Dried fish production and trade in Negombo, Sri Lanka

T.P.U. Neranjala, W.G.D. Eranga and D.C.T. Dissanayake*

Department of Zoology, University of Sri Jayewardenepura, Gangodawila, Nugegoda

.

*Corresponding author: chamari@sjp.ac.lk

https://orcid.org/0000-0001-8270-1641

Received: 22.10.2021 Revised: 18.02.2022 Accepted: 20.02.2022 Online: 15.03.2022

Abstract A well-established year-around dried fish production process is practiced at Negombo, the west coast of Sri Lanka, and this study evaluates the present status of this industry using the data collected from February to December 2017. There are forty-two dried fish processing centres at Negombo sea street area, providing livelihood opportunities for ~320 employees. Eighteen fish species belonging to 9 families are used in dried fish production and species belonging to the family Carangidae made the highest percentage contribution (21.6%), followed by the Clupeidae (21.4%), and Scombridae (21.4%). The results of the Quality Index (QI)Method revealed that both high-quality and very low-quality fish are used in dried fish production, and the overall QI of *Katsuwonus pelamis*, *Euthynnus affinis*, *Decapterus macarellus,* and *Elagatis bipinnulata* ranged from 15–16. Effects of drying on proximate composition were assessed, and significantly higher crude protein, content was recorded in dried fish than in fresh fish ($p<0.05$, t-test). Drying has also resulted in a significant increase in crude fat content in all these species except for *Canthidermis maculatus* ($p<0.05$; t test). De-heading and gutting, washing, salting, rewashing, drying, and packing were the major steps in the dried fish production process. Although the total coliform was reported in water samples used in the dried fish processing centres, it was not encountered in any of the dried fish samples. The dried fish value chain mainly consisted of fishermen, buyers, processors, sellers, and consumers, and upgrading of products, processes, and functions along the value chain was suggested to produce better quality dried fish and increase the profit margins of value chain actors.

Keywords: Dried fish, Processing, Quality Index Method, Value chain

INTRODUCTION

Fish, a major source of animal protein in humans, is consumed in different forms such as fresh, frozen, dried, and smoked. According to the FAO, (2020), approximately 17 million Mt of fish (12% of total fish production) were consumed as dried, salted, and smoked forms around the globe.

Drying is a well-known method of fish preservation as well as an alternative way of reducing the fish post-harvest losses. The most distinct phases of dried fish production process include selection of suitable fish, cleaning, removal of internal organs, salting, and drying. Dried fish are very popular among developing nations rather than developed ones, and Bangladesh, Thailand, India, and China are the major dried fish producers in Asia (Balachandran 2001; Payra et al. 2016). Dried fish production provides employment opportunities in addition to contributing to the nutritional security of poor people (Kallon et al. 2017). According to Kumar et al. (2013), different forms of dried fish such as whole, skinless headed and gutted, fillets, canned in oil and snack varieties are available in the markets. Many players, including raw fish suppliers, dry fish producers, middlemen, wholesalers, retailers, and consumers (Shamsuddoha 2007) are mainly involved in the dried fish value chain and rough handling, improper cleaning, poor packaging, inadequate storage facilities, and bad weather are the major problems faced by dry fish producers (Islam et al. 2001).

Dried fish are very popular among Sri Lankans and a very high demand exists, especially from country-side people, who do not receive fresh fish of good quality. Although the total dried fish consumption of Sri Lankans varies from year to year, the average annual consumption remains around 90,000 Mt. Large-scale, medium-scale, and small-scale domestic level processors distributed

along the coastal belt of Sri Lanka cater for around 60–63% of the dried fish demand in the country, mainly through traditional processing practices. As local production is not enough to supply the demand, dried fish are frequently imported to the country mainly from India, China, Thailand and Norway. In 2019, a total of 34,969 Mt of dried fish worth approximately 15 billion rupees has been imported into Sri Lanka fulfilling around 37% of dried fish demand in the country (MFAR, 2020).

Although the dried fish industry plays a significant role in livelihood improvement in the coastal fishing community and nutrition security of the Sri Lankan people, very limited or no scientific information is available on different aspects of dry fish production process, i.e., main fish species used, their quality status, production process, marketing channel, and socio-economic information of major players in the production chain. Therefore, this study aims to address these research gaps by focusing to Negombo Sea Street area which is one of the most popular dried fish production and marketing sites in the country.

MATERIALS AND METHODS

Data collection

This study was carried out at Negombo, Sea Street dried fish processing site (7°12'37.22 "N, 79° 49'51.39" E), where there is year-round dried fish production. Field data were collected by making fortnightly field visits to this site from February to December 2017. On each sampling day, active dried fish processing centres were counted and around 50% of these centres were selected randomly to collect data on fish species used for dried fish production as well as their origin, quality, quantity, and unit price (1 kg). Samples of fresh fish species were obtained randomly from dried fish processing centres (n=20) and the total length (TL) and standard length (SL) were measured individually to the nearest 0.1 cm using a measuring board.

Assessment of the quality of fresh and dried fish

The quality of fresh fish used for dried fish production was evaluated at the dry fish processing site using the Quality Index (QI) Method proposed by Hyldig et al. (2003). To judge the overall quality of fish, the appearance of the gills, eyes, abdomen, and skin were carefully observed and scored using the sensory evaluation attributes. As a significant portion of the fresh fish that reaches the Negombo dried fish processing site originated from the southern area, the quality loss of fresh fish during this process was assessed by considering *Decapterus macarellus (*Mackerel scad), the most widely used fish in the dried fish production process.

Sodium Chloride content in dried fish samples was analyzed using Mohr's method and values were compared with ISO standards published by the Sri Lanka Standard Institute (SLSI). Three water samples, each of 100 mL, used to wash and clean the fresh fish were collected from randomly selected dried fish processing centres at two-month intervals. Dried fish samples (~100g) were also purchased from these processing plants. These samples were packed in autoclaved plastic bottles and transported to the laboratory of the department of Zoology, University of Sri Jayewardenepura. Total coliform in water samples as well as in dried fish samples was determined following the MPN method (Adebayo et al. 2012).

Analysis of proximate composition of fresh and dried fish

The proximate composition of fresh and dried fish samples collected from the processors (n = 5) was analyzed in order to determine their changes during the processing process. Five fish species (i.e., *Encrasicholina heteroloba, Sardinella gibbosa, Cheilopogon furcatus, Decapterus macarellus,* and *Canthidermis maculatus*), widely used to produce dried fish were considered for this analysis. Representative samples (n = 30, mostly the same size) were selected from each species, cleaned properly, cut into small pieces, and ground well using a grinder to obtain a homogenous sample. Each sample was analyzed for percentage moisture and dry matter percentages of crude ash, crude fat, and crude protein. The moisture content was determined by drying the samples in a thermostat oven at 100±5ºC until a constant weight was obtained (AOAC 1990). Crude ash content was determined by incinerating the samples in a muffle furnace at 550ºC for 24 hours (AOAC 1990). The micro-Kjeldahl method with acid digestion was used to determine the crude protein content, and conversion factor 6.25 was used to convert total nitrogen to crude protein (AOAC 1990). Bligh and

Dyer's method was used to determine the crude fat content (Bligh and Dyer 1959). Each experiment was carried out in triplicate.

Production and marketing of dried fish

All the key players involved in the dried fish production chain were identified and interviewed to gather information on their socio-economic status, production process, and existing value chain. Questionnaires, semi-structured interviews, and focus group discussions targeting processors (n = 30), workers (n = 110), and buyers (n = 6) were used to collect relevant information. Descriptive statistics were used to analyze socio-economic factors. The production cost for 1 kg of dried fish was determined separately for these species.

RESULTS

Status of the dried fish industry

Forty-two dried fish processing centres were operated at Negombo, sea street dry fish processing site providing livelihood opportunities for approximately 320 employees. Eighteen fish species belonging to 9 fish families were mainly used in dried fish production (Table 1).

Table 1 Major fish species used to produce dried fish at Negombo, Sea Street dry fish processing site from February to December 2017.

Family	Species	English name
Arridae	*Arius jella*	Black fin sea catfish
Balistidae	*Canthidermis maculatus*	Trigger fish
Carangidae	*Decapturus macarellus*	Mackerel scad
	Scomberoides commersonianus	Talang queenfish
	Elagatis bipinnulata	Rainbow runner
	Selar crumenophthalmus	Bigeye scad
Clupeidae	*Sardinella albella*	White sardinella
	Sardinella gibbosa	Goldstripe sardinella
	Amblygaster sirm	Spotted sardinella
	Amblygaster clupoides	Bleeker's smoothbelly sardinella
Coryphaenidae	*Coryphaena hippurus*	Mahe Mahe / Dolphin fish
Engraulidae	*Stolephorous insularius*	Hardenberg's anchovy
	Encrasicholina heteroloba	Short head anchovy
Exocoetidae	*Cheilopogon* spp.	Flying fish
Scombridae	*Katsuwonus pelamis*	Skipjack tuna
	Euthynnus affinis	Kawakawa
	Rastrelliger kanagurta	Indian mackerel
Sphyraenidae	*Sphyraena* sp.	Baracuda

The percentage contribution of major fish families to the total dried fish production at the Negombo sea street processing site during the year 2017 was computed and compared (Figure 1). Species belonging to family Carangidae made the highest percentage contribution (21.6%), followed by Clupeidae (21.4%) and Scombridae (21.4%). The least contribution was reported from family Sphyraenidae (1%).

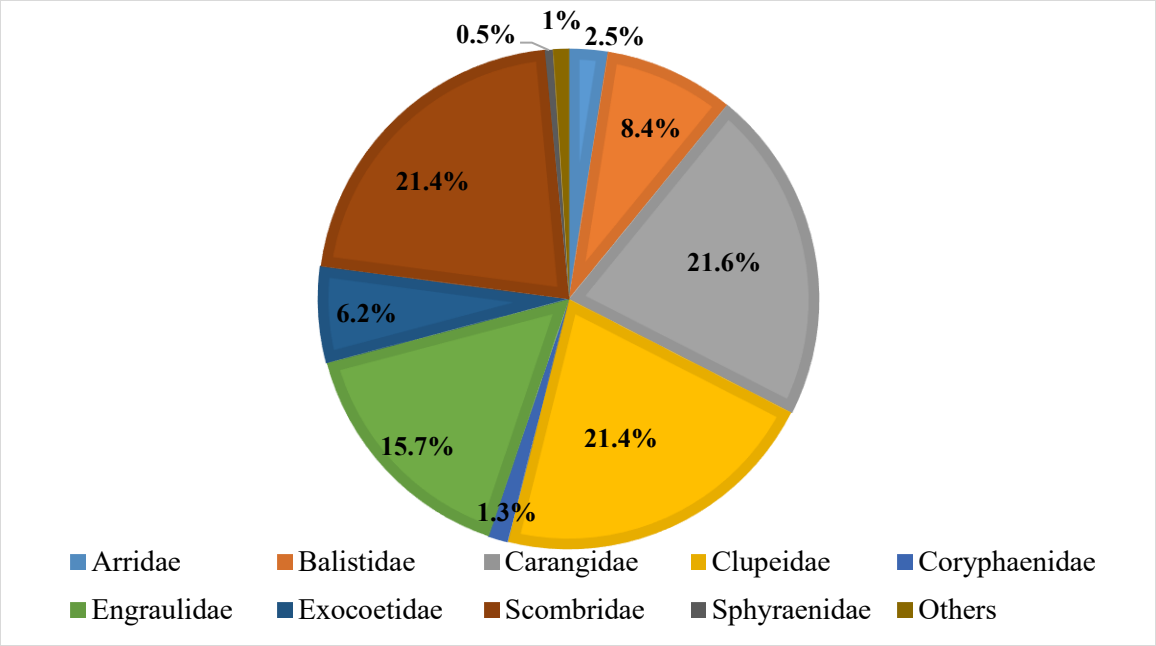

Fig 1 Percentage contribution of major fish families to the total dried fish production at Negombo, Sea Street landing site from February to December 2017.

The percentage contribution of major fish species to the dried fish production is shown in Figure 2. Almost all species except flying fish (*Cheilopogon spp.)* were used to produce dried fish throughout the study period but with varying percentages. However, *Katsuwonus pelamis*, *Decapturus macarellus,* and anchovies (*Stolephorous insularis* and *Encrasicholina heteroloba*) made the highest percentage contributions to the dried fish production process. *Sardinella* (25.7%) and *Amblygaster* (36%) species showed their highest contributions in May, and for *K. pelamis* and *D. macarellus*, it was in June (24.2%) and August (29%), respectively. Although *C. maculatus* reported its maximum contribution of 17.4% in December, it was less than 10% in all the other months.

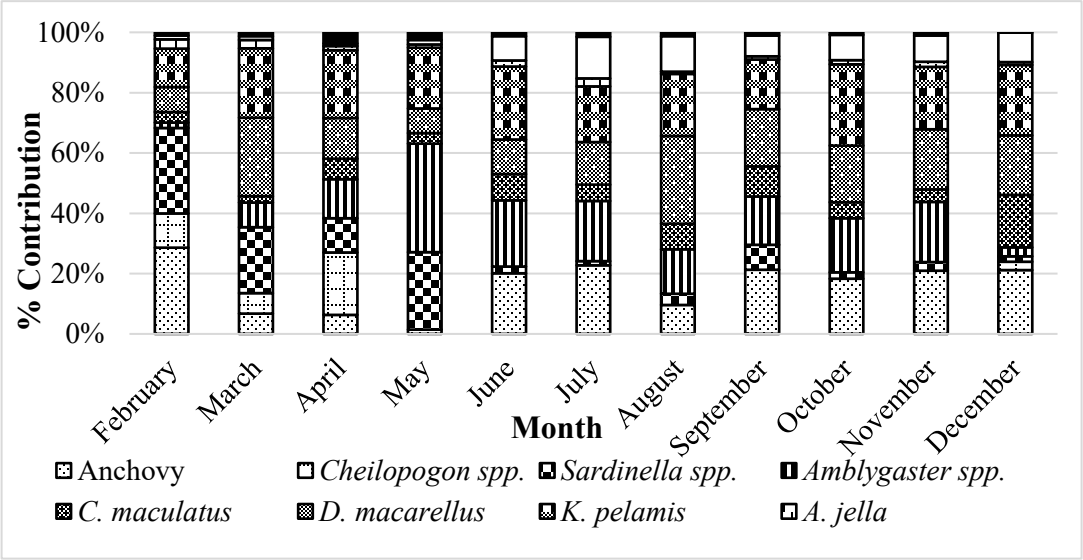

Fig 2 Percentage contribution of major fish species to total dried fish production during the study period.

Table 2 summarizes the variations in origin, size, unit price of fresh fish (1 kg), fresh to dried fish conversion factor, unit production cost (1 kg), percentage NaCl content, and retail price of dried fish (1 kg) with respect to each species.

Most of the small pelagic schooling fish species, i.e., *Sardinella* spp., *Amblygaster* spp., and anchovies used for dried fish production, were purchased at the Negombo fish landing site, while *K. pelamis, D. macarellus, C. maculaus, Euthynnus affinis,* and *Elagatis bipunulata,* mostly came from the southern region of the country. Highly seasonal *Cheilopogon* spp. were received from Mannar area.

Although the unit price (1 kg) of fresh fish varied from time to time, the average price for all species was between LKR 90.00 and 170.00, having the highest price for *Amblygaster* species. As most of these species are schooling fish, their body size fluctuates within a narrow range. This study reveals that the fresh to dried fish conversion factor is 1: 2 or 1: 2.5 for most of the species considered, but it is 1:3 for anchovies.

The retail price of dried fish varies from species to species and anchovies (LKR 638.33) fetched the highest market price while the lowest value was for *Cheilopogon* spp. (LKR 408.30) followed by *E. bipinulata.* The same trend was observed when analyzing the unit production cost of dried fish. All the dried fish reported higher levels of sodium chloride content than the SLSI standard (Sri Lanka Standard Institute; 643:2007) of 12%.

Quality of fish used in dried fish production.

Results of the sensory evaluation are summarized in Table 3. The overall score claimed by *E. heteroloba*, *S. gibbosa*, *A. sirm* and *C. maculatus* ranged from 3.7 to 6.3, proving that high quality fish of these species are used for dried fish production. Moderate quality fish of *Arius jella* and *Cheilopogon* spp. are mainly used to produce dried fish and their overall score ranged from 8.0 to 8.2. The overall quality index of *K. pelamis*, *E. affinis*, *D. macarellus,* and *E. bipinnulata* lies in the range of 15 – 17. This indicates that poor quality fish of these species are mainly used for dried fish production.

As most of these species reached to the Negombo dried fish processing site from the southern region, the change in quality index along the supply chain was mapped for *D. macarellus,* starting from the Galle fishery harbour (Figure 3). Although the trip duration of multiday boats ranged from an average of 8 to 15 days, the overall quality of *D. macarellus* landed at the Galle fishery harbor was in good condition. Neutral to moderate quality *D. macarellus* were mainly reported at Peliyagoda central fish market. However, an overall quality index value of 15-17 was reported when they reached the Negombo dried fish processing site. Almost all the other species received from the southern region followed a similar supply chain, except *C. maculatus,* which was directly received from landing sites without going through the central fish market.

Proximate composition of fresh and dried fish

The proximate composition of fresh and dried fish species was analyzed and the results are summarized in Table 4. The moisture content of fresh fish ranged from 71.1to 81.2%, reporting the highest value in *S. gibbosa* and the lowest in *D. macarellus*. Anchovy (19.9%) and *Cheilopogon furcatus* (48.7%), respectively, reported the lowest and highest moisture content among dried fish.

Dried fish always reported a higher ash content than fresh fish and it was significantly higher in *E. heteroloba*, *S. gibbosa* and C. *furcatus* ($p<0.05$; t-test). The crude protein content of dried fish was significantly higher than the fresh fish ($p<0.05$, t-test). *E. heteroloba* had the highest crude protein content in both fresh and dried fish, while *C. maculatus* reported the lowest. Crude fat content ranged from 1.8 to 16.6% in fresh specimens and 7.4 to 17.0% in dried specimens. Except for *C. maculatus,* drying has resulted in a significant increase in crude fat content in all these species ($p<0.05$; t test).

Table 2 variations in origin, size range, unit price (1 kg) of each fish species used for dried fish production and production cost, Nacl content and retail price of dried fish

Species	Origin of fresh fish	Size range of fresh fish (cm)	Price of 1 kg of fresh fish (LKR)	Conversion factor (fresh fish: dry fish)	Production cost for 1 kg of dry fish (LKR)	NaCl content	Retail price of 1 kg of dry fish (LKR)
Anchovy (sprats)	N	6.0 - 8.4	90.77±12.50	1:3	487.45±52.15	14.77±0.1	638.33±62.91
Sardinella spp.	N	6 .0– 6.9	98.00±02.88	1:2	349. 50 ±25.80	16.65±0.2	495.00±25.00
Amblygaster spp.	N	16.2 – 17.9	168.75±14.36	1:2	392. 83 ±77.91	16.13±0.2	561.50±28.72
K. pelamis	DS,M,J	27.9 - 31.5	115.33±05.77	1:2.5	427.10 ±94.14	16.91±0.2	558.33±14.43
A. jella	N,M	23.3 - 34.6	148.00±16.32	1:2	395.65 ±118.32	14.51±0.2	493.50±62.91
D. macarellus	DS	20.9 - 35.0	100.00±20.00	1:2	385 ± 57.50	17.06±0.2	433.00±25.00
C. maculaus	DS	30.9 - 35.2	105.00±05.77	1:2.5	411 ± 65.70	16.10±0.1	505.00±28.86
E. affinis	DS, M	32.3 - 35.8	106.60±11.50	1:2.5	386 ± 33.45	16.73±0.2	466.60±14.40
Cheilopogon spp.	M	19.2 - 20.2	108.33±14.43	1:2	341 ± 28.35	14.53±0.3	408.30±14.40
E. bipinulata	DS	32.8 - 6.1	100.00±20.00	1:2.3	326 ± 34.27	17.00±0.2	411.66±28.86

N- Negombo; **DS** - Down South; **M** - Mannar; **J** - Jaffna

Table 3 Overall quality of some selected fresh fish used for dried fish production based on Quality Index Method

Quality parameter		Description	Score	**A** (n=735)	**B** (878)	**C** (n=903)	D (n=709)	E (160)	F (n=211)	G (n=514)	H (n=1121)	I (n=348)	J (749)
Skin	Colour	Pearl shiny all over the skin	0										
		Skin is less pearl shiny	1										
		The fish is yellowish especially near abdomen	2	0.5±0.5	0.4±0.5	0.4±0.5	1.4±0.6	1.12±0.6	0.33±0.5	1.5±0.5	0.91±0.7	1.33±0.4	0.83±0.3
	Mucus	Clear,not clotted	0										
		Milky,clotted	1										
		Yellow,clotted	2	0.5±0.5	0.5±0.5	0.4±0.6	1.3±0.6	1.5±0.7	0.5±0.5	1.4±0.5	1.16±0.8	1.66±0.4	0.75±0.8
	Odor	Fresh sea weedy, neutral	0										
		Cucumber, metal, hey	1										
		Sour, dish cloth	2										
		Rotten	3	0.2±0.4	0.2±0.4	0.25±0.4	2.1±1.1	0.62±1.0	0.66±1.0	0.2±0.4	1.25±1.2	1.83±1.1	0.33±0.4
	Texture	In rigger	0										
		Finger mark disappear rapidly	1										
		Finger leaves mark over 3 minutes	2	0.5±0.5	0.3±0.4	0.25±0.4	1.8±0.4	1.37±0.5	1.66±0.5	0.9±0.7	1.5±0.5	1.33±0.7	0.25±0.4
Eyes	Pupils	Clear and black, metal shiny	0										
		Dark grey	1										
		Mat grey	2	4±0.5	0.4±0.6	0.75±0.8	1.7±0.4	1.75±0.4	0.33±0.5	0.4±0.6	1.08±0.7	1.66±0.4	0.66±0.6
	Form	Convex	0										
		Flat	1										
		Sunken	2	0.4±0.5	0.4±0.5	0.5±0.6	1±0.9	1.5±0.7	0.66±0.5	0.8±0.9	0.91±0.7	1±0.7	0.66±0.6
Gills	Colour	Red/dark brown	0										
		Light red,pink/hazel	1										
		Grey brown,green	2	0.3±0.4	0.6±0.6	0.58±0.6	1.2±0.6	1.75±0.4	1.16±0.7	0.7±0.6	1.5±0.5	1.33±0.7	0.66±0.6
	Mucus	Transparent	0										
		Milky, clotted	1										
		Brown clotted	2	0.4±0.5	0.4±0.6	0.33±0.4	1.7±0.4	1.5±0.7	0.83±0.9	0.7±0.6	1.58±0.5	1.33±0.7	0.66±0.6
	Odor	Fresh,s eaweed	0										
		Metal, cucumber	1										
		Sour, mouldy	2										
		Rotten	3	0.2±0.4	0.4±0.6	0.2±0.4	2.4±0.9	2.62±1.0	0.16±0.4	0.2±0.6	2.5±0.9	1.91±1.0	0.33±0.7
Abdomen	Blood in abdomen	Blood red/not present	0										
		Blood more brown/yellowish	1	0.2±0.4	0.4±0.5	0.3±0.4	0.7±0.4	0.87±0.3	0.83±0.4	0.6±0.5	0.75±0.4	0.66±0.4	0.66±0.5
	Odor	Neutral	0										
		Cucumber, melon	1										
		Sour, reminds of fermentation	2										
		Rotten	3	0.1±0.3	0.2±0.4	0.3±0.4	1.6±1.4	1.62±1.5	1±1.5	0.7±1.1	2.41±0.6	1.83±1.1	0.5±0.9
Quality index 0 – 24				**3.7±0.1**	**4.2±0.1**	**4.3±0.1**	**16.9±0.4**	**16.25±0.5**	**8.16±0.4**	**8.1±0.4**	**15.58±0.5**	**15.91±0.3**	**6.3±0.1**

A- Anchovy B- *Sardinella* sp. C- *Amblygaster* sp. D- *K. pelamis* E- *E. affinus* F- *A. jella*
G- *Cheilopogon* sp. H- *D. macarellus* I- *E. bipinnulata* J- *C. maculatus*

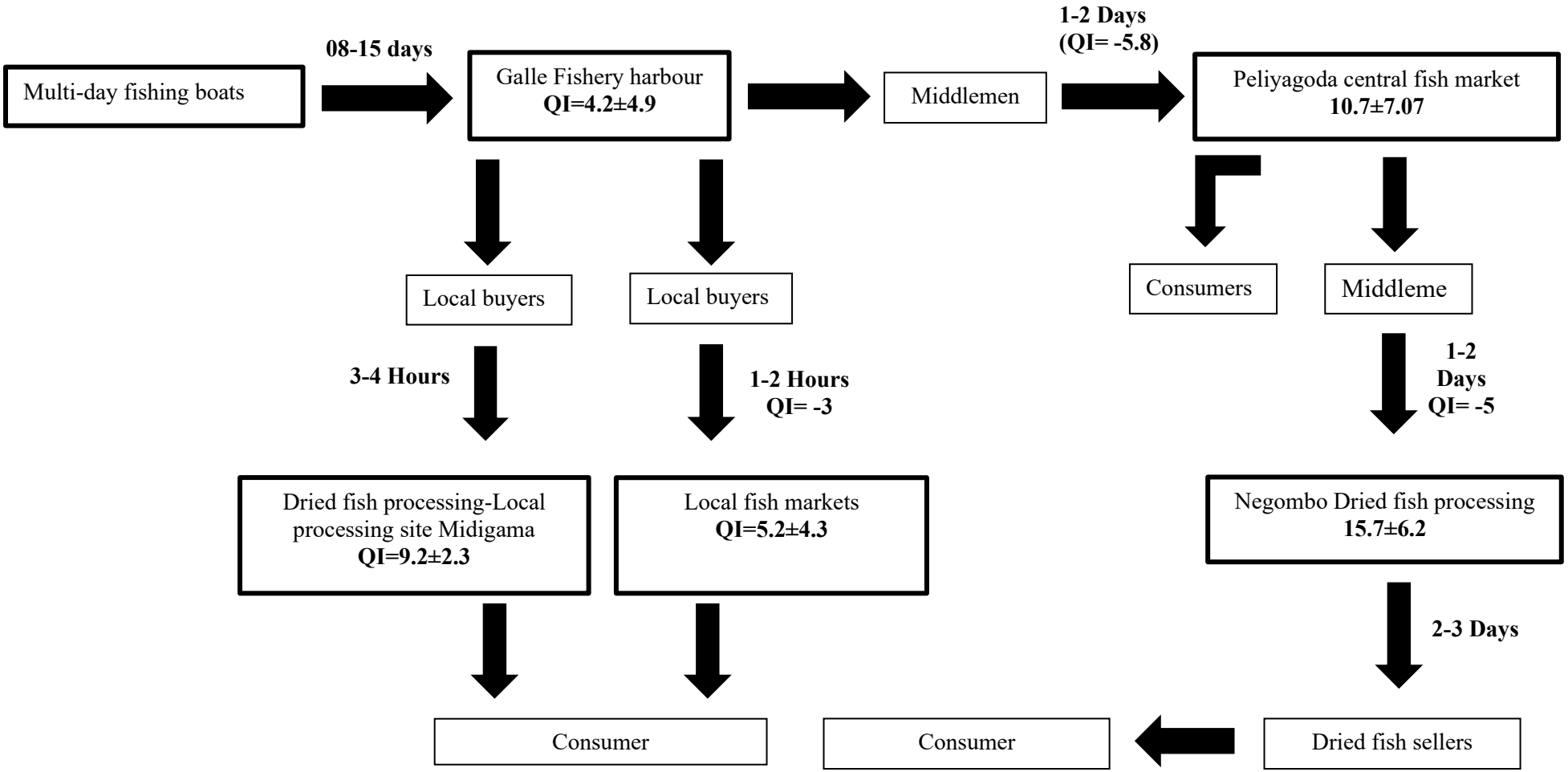

Fig 3 Quality changes of *D. macarellus* catches along the supply chain from Galle fishery harbor to Negombo dried fish processing site

.

Table 4 The proximate composition of fresh and dried fish collected from Negombo, Sea Street dry fish processing site of Sri Lanka.

Species	Moisture%	Ash%	Crude protein%	Crude fat%
Encrasicholina heteroloba				
Fresh	75.7±0.8	4.4±0.0	60.2±0.5	4.9±0.6
Dry	19.9±0.4	6.0±0.1	62.1±1.3	7.4±0.5
p value		0.001	0.001	0.002
Sardinella gibbosa.				
Fresh	81.2±0.7	5.6±0.2	53.7±0.0	5.1±0.1
Dry	32.0±0.5	6.2±1.0	56.3±1.6	7.4±1.2
p value		0.034	0.001	0.03
Decapturus macarellus				
Fresh	77.3±2.1	6.8±0.3	54.4±0.1	1.8±0.1
Dry	44.8±3.3	7.8±2.0	57.2±0.7	13.6±0.3
p value		0.082	0.001	0.001
Cheilopogon furcatus				
Fresh	75.1±0.5	4.4±0.1	55.7±0.3	9.9±0.7
Dry	48.7±0.5	5.2±0.6	59.9±0.3	11.7±0.6
p value		0.051	0.000	0.014
Canthidermis maculatus				
Fresh	71.1±0.7	6.2±0.7	45.5±1.4	16.6±4.7
Dry	43.6±8.0	7.2±1.9	49.2±0.9	17.0±4.7
p value		0.146	0.002	0.417

Production and marketing of dried fish

Six major steps, i.e., de-heading and gutting, washing, salting, re-washing, drying, and packing are mainly involved in the dry fish production process, although slight modifications were noted with respect to species.

De-heading and gutting are carried out to remove unnecessary parts (gut and head) of fish and this is done for most of the fish species except for small pelagic fish. The outer skin of *C. maculatus* is removed together with the head and gut. Larger fish species like *K. pelamis*, *E. affinis,* and *E. bipunulata* are cut into pieces after removing gut and head.

Washing is mainly carried out to remove slime, blood and sand particles on fish. Fish are washed in bulk by shaking 2-3 times in shallow coastal waters adjacent to the fish processing site.

Both iodized (27%) and non-iodized (73%) salts are used for salting. Fish species like *Sardinella,* anchovy, *Amblygaster, D. macarellus,* and *Cheilopogon* are dipped in brine solution while salt is applied to the bodies of large fish species including *K. pelamis*, *E. bimaculatus,* and *E. affinis*. The estimated fish to salt ratio is 3:1 and salting is mainly done in plastic barrels which are covered with black polythene after introducing fish. Salting time varies with species. Except for anchovies and *Sardinella* spp., all other species are kept in salt for two days. Salting time for anchovy is around 6 ±2 hours and it is 8 ±2 hours for *Sardinella* species.

Rewashing is done to remove excess salt and contaminants. Sun drying is the widely practiced method of drying fish, and it is carried out on an open beach. Drying time ranges from a few hours to 3 days, depending on species, the size of individuals, and local weather conditions. The average drying time for anchovy and *Sardinella* species is around 6-8 hours, while it is 2-3 days for other species. Dried products are packed in cardboard boxes and tightly sealed. Normally, boxes weighing 20, 25 and 30 kg are produced.

Fishers, buyers, processors, sellers, and consumers are the main players in the dry fish value chain. Dried fish produced at Negombo, sea street processing site, reach the consumer through three different marketing channels (Figure 4). Around 16% of dried fish is reached directly by dried fish producers, while 29.5% is distributed through retailers. Wholesalers directly buy the rest (54.5%) from dried fish producers and distribute it to consumers through retailers.

Of the 320 employees in 42 processing centers in the Negombo Sea Street area, 32% are males while 68% are females. Most of the dry fish processing centres are owned by males, and 69% of them have obtained only primary education while the rest (31%) have secondary education. Young adults (11.9%) and elderly people (88.1%) in the age range of 25–67 years engage in dried fish processing-related activities.

Women's activities are mainly confined to sorting, grading, de-heading, gutting, and drying of fish, while washing, salting, and packing are mainly carried out by men. Most of the women are employed as part-time workers (71%) and they are called for duty when their service is needed. The work of the part-time women is restricted to 4-5 hours and their average daily wage ranges from LKR 600.00 to 800.00.

Most of the women involved in dried fish processing are the wives of fishermen, and they belong to different age classes, but 75% of them were in the age range of 40-55 years. Most of them have received only primary education (86%) and are badly experiencing in poverty. Thus, their children are also involved in dried fish production activities instead of going to school, showing a key socio-economic perspective of the fishing community.

Most of the processors and workers are Sinhala Catholic (68.2%), and Tamil Catholic (30.6%) while Muslim (1.2%) workers were rarely encountered.

DISCUSSION

Although there is a well-established dry fish industry in Sri Lanka, no detailed studies have been conducted so far to assess the status of this industry. Therefore, there is no previous information to make comparisons on any of the aspects focused on in this study.

This study revealed the use of different fish species for dried fish production and similar observations were made in Visakhapatnam fishing harbour (Das et al. 2013) and South West Bengal in Asia (Payra et al. 2016).

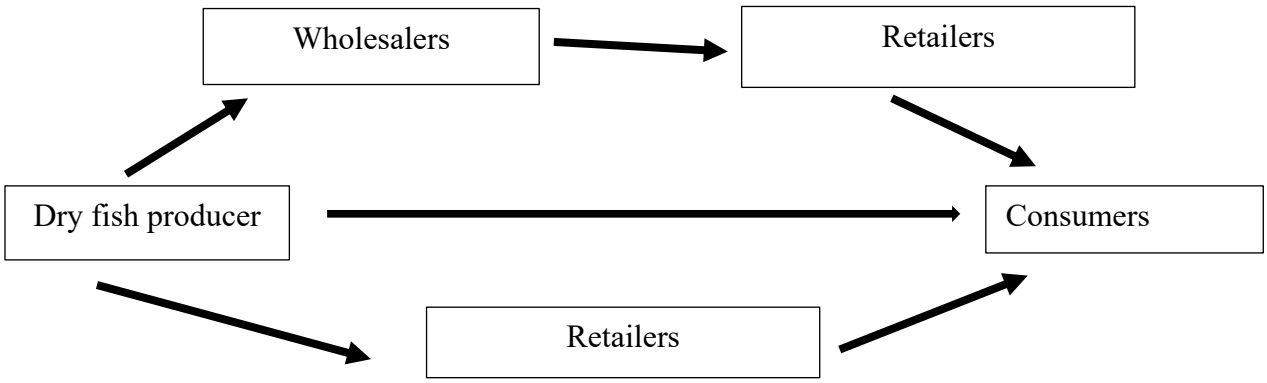

Fig 4 A typical supply and marketing chain of dried fish production in Negombo, Sea Street West coast of Sri Lanka

The observed temporal variations in the percentage contribution of fish species to the total dried fish production could be attributed with many factors, including fluctuations in fish landings, market price, and their quality. A study carried out by Zynudheen et al. (2004), reported that fresh fish imported from other landing sites are widely used to produce dried fish in Gujarat, India. Similarly, raw fish used for dried fish production at Negombo has been reported to have various origins.

Variations in dried fish market prices with respect to fish species were reported, and this could be due to quality and availability of raw materials, consumer preference, and climatic conditions as stated by Conover et al. (1998). The findings of this study also support the fact that the dried fish produced using high-quality raw materials always fetches a higher price than the low-quality materials specially received from various parts of the country.

Fish species used for dried fish production at Negombo dry fish processing site received various quality indices according to the Quality Index Method proposed by Hyldig et al. (2003). Accordingly, small pelagic fish such as anchovy, *Sardinella* spp., and *Amblygaster* spp. caught in the adjacent waters of Negombo have high quality and are widely used for dried fish production. Despite the fact that *C. maculatus* is transported from the south, the Quality Index assessment revealed that they are of high quality. This is because *C. maculatus* is a very hardy fish and it takes time to deteriorate. On the other hand, this species is rarely marketed as fresh fish, therefore, they are transported directly to the dry fish processing site at Negombo as soon as they are unloaded. However, this study proved that very poor-quality fish of *K. pelamis, E. affinis, D. macarellus,* and *E. bipinulata* are used for the dried fish production process. This could be due to reported continuous quality losses along the supply chain while they are received from distant areas. Similar observations were reported previously by Beatty and Fougere (1957), and according to them, poor quality raw fish is always used to produce dried fish, except for a few small pelagic fish.

A larger percentage of consumers do eat dried fish because of its availability, flavour, and palatability, while others do so because of its nutritional value. Although the proximate compositions of fresh fish species have been studied in detail, such information is scarce for dried fish. Further, changes in proximate composition when producing dried fish are not invented in detail. Gandotra et al. (2017) showed that the moisture content of fresh fish ranged from 77.2 to 83.1%, and the results of this study also support their finding. According to Flowra et al. (2004), sun-dried fish typically have a moisture content of 10–20%. However, this study reported 19.9 - 48.7% moisture content in dried fish. This high moisture content could lead to a reduced shelf life as well as enhanced microbial growth in dried fish (Immaculate et al. 2013). According to Akinneye et al. (2007), there could be some

differences in moisture content with respect to drying method and drying time. Though there is a SLSI standard (Sri Lanka Standard 643:2007) for Sri Lankan dried fish, the % moisture content is not considered as a standard.

This study reported a significantly higher ash content in dried fish than in fresh fish. Boran et al. (2008) proposed that ash content in dried fish should be in the range of 1.2–1.5%, but dried fish produced at Negombo reported 5.2–7.8% of ash. This could be mainly due to the high amounts of salt added during the dried fish production process. The analysis of sodium chloride content in dried fish showed that all the products contained a higher percent of NaCl than the SLSI standard limit of 12%. Local processors probably use a high amount of salt in the dried fish production process to overcome the poor quality of fish, especially the bad smell and bad taste. The crude protein content of fresh fish was found to be in the same range as Gandotra et al. (2017) and Flowra et al. (2012). The observed significant changes in protein content of dried fish could be a result of alterations in protein content due to different processing tactics, removal of some body parts, and relative losses or additions of other constituents during processing (Nishanthan et al. 2018). Similarly, changes in some fatty acid constituents as a result of oxidation during the drying may have contributed to the elevated levels of crude fat in dried fish. According to the results of this study, the proximate composition of fresh fish can be significantly affected by the drying process.

The total coliform was evident only in water samples but not in dried fish samples. Adding a high amount of salt and drying fish under heavy sunlight may be some of the possible reasons for the absence of pathogenic organisms on dried fish.

Major steps in the dried fish production process, such as de-heading and degutting, washing, salting, rewashing, drying, and packing, were found to be similar to those used by regional countries (Marine et al. 2015). According to Reza (2005), Bangladesh uses very poor-quality sea water to wash and clean the fish used for dried fish production, and a similar situation was reported in this study. Although drying fish under sunlight by putting them on mats or gunny bags laid on open beaches is a common practice in the dry fish production process, many drawbacks of this method were highlighted in this method (Marine et al. 2015). As per the proposals made by Marine et al. (2015), the use of ropes or racks can be considered to address these issues.

It was noted that most of the dry fish processors do not comply with existing standards such as sanitation and Hazard Analysis and Critical Control Points (HACCP). Therefore, high quality local products are rarely warranted. Furthermore, currently used processing methods are highly traditional, and there is a need to develop standard processing protocols for dry fish production in the country. Some unnecessary functions, including the moving of products through intermediate buyers, are apparent in the current value chain. Therefore, it is necessary to build direct relationships between fishers, processors, retailers, and consumers in order to upgrade the current value chain. Further, an efficient way of getting market and price information on dried fish should be developed to upgrade the functions of the current value chain.

REFERENCES

Adebayo, B. C., N. N. Odu, L. M. Anyamele, N. J. P. N. Igwiloh, & I. O. Okonko. 2012. Microbial quality of frozen fish sold in Uyo Metropolis. Nature and Science 10(3): 71-74.

Akinneye, J. O., I.A. Amoo, & S. J. Arannilewa. 2007. Effects of drying methods on the nutritional composition of three species of fish (*Bonga* sp., *Sardinella* sp. and *Heterrotis niloticus*). Journal of Fisheries International 2(1): 99-103.

AOAC 1990 Official Methods of Analysis of AOAC International, 17th edition.

Balachandran K. K. 2001 Post-harvest Technology of Fish and Fish Products. Daya Publishing House, Delhi- 110035, pp. 77.

Beatty, S. A. & H. Fougere. 1957. The processing of dried Salted fish. Bulletin No. 112, Fisheries Research Board of Canada. Technological Station, Halifax, N.S. 61 pp

Bligh, E. G. & W.J. Dyer. 1959. A rapid method of total lipid extraction and purification. Canadian Journal of Biochemical Physiology 37: 911–917. https://doi.org/10.1139/o59-099

Boran, G., M. Boran, & H. Karaçam. 2008. Seasonal changes in proximate composition of anchovy and storage stability of anchovy oil. Journal of Food Quality 31(4): 503–513. https://doi.org/10.1111/j.1745-4557.2008.00215.x

Conover, S. A., Y. F Dong & S. K. Grant. 1998. Hong Kong dried fish market. Prepared in connection with Saltonstall-Kennedy Grant: Dried Fish Market Investigation and Industry Demonstration Project, 29.

Das, M., P. Rohit, G. Maheshwarudu, B. Dash & P. V. Ramana 2013. An overview of dry fish landings and trade at Visakhapatnam fishing harbor. Marine Fisheries Information Service, No 215.

FAO 2020. The State of World Fisheries and Aquaculture 2020. Sustainability in action. Rome. 224 pp. (Also available at https://www.fao.org/3/ca9229en/ca9229en.pdf).

Flowra, F. A., M. S. Mohmud, & I. R. C. Monda, 2004. Traditional fish drying activities and socio-economic status of dried fish processors of ChalanBeel area, Sirajgani, Bangladesh. Bangladesh Journal of Progress Science Tech 10(1): 65-68.

Flowra, F.A., D.G. Nahar, A.S. Tumpa & M.T. Islam. 2012. Biochemical analysis of Five Dried Fish species of Bangladesh. University Journal of Zoological Society 31: 9-11. https://doi.org/10.3329/ujzru.v31i0.15373

Gandotra, R., M. Sharma, S.Sharma, & R. Kumari. 2017. Studies on the variations in the proximate composition of *Labeo boga* in relation to habitat and season. International Journal of Recent Scientific Research 8: 17544-17549.

Hyldig, G., M. B. Ditte, & G. Petersen. 2003. Quality Index Method, An Objective Tool for Determination of Sensory Quality. Journal of Aquatic Food Product Technology 13(4): 71–80. https://doi.org/10.1300/J030v13n04_06

Immaculate, K., P. Sinduja, A. Velammal, & J. Patterson, 2013. Quality and shelf-life status of salted and sun dried fishes of Tuticorin fishing villages in different seasons. International Food Research Journal 20(4): 1855-1859

Islam, M. S., T. H. Miah, & M. H. Haque 2001. Marketing system of marine fish in Bangladesh : An empirical study. The Bangladesh Journal of Agricultural Economics 2: 127–142.

Kallon, A., A. Lebbie, B. Sturm, T.Garnett & R.Wadsworth, 2017. Comparative studies of fish smoking and solar drying in the Sierra Leone artisanal fishing industry. Journal of Stored Products Postharvest Research. 8(3), 40–48.

Kumar, A., P. Singh & M. Danish. 2013. Changes in proximate biochemical and microbiological characteristics of dried *Labeo gonius* fillets during storage at room temperature. African Journal of Biotechnology 12(20): 2997-3005.

Marine, S. S., M. A. Sayeed, P. P. Barman, R. Begum, M. M. Hossain, & M. T. Alam. 2015. Traditional methods of fish drying: An explorative study in Sylhet, Bangladesh. International Journal of Fishery Science and Aquaculture 2(1): 28-35.

MFAR 2020. Fisheries statistics. Ministry of Fisheries Maligawatta, Colombo.

Nishanthan, G., M. D. S. T. de Croos, D. V. P.Prasada & D. C. T. Dissanayake. 2018. Effects of processing on proximate and fatty acid compositions of six commercial sea cucumber species of Sri Lanka. Journal of Food Science and Technology, 55(5), 1933-1941. https://doi.org/10.1007/s13197-018-3111-4

Payra, P., R. Maity, S. Maity. & B. Mandal, 2016. Production and marketing of dry fish through the traditional practices in West Bengal Coast: Problems and prospect. International Journal of Fisheries and Aquatic Studies 4(6): 118-123.

Reza, M. S., M. A. J. Bapary, K. M., Azimuddin, M. Nurullah, & M. Kamal. 2005. Studies on the traditional drying activities of commercial important marine fishes of Bangladesh. Pakistan Journal of Biological Science 8(9): 1303-1310. https://doi.org/10.3923/pjbs.2005.1303.1310

Shamsuddha, M. 2007. Supply and value chain analysis in the marketing of marine dried fish in Bangladesh and non-traffic measures (NTMs) in international trading. No. 691-2016-47361

Zynudheen, A. A., G. Ninan, A. Sen, & A. Badonia. 2004. Utilization of trawl by-catch in Gujarat (India). NAGA, World Fish Center Quarterly 27: 3-4.