, $13.0\pm 2.5^\circ\text{C}$ and $17.0\pm 2.4^\circ\text{C}$ respectively. Fish is stored in fish hold of the MDB for about 7 days and after unloading, fish reaches retail shop within around 5 h. Based on criteria for levels of APC, six out of nine lots of fish were acceptable, in MDB, at pier and in vehicle. At retail stalls only three out of nine fish lots were acceptable. Average trimethyl amine (TMA) and total volatile base (TVB) contents of fish in all stages were found in the ranges of 7.67–11.89 mg/100g and 13.65–26.92 mg/100g respectively. Poor infrastructure and bad handling practices in boat, pier, transport vehicle, retail markets are found to be responsible for quality deterioration along distribution channel, which results in poor quality of fish available for consumers.

Introduction

There is an increasing concern over the quality of the fish consumed. At present tuna is the major fishery among large pelagics and tuna production amounted to 112,217 mt in 2001 (Anon. 2001a). Skipjack tuna (*Katsuwonus pelamis*) is one of the main species in the catch of multi-day boats (MDBs). Beruwala fishery harbour is one of the main fish landing sites of the Kalutara district in Sri Lanka and annual marine fish catch landed in this district in 2001 was 32110 mt (Anon. 2001a). The total number of MDBs registered in Beruwala fishery harbour was 322 in 2001. The fish landed at Beruwala fishery harbour is transported inland through two main distribution channels that end up in Matugama and Horana. The average distance is 25 km in Matugama chain and 40 km in Horana. Recent studies have shown that the most of the landed fish used for local consumption is not in acceptable quality mainly due to poor handling practices. Sensory evaluation based percentage post harvest loss recorded in MDBs landed at Beruwala in 1997 was around $27 \pm 11.5\%$ (Ganegama Arachchi et al. 1999).

Main objective of this study was to investigate the quality deterioration of skipjack along different handling stages starting from MDBs operating from Beruwala fishery harbour to final retailing stage through the two main commercial channels that ends up in Matugama and Horana. Monitoring of faecal coliform contamination along the handling chain, investigations on chilling temperatures of fish along the distribution channel and handling practices along the fish distribution channel were carried out with the view of suggesting remedial measures to reduce the quality deterioration along the handling chain.

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Materials and methods

Sampling

Sampling was carried out from March to November 2001. Skipjack tuna that belongs to commercial-grade-one which was characterized by rigid back bone, firm and elastic flesh, no physical damages on skin, red gills and prominent or flat eyes, were sampled at the five main stages along the fish distribution chains from Beruwala to Matugama and Horana. These five stages were at MDB, pier, transport vehicle, stall in retail market and fish sold to consumers at Matugama and Horana. Data were collected at 10 sampling visits. Sampling of fish from MDB, pier, transport vehicle, stall and at the time of retailing was carried out at 0500-0600 h, 0830-0930 h, 1100-1130 h, 1130-1230 h and 1300-1400 h respectively. Fifty fish were sampled from MDB, pier, transport vehicle and stall, and twenty five fish were sampled at the time of retailing. Fish were collected in sterile polythene bags, and stored in ample amounts of flake ice in insulated boxes and transported to field laboratory situated at Kalutara.

Microbiological and biochemical parameters

Aerobic Plate Count (APC): Skinned fish (flesh) sample was homogenized with 0.9% saline and the dilutions were plated on APC Petrifilm (3MTM PetrifilmTM Aerobic Count Plate) in duplicate. Counts were made after incubation at 30°C for 48 h as cfu/g (Anon. 1997a). Sensitivity of the method was <10 cfu/g.

Escherichia coli (E. coli) count: Surface (Swab)/flesh samples were prepared as for APC and plated on *E.coli* Petrifilm (3MTM PetrifilmTM *E. coli*/Coliform Count Plate). Counts were enumerated after incubating at 37°C for 48 h as cfu/g (Anon. 2000). Sensitivity of the method was <10 cfu/g.

Tri Methyl Amine (TMA) and Total Volatile Base (TVB) contents: Modified micro-diffusion method described by Beatty and Gibbon (1937) was used to assess the TMA and TVB contents.

Handling and storage temperature of fish

Gemini Data Loggers (Tinytag Plus 2- channel)) were used to measure the core temperatures of fish (Anon. 2001b). Continuous records on fluctuations of temperature of fish moved along the distribution channel from MDB to final retailing stage were obtained by inserting the probe of Data Logger in to the flesh of fish behind the pectoral fin before storing on board of MDB.

Analysis of data

Means of APC at each stage were compared using "Satterthwaite" approximation. Bartlett's test statistics were used to compare the variance of TMA and TVB values at each stage.

Results

Microbiological quality of fish

Mean APC of skinned fish from MDB and piers were $\log 5.20 \pm 1.10$ cfu/g and $\log 5.35 \pm 1.20$ cfu/g respectively. APC of fish from vehicle, stall and retailed stage along Matugama channel were $\log 6.16 \pm 0.94$ cfu/g, $\log 7.08 \pm 0.96$ cfu/g and $\log 6.96 \pm 0.46$ cfu/g respectively. In Horana distribution channel mean APC were $\log 5.14 \pm 0.71$ cfu/g, $\log 6.13 \pm 0.49$ cfu/g and $\log 6.40 \pm 0.15$ cfu/g in fish from vehicle, stall and retailed stage respectively (Fig. 1).

Figure 1. Variation of Aerobic Plate Count of skipjack tuna in multi-day boat, at pier, in vehicle, at stall and at retailed stage along the two distribution channels i.e., Matugama and Horana. (Vertical lines indicate the standard deviation.)

Based on criteria for the levels of APC of fresh fish by International Commission on Microbiological Specifications for Food (ICMSF), three lots of fish out of nine lots in MDB, at pier and in vehicle were found to be unacceptable while seven out of nine lots were unacceptable at the fish stall in retail market (Fig. 2.).

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E. coli was positive (>10 cfu) in 17%, 43%, 50%, 87% and 100% of the sample of flesh (skinned) of skipjack tuna in MDB, at pier, in transport vehicle, at stall and retailed stage respectively (Table 1.). Out of 117 skinned samples from all five stages, 61% samples were found with >10cfu/g of *E. coli*. In the skin-on-samples analyzed from all stages, *E. coli* counts were found to be in the range of 10^2 - 10^3 cfu/g.

Figure 2. Number of unacceptable lots out of nine tuna lots of skipjack tuna in multi-day boat, at pier, in vehicle and at stall from both Matugama and Horana distribution lines.

Table 1. *E. coli* counts of skinned skipjack tuna in multi-day boats, at pier, in transport vehicle, at stall and at retailed stage.

Stage	Number of samples positive for <i>E. coli</i> count (>10 cfu/g)	Total number of samples analysed	Percentage of <i>E. coli</i> positive samples
Boat	5	30	17
Pier	13	30	43
Vehicle	10	20	50
Stall	26	30	87
Retailed	7	7	100

Biochemical quality of fish

TMA content of skinned fish in MDB and at pier were 9.02 ± 6.71 mg/100g and 7.28 ± 3.75 mg/100g respectively. In transport vehicle, at stall in the market and at retailed stage along Matugama channel, TMA contents

of skinned fish were 9.40 ± 6.90 mg/100g, 7.58 ± 5.47 mg/100g and 8.43 ± 4.84 mg/100g respectively. Along Horana distribution channel, skinned fish in vehicle, stall and retailed stage were found with 7.67 ± 3.52 mg/100g, 9.77 ± 6.00 mg/100g and 11.89 ± 3.79 mg/100g of TMA contents respectively (Table 2). Fish in MDB and at pier were found with 26.76 ± 13.03 mg/100g and 27.76 ± 2.02 mg/100g of TVB contents respectively. Along the Horana channel, in vehicle, at stall and retailed stage fish recorded a TVB content of 14.96 ± 9.90 mg/100g, 26.83 ± 8.20 mg/100g 13.65 ± 8.04 respectively. Along Matugama distribution channel, fish in transport vehicle, at stall and at retailed stage were found with 25.87 ± 6.38 mg/100g, 26.92 ± 8.30 mg/100g and 26.20 ± 2.96 mg/100g of TVB content respectively (Table 2).

Table 2. Variations in tri methyl amine (TMA) and total volatile base (TVB) contents of skinned skipjack along the distribution channels: Horana and Matugama.

Stage		TMA mg/100g (Mean $\pm$ SD)	TVB mg/100g (Mean $\pm$ SD)
MDB		9.02 ± 6.71	26.76 ± 13.03
Pier		7.28 ± 3.75	27.76 ± 2.02
Vehicle at destination	Matugama	9.40 ± 6.90	25.87 ± 6.38
	Horana	7.67 ± 3.52	14.96 ± 9.90
Stall	Matugama	7.58 ± 5.47	26.92 ± 8.30
	Horana	9.77 ± 6.00	26.83 ± 8.20
Retailed	Matugama	8.43 ± 4.84	26.20 ± 2.96
	Horana	11.89 ± 3.79	13.65 ± 8.04

Temperature of fish

During the fishing trip, the fish was stored in fish hold of MDB for about 07 days at a temperature of around 5°C . Fish landed from MDB was auctioned at pier during 0415 h to 0800 h, transported by a lorry during 0800 h to 0930h and displayed for sale in stall during 0930 h to 1150 h. Temperature of fish during handling on land increases from about 0°C at pier to 18°C at final retailing stage (Fig. 3.).

Average ambient temperature of fish on board the MDB during fishing trip was $29.8 \pm 3.7^{\circ}\text{C}$. Core temperature of fish stored in fish hold of MDB was $2.7 \pm 2.1^{\circ}\text{C}$. After unloading from MDB, temperature of fish at pier, in transport vehicle and stall were recorded as $6.3 \pm 4.1^{\circ}\text{C}$, $13.0 \pm 2.5^{\circ}\text{C}$ and $17.0 \pm 2.4^{\circ}\text{C}$ respectively (Table 4).

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Table 4. Temperature fluctuations of skipjack tuna along the Matugama distribution channel

Stage	Temperature (Mean $\pm$ SD) °C
On-board MDB	29.8 $\pm$ 3.7
Fish hold of MDB	2.7 $\pm$ 2.1
Pier	6.3 $\pm$ 4.1
Vehicle	13.0 $\pm$ 2.5
Stall	17.0 $\pm$ 2.4

Figure 3. Typical pattern of the fluctuation of core temperature of skipjack tuna handled at different time periods along the Mathugama distribution channel: MDB, pier, transport vehicle and stall in retail market of Matugama.

Handling practices

Multi-day boats: MDBs studied were in the size categories of 9-10.5 m, 11-12 m, 13-13.8 m and 14-15 m. Skipjack is caught using gillnets. The fish caught are hauled on board and stored in fish hold. About 95% of boats have only one fish hold and rest have two separate fish holds opened by separate hatches. At the time of storing the fish in the fish hold, fish hold is partitioned *in situ* with wood panels in to 2-3 shelves and several compartments depending on the size of the boat. Fish are stored with ice in 1:1 or 1: >1 ratio of fish to ice. Whole fish is stacked in belly side down in about 90% and belly side up in about 10 % of boats. Fish is stored with ice as 3-4 layers per shelf. Duration of boat trip in sea ranged from 10 days to 25 days. Fish sampled were in fish hold for 8-12 days during the fishing journey. It was observed that there were no adequate sanitary facilities to the crew in the MDBs investigated.

Pier: Length of the pier is about 220 m and it provides anchorage facilities to about 500 boats at a given time. Individual fish is landed by hand to hand transfer from boat to bare cement floor of the pier. Fish landed is washed with water drawn from the harbour basin and potable water is not available in adequate quantities at the pier for washing of fish. Fish is then sorted for commercial grades. Fish are laid without ice during the auction on pier for about 1-2 hours. The auctions are held from 0400 h to 0800 h. A stall for sale of ice has been established in the harbour.

Transport vehicles: Fish purchased at the auctions are transported in insulated trucks, lorries, tractors, motor cycles and bicycles. Area of the vehicle park is about 1300 m². It was observed that the ice used in MDB is reused in subsequent transportation as a common practice. Fish were transported in lorries for about 90 minutes and 45 minutes from Beruwala along two distribution channels to Matugama and to Horana fish retail stalls respectively.

Retail stalls: Retail stalls do not have good infrastructure required for fish handling and potable water supplies. Fish is handled on surfaces made up of wood, ceramic tiles or aluminum sheets. Fish is displayed for sale without ice for 3-4 h in retail stall and at the end of day unsold fish is stored in ice boxes made up of styrofoam or fiber-glass. Generally the entire quantity of fish bought from the auction at harbour is sold out at the retail stall in market places at Matugama and Horana within two days.

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Discussion

There are four commercial grades in auction at pier depending on the sensory attributes such as appearance, firmness of flesh and rigidity of backbone of fish (Ganegama Arachchi et al. 2000a). The fish of commercial grade one was used for this study. Interviews with crew revealed that gillnets are soaked for more than 6 hours in order to catch a large number of fish from fish shoals which segregate in late night and early morning. This long soaking time of the net may lead to deterioration of the quality of a large number of fish. Under very good conditions, flesh of the fish is not contaminated with bacteria. Fish with 10^3 cfu/g of APC is considered as acceptable (Jayaweera et al. 1988) and presence of higher APC than that number reflects the poor handling of fish. According to the guidelines such as Recommended International Code of Production for Fresh Fish, fish has to be handled at ice melting temperatures to maintain the quality (Graham 1983; Anon. 1978). Higher core temperature of fish in boat with wide fluctuation ($2.7 \pm 2.1^\circ\text{C}$) as indicated in Fig. 3 and Table 4 due to use of inadequate ice, melting of ice at higher rates due to poor insulation and longer trip duration may have contributed to higher APC of fish in boat. Infrastructure and handling practices of fish in MDBs operating from Beruwala are similar to those operating from Negombo (Ganegama Arachchi et al. 2000b).

Average temperature of the fish stored in the fish hold was recorded as 2.7°C with a standard deviation of $\pm 2.1^\circ\text{C}$ for 7 day storage time. When the fish is unloaded from the boat to the pier, it gets exposed to the environmental temperatures from around 0415 h to around 0800 h and core temperature of fish rises to about 6°C . During transportation period from around 08.00 h to 0930 h, the core temperature further increases to about 13°C . Fish is displayed without ice at the retail stall and the core temperature rises further up to about 17°C from 0930 h to 1150 h (Table 4 and Fig. 3).

A general trend to increase APC along the distribution chain was observed from an initial count of $\log 5.20 \pm 1.10$ cfu/g in the fish of MDB to $\log 6.96 \pm 0.46$ cfu/g and $\log 6.40 \pm 0.15$ cfu/g of APC found in retailed fish in Matugama and Horana respectively (Fig. 1). According to "Satterthwaite" approximation statistics, there was no significant change in APC of fish from boat to pier ($p > 0.05$). This may be due handling of fish in pier for a short period before the sunrise. However, the handling of fish without ice at pier will onset the irreversible deterioration of quality at latter stages of handling. A significant increase was observed in APC from pier to vehicle and from vehicle to stall in market in Matugama distribution channel at ($P < 0.05$). The increase from pier to vehicle was 104% and vehicle to stall in market was 870%. In the Horana distribution channel, too a significant increase in APC in fish was observed from vehicle to stall in market ($p < 0.05$) and this increase was 645%.

Acceptability of a batch of fish can be determined using a three class plan, which assesses five sample units of a batch or a lot, as described by International Commission on Microbiological Specifications for Food (ICMSF) in 1986 (Anon. 1986). A Batch is acceptable when all the five sample units are found with $<10^7$ cfu/g of APC or APC in the range of $5 \times 10^5 - 10^7$ cfu/g in maximum of three sample units. Single fish is considered as one sample unit. In the present analysis, a sample comprising of five sample units was drawn from a batch of fish at each stage. All fish that belong to commercial grade one of a MDB were considered as a batch of fish from that MDB. Fish of same MDB moved over each stage of the distribution channel, were treated as a batch from that particular stage. During this study, nine lots of fish from each stage; i.e., boat, pier, vehicle and retail stall from both Matugama and Horana distribution channels were assessed using the above sampling plan. Based on criteria for levels of APC, six number of lots of fish, out of nine lots were acceptable in MDB, pier and the vehicle. At the retail stalls only three fish lots were acceptable indicating the consequences of cumulative effect of poor handling conditions of fish along the distribution channel (Fig. 2.).

E. coli was detected in 17% of skinned fish from MDBs. It was found that the fish is washed with harbour basin water, which was found to be contaminated with *E. coli* (Hemantha and Amarasinghe 1994; Ganegama Arachchi et al. 1999). A tendency to increase the *E. coli* counts along the distribution channel was observed. All fish at the retail stage were found to be *E. coli* positive (Table 1) indicating higher contamination rates. At the retail stall, large fish like tuna are sold as cut pieces to consumers. Since the surface of fish (skin-on-sample) is contaminated with *E. coli*, these cut pieces will also get easily contaminated when cutting at the stalls where the same water is repeatedly used for cleaning fish. Washing with clean water can significantly reduce microflora on fish skins (Lakshaman et al. 1984).

Average TMA and TVB contents of fish in all stages were in the ranges of 7.67–11.89 mg/100g and 13.65–26.92 mg/100g respectively. Similar results have been reported in previous analysis of skipjack tuna landed at Negombo (Serasinghe et al. 1999; Ganegama Arachchi et al. 2000b).

There were no statistically significant differences in the TMA and TVB contents among skinned tuna samples obtained from the MDB, pier, transport vehicle and stall along the Matugama distribution channel. The average TMA and TVB contents were found to be in the acceptable or marginally acceptable ranges (5–10 mg/100g of TMA and 30–35 mg/100g of TVB) as described by Huss (1994).

In order to produce a high quality fish product, it is required to use good infrastructure and handling practices according to the recommended international codes and national regulations of practices (Anon. 1978, 1997b, 1998). It has been noted that the improper handling practices and inadequate

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infrastructure such as use of water from harbour basin, application of ice discarded from MDBs to transport the fish and disturbed chilling chain by dumping of fish on pier without ice, and un sanitized surfaces at retail stalls contribute significantly to quality deterioration. Unacceptable higher handling temperatures have also been observed parallel to these quality deterioration along distribution channels as indicated in Table 4 and Fig. 3. All these factors may have contributed to proliferation of bacteria in fish at higher rates at latter stages of the distribution channel.

Conclusion

Skipjack tuna landed from MDB was found with high APC even in fish falling into to Commercial Grade One category. Significant increase in bacterial counts along the handling chain was evident. Poor handling practices, abuse of chilling temperature and poor infrastructure facilities are found to be responsible for quality deterioration of fish along the handling chain.

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References

Anonymous 1978.

Recommended International Code of Production for Fresh Fish (1978), Joint FAO/WHO Food Standards Programme, Codex Alimentarius Commission, CAC/RCP 9-1976. Food and Agriculture Organization of United Nations, Rome and World Health Organization, Geneva.

Anonymous 1986.

ICMSF, (1986). Microorganisms in foods. 2. Sampling for microbiological analysis: Principles and specific applications, 2nd ed. University of Toronto Press, Buffalo, NY. Available on <http://seafood.ucdavis.edu/organize/icmsf.htm>, Accessed on 4/5/03.

- Anonymous 1997a
3M Petrifilm Aerobic Count Plate 34-7042-1562-2.,(1997), 3M Microbiology products, 3M Center, St. Paul, MN 55144-1000. www.3M.com/microbiology, Accessed on 4/5/03
- Anonymous 1997b.
Handling and distribution of fish regulations (1997), No 972/14 - Gazette Extraordinary of the Democratic Socialist Republic of Sri Lanka 25.04.1997.
- Anonymous 1998.
Fish products (Export) regulations (1998), No. 1045/1 of the Gazette Extraordinary of the Democratic Socialist Republic of Sri Lanka 14.09.1998.
- Anonymous 2000.
3M Petrifilm E. coli/Coliform Count Plate, 34-7049-3886-8., (2000), 3M Microbiology products, 3M Center, St. Paul, MN 55144-1000. www.3M.com/microbiology, Accessed on 4/5/03
- Anonymous 2001a.
Sri Lanka Fisheries Year Book 2001. National Aquatic Resources Research and Development Agency, Crow Island, Colombo 15, Sri Lanka. 68 p.
- Anonymous 2001b.
Gemini Data Loggers (2001) Gemini Data Loggers (UK) Ltd, Scientific House, Terminus Road, Chichester, West Sussex PO19 2 UJ, England. www.geminidataloggers.com, Accessed on 4/5/03
- Beatty, S.A. & N.E. Gibbons 1937.
The measurement of spoilage in fish. *Journal of Biology Board*, Canada. 3(1): 77-91.
- Ganegama Arachchi, G.J., W.M.K. Perera, J.M.P.K. Jayasinghe, S. Jayasooriya, K. Hettiarachchi and J.M. Chandrika 1999.
Quality and post harvest losses in offshore tuna fishery in Southern and Western coasts of Sri Lanka. In: *Proceedings of the 55th Annual Session, Part 1-abstracts*, p. 36. Sri Lanka Association for the Advancement of Science, Colombo, Sri Lanka.
- Ganegama Arachchi G.J., J.M.P.K. Jayasinghe, M.J.S. Wijeyaratne, W.M.K. Perera, S. Jayasooriya & K. Hettiarachchi 2000a.
Handling practices and post-harvest losses of tuna catches from multi-day boats operating from fish landing site Negombo, Sri Lanka. *Sri Lanka Journal of Aquatic Sciences* 6: 87-95
- Ganegama Arachchi G.J., K.G.C. Ariyadasa, W.M.K. Perera, & J.M.P.K. Jayasinghe 2000b.
Investigations on quality aspects of tuna catches of multi- day boats at the Negombo fish landing site, in Sri Lanka. *Sri Lanka Journal of Aquatic Sciences* 6: 97-104

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Graham J. 1983.

The use of the ice in the tropics. Info-fish Marketing Digest 4:35-38.

Hemantha, D. & D. Amarasinghe 1994.

Present status of Negombo fish landing center with special reference to pollution of the harbour environment. Report submitted to the Ministry of Fisheries and Aquatic Resources, Bay of Bengal Programme and International Maritime Organization. National Aquatic Resources Research & Development Agency, Colombo, Sri Lanka. 26 p.

Huss, H. H. 1994.

Assurance of sea food quality. FAO Fisheries Technical Paper No 334, pp. 57. FAO, Rome.

Jayaweera, V., S. de Silva & J.C. Godakanda 1988.

Quality of Fish at Landing Sites along Southern Coast of Sri Lanka, NARA, Colombo, Sri Lanka. 37p.

Lakshmanan, P.T., C. Mathen, P.R.G. Varma & T.S.G. Iyer 1984.

Assessment of Quality of Fish Landed at the Cochin Fisheries Harbour. Fishery Technology 21(2): 98-108.

Serasinghe, B.S.G.N.N., D.G.N.G. Wijesinghe, G.J. Ganegama Arachchi & J.M.P.K. Jayasinghe, 1999.

Assessment of quality and post harvest losses of landings in multi-day boats at Beruwala, Sri Lanka. Proceedings of Fifth Annual Sessions: Sri Lanka Association for Fisheries and Aquatic Resources, 23-24 June 1999, Colombo, Sri Lanka, p. 30 (abstract only).