The Journal of Nutrition and Food Sciences

Journal Home Page: https://nutritionsocietyofsrilanka.org/the-journal-of-nutrition-and-food-sciences-2/

Contribution of Dried Fish to Food and Nutrition Security in Sri Lanka: A review

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ARTICLE INFO

Article history:
Received:
29.10.2021
Revised version received:
12.12.2022
Accepted:
15.12.2022
Available online:
21.02.2023

Keywords:
COVID-19 pandemic
Dried fish
Food and nutrition security
Sri Lanka

Citation:
Jayasekara, I. G. R. I., Wijekoon, A. P., & Somaratne, G. M. (2022). Contribution of dried fish to food and nutrition security in Sri Lanka: A review. *The Journal of Nutrition and Food Sciences*, 1(1), 61–76.

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ABSTRACT

Dried fish is a widely consumed dietary source of macro and micronutrients, especially in low- and middle-income households. It is a pool of bioavailable high-quality animal protein with essential amino acids, essential minerals, vitamins, omega 3 and 6 fatty acids. Dried fish is generally acceptable to all regardless of region, religion, race, gender, and age across Sri Lanka. However, the role of dried fish production had been rarely elaborated on food and nutrition security in Sri Lanka. Therefore, this review aimed at delivering an overview of the contribution of dried fish towards food and nutrition security in Sri Lanka together with nutritional value of fish and dried fish products. The aim of dried fish production is to deliver a safe and wholesome final product to the consumer by preserving fish facilitating long shelf life. Sun drying, salting and drying, and smoked drying are the main dried fish processing methods. The contribution of dried fish is high in poor and marginalized communities in Sri Lanka. Dried fish provides a significant proportion of affordable and readily available animal protein to a large segment of the people in the country. Adequate emphasis should be given to enhance the dried fish production to meet the requirements. More investments are necessary to enhance the production of safe and quality dried fish.

INTRODUCTION

Malnutrition and hunger are among the most suffering problems in the world at present, especially in lower and middle-income countries (Bogard, 2017, Thilsted *et al.,* 2014). As Sri Lanka is still a developing country, malnutrition exists among rural poor and estate households more than the urban population (Abeywickrama *et al*., 2018; Reksten, *et al*., 2020). Furthermore, children under 5 years old as well as pregnant, and lactating women are highly vulnerable to under-nourished conditions (Amarasinghe, 2014). Anemia, iodine, zinc, vitamin A, folate, and calcium deficiencies are nutrient deficiency problems reported in Sri Lanka that were prevalent among low-income families (Reksten, *et al*., 2020, Abeywickrama *et al*., 2018; Weerahewa *et al*., 2018). Fundamental factors such as uncertainty in the politics and economy of the country, healthcare status, food culture, gender equality, education, and environmental issues play a critical role in the causal pathways of malnutrition (Abeywickrama *et al*., 2018). The significance of this global challenge is highlighted in the United Nations Sustainable Development Goals (SDGs), where goal two is designed to address ending hunger, achieving food security, improving nutrition, and ending all forms of malnutrition (Laborde *et al*., 2016).

Food and nutrition security is defined as the ability of all people to have physical, social, and economic access to sufficient, nutritious, and safe food to meet their dietary needs and food preferences for an active and healthy life, coupled with a sanitary environment, adequate health, education, and care (Bilali *et al*., 2019). Pervasive food and nutrition insecurity has emerged as a global humanitarian crisis during the coronavirus disease (COVID-19) pandemic. Across the world, fisheries have been identified as being an important component in achieving food and nutrition security, especially in less-developed countries including Sri Lanka (Khan *et al*., 2021). The fisheries sector in a country can contribute to food and nutrition security in two ways. On one hand, fish and related products are rich dietary sources of essential macro and micronutrients. On the other hand, it can be a direct nutrient source or an income source that can be used to buy other types of food for fishing communities (Emmanuel *et al*., 2019).

The fisheries sector in Sri Lanka plays a crucial role in the economy of the country contributing around 1.3% to the gross domestic production. Fish products are an important source of animal nutrients, providing nearly 50% of animal protein and 22.2% of animal fat (Fisheries Statistics, 2019). Direct and indirect employment is also provided to around 585,000 people (Fisheries Industry Outlook, 2018). In the year 2019, the marine sector contributes 415,490 MT for annual fish production while 90,340 MT is supplied by the inland and aquaculture sector. Per capita, fish consumption was around 16.6 kg/year (Fisheries Statistics, 2019).

Dried fish is an important commodity consumed for centuries in Sri Lanka which plays a significant role in nutrient security, livelihood, and foreign exchange similar to fresh fish production. Dried fish supports to minimize postharvest losses of fresh fish while giving a value-added product (Koralagama *et al*., 2021). Poor handling and storage of fish allow rapid postharvest deterioration limiting the availability. Consequently, salting, smoking, and/or sun-drying of fish are used to preserve and produce a microbiologically stable products at a reasonable cost (Guizani *et al*., 2008). Dried fish is considered the poor man's protein because it is one of the main affordable sources of animal protein compared to other animal proteins (i.e., meat, dairy, and eggs) for the underprivileged community in low-income groups, especially the people living in areas other than the coastal belt

(Aall, 1982; Dona *et al*., 2018). Additionally, due to the prevailing COVID-19 pandemic situation in recent years, the demand for shelf-stable dried fish products has spiked at households as it is a non-perishable food item (Mandal *et al*., 2021). It is acknowledged that increased dried fish supplies are needed to meet the growing food demand in Sri Lanka. However, there is limited information regarding the contribution of dried fish consumption to overall food and nutrition security among Sri Lankans. This review was to present an overview of the contribution of dried fish towards food and nutrition security in Sri Lanka while describing the nutritional value of dried fish products and consumption behavior of the Sri Lankans.

MATERIALS & METHODS

The review focused on the link between dried fish and food and nutrition security in Sri Lanka and their contribution to selected areas of four dimensions of food security: food availability, food access, utilization, and stability (Figure 1). Quantitative and qualitative research articles fulfilling the following criteria were identified; written in English, published after the year 2005, presenting local and international data, available online, and relevant to one of the selected topics highlighted in Figure 1. Previously published research articles (between 2007 and 2020) relating to fish and dried fish nutrition towards human health were browsed using reputed browsing tools and websites such as Google scholar, Medline, Science Direct, and Web of Science. To reach for more relevant articles, a reference list of major studies was examined while using terms regarding the nutrient composition of dried fish and dried krill, nutrient composition of fish, fish and dried fish consumption, dried fish-based product development, and malnutrition status of Sri Lanka as keywords. This review also includes data published by annual reports and statistics of the Ministry of Fisheries and Aquatic Resource Development (MFARD), National Aquatic Resources Research and Development Agency (NARA), Department of Census and Statistics, Food and Agriculture Organization (FAO) in recent years.

RESULTS

Dried fish for food and nutrition security in Sri Lanka

Availability of dried fish to strengthen food and nutrition security in Sri Lanka

Fish and its processed foods including dried fish and canned fish are the most frequently consumed animal protein sources in Sri Lanka, irrespective of socioeconomic status or locality. Dried fish is not only a value-added commodity derived from fish, but also it is an important source of nutrition among Sri Lankan cuisines. It is consumed as a main dish as well as a flavor-enhancing condiment in many dishes (Koralagama *et al*., 2021). Until 2012, it remained the second highest animal origin food product consumed per capita after fresh fish (Department of Census and Statistics, 2016). However, dried fish prices have increased considerably since 2012 compared to fish and chicken prices, and consequently dried fish consumption has fallen to third place (Fisheries Industry Outlook, 2018). However, it is still significant as an animal origin protein source in low-income households, particularly in the island's rural areas, dry zone, and hill-country regions (Krishnal and Dayaani, 2014) as it is a low-cost, readily available, and shelf-stable substitute compared to other animal protein sources such as chicken, seafoods, eggs, and dairy products (Dona *et al*., 2018). The most demanding dried fish variety in Sri Lanka is sprats (anchovy) followed by skipjack tuna, shark, smooth belly sardines, and Thalang queen fish (Wickrama *et al*., 2021; Koralagama *et al*., 2021). Average fish consumption is 16.6 kg/year in 2019 in all sectors. Monthly

expenditure on dried fish data showed estate households expenditure is more compared to the urban and rural communities (Dona *et al*., 2018). Demand for dried fish is increased by the religious and cultural barriers to the consumption of meat and the unavailability of other animal protein sources (Koralagama *et al*., 2021). Most of the local consumers have declared that price fluctuation as the main problem for purchasing dried fish. In addition, poor production facilities, disorganized market facilities, and poor-quality products are existing problems that affect the availability of dried fish in Sri Lankan market (Krishnal and Dayaani, 2014).

In 2019, the total dried fish supply to Sri Lankan market was 89,849 MT and from that, 54,880 MT was domestically produced, and 34,969 MT was imported (Fisheries Statistics, 2019). Thus, nearly 65% of local dried fish demand is produced within the country, and the remaining was imported mainly from Maldives, Pakistan, Thailand, India, Indonesia, and United Arab Emirates. Anchovies (sprat) share 70% of total imports of dried fish and it is considered the major fishery product imports to the country (Fisheries Industry Outlook, 2018). Marine and inland are the major two sectors of dried fish production in the country. Marine dried fish production far outpaces inland production and with little research on inland dried fish production.

Even though processing of marine dried fish is practiced in all coastal belt areas in Sri Lanka, on a large scale, it is implemented in Trincomalee, Mannar, Kalpitiya, Chilaw, Jaffna, Beruwala, Negambo, Mulathivu, Ampara, Hambanthota, Galle, Kaluthara and Batticalo. Inland dried fish production is mainly carried out in Ampara, Anuradhapura, Polonnaruwa, Minneriya, and Monaragala in natural reservoirs and tanks (Fisheries Industry Outlook, 2018). Table 1 depicts the marine and freshwater fish varieties used to produce dried fish in Sri Lanka. As presented in Table 1, the main marine dried fish species produced in Sri Lanka are sprats, Katta, Balaya, Keeramin, Seer, and Maduwa. Most freshwater fish are low in price because they are small in size, and the bone percentage is high compared to flesh. Therefore they are used for drying. Tilapia, Catfish, Pearl spot Cichlid, and filamented Barb are the inland fish varieties used for drying (Fisheries Industry Outlook 2018; Koralagama *et al*., 2021). In Sri Lanka, it is estimated that 14% of the harvested fish is well-preserved using simple processing techniques such as sun drying, solar drying, salting, smoking, and fermentation, collectively known as "dried fish."

Figure 2 illustrates the two different methods of fish drying and processing methods in Sri Lanka. Salt and fish are used as the main raw materials for the processing dried fish (Boziaris, 2014). Low-quality fish (which are brought in by multiday boats late/ "Dawal malu" or fish at the bottom of net/ "Yata malu") and part of excess fish supply in peak seasons are mainly used for dried fish production (Koralagama *et al*, 2021). Additionally, fish susceptible to spoilage and difficult to sell at the fisherman level is processed into dried fish (Agustini *et al*., 2009). Sun drying is a conventional method of drying fish; under the hot sun without adding salt. Generally, multiday boats use this method to make sun-dried fish with initial catches of their harvest, locally these are called "bottu karawala", boat-dried fish (Koralagama *et al*., 2021).

The traditional drying and salting method of preserving fish continues to be very popular because it produces such great flavor, long shelf life, and more expected quality attributes of consumers (with or without sun) (Surendra *et al*., 2015,

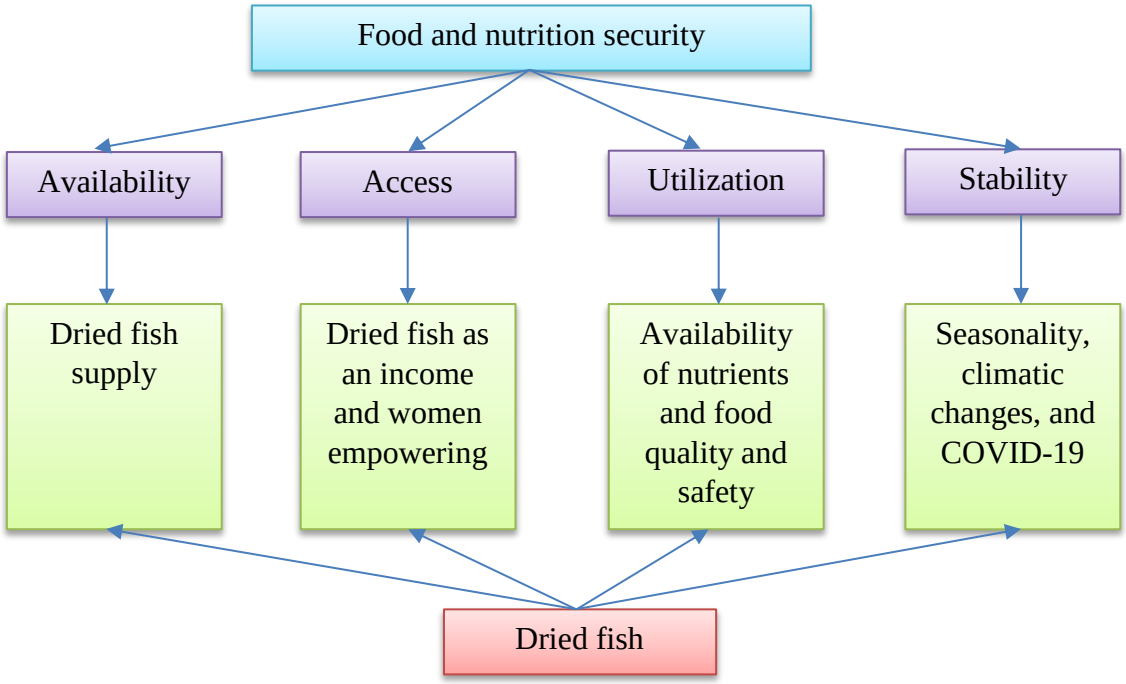

Figure 1. Conceptual framework for the review article, the four pillars of food security (Bilali *et al*.,2019) and selected focus areas related to dried fish and food and nutrition security in Sri Lanka

Boziaris, 2014). Maldive fish or in other words cooked, smoked, and hard dried Tuna variety fish is another popular type of dried fish in Sri Lanka. Lengthy smoking is based on the principle of reducing the internal water content. Smoke particles provide an added flavor, color, and taste to the product and it also has antioxidant and antimicrobial properties confirming the preservation of fish (Abraha *et al*., 2018).

Contribution of dried fish industry on food accessibility in Sri Lanka

The growing economic inequality has serious implications for food and nutrition and emphasizes the importance of having access to affordable, nutritious foods. The role of dried fish is crucial in this regard, as it is available throughout the country at relatively low prices, and can be purchased in small quantities. According to the estimates of Household Income and Expenditure Survey (2016), the average monthly consumption of dried fish per Sri Lankan household is 1.1 kg and dried fish provides 60% of the total animal protein intake (Olaidipo and Bankole, 2013).

Livelihood built up with the dried fish value chain helps to generate income and allows people to access nutritious foods. The dried fish industry is mainly carried out as cottage level industry by women in the fishing communities as an extra source of income (Wickrama *et al*., 2021). Women in the coastal belt in Sri Lanka play a vital role in food and nutrition security, making smoked and dried fish available in urban and rural markets at relatively affordable prices. Dried fish can be stored in households lacking electricity, refrigerators, and freezers.

Although women's roles in the dried fish industry are considered essential, these women's communities have limited access to funding, education, and institutional support compared with their male counterparts, which limits the role of women in decision-making and their opportunities for enterprise expansion in

the fisheries sector (Koralagama *et al*., 2021). Additionally, the main obstacles to dried fish processing in Sri Lanka are high labor cost, inadequate fish supply for processing, especially during the off-season, uncertain weather, and poor storage facilities. Women's engagement in dried fish processing is the lowest in Muslim fishing communities.

On the other hand, women's engagement in dried fish processing appears to be highest in Sinhala Catholic and Tamil Hindu fishing communities in Sri Lanka (Yuganthan *et al*., 2019). Moreover, accessibility to fresh fish (key raw material), beach (location), market (revenue), finance (decision making), as well as lack of social recognition and powerlessness are reported as constraints by women dried fish processors in Sri Lanka (Koralagama and Bandara, 2018). Despite these limitations, the purchasing power from selling dried fish (i.e., increased access) resulted in a greater proportion of income being spent on other staple nutritious food when women were engaged in these activities.

Contribution of dried fish to the nutrition security in Sri Lanka

This section highlights three important dimensions of dried fish as food: 1) the bioavailability of essential nutrients in dried fish, 2) the contribution of fish to nutrition security for vulnerable populations in Sri Lanka and, 3) food quality and safety concerns regarding dried fish handling and consumption.

Bioavailability of essential nutrients in dried fish

Dried fish is rich in highly bioavailable nutrients which are beneficial for human health including animal protein/essential amino acids, essential polyunsaturated fatty acids, and micronutrients such as vitamins and minerals with a low amount of calorie (Gephart *et al*., 2020, Balami *et al*., 2019). The nutritional composition of dried fish varies according to sex, age, season, habitat, region, water temperature, type of dietary ingredients, and abundance of available fish (Reksten, *et al*., 2020, Abraha *et al*., 2018, Boziaris, 2014).

Table 2 shows the proximate composition of commonly consumed dried fish species. The water activity of dried fish is nearly 0.73 (Surendra *et al*., 2015) while water content is nearly 15-40% (Sachithananthan, 1977), 18.23-24.46% (Azam *et al*., 2003), 29.25-34.43% (Islam *et al*., 2013) and 14.06-24.58%. Depending on the relative humidity of the surrounding environment and the fish species, water content of dried fish gives different values (Flowra *et al*., 2012). Except for moisture content, other nutrients show lower values in fresh fish than in dried fish (Pal *et al*., 2018). Therefore, dried fish is identified as a nutrient-dense product. Moreover, it is reported that the nutritional value of 1.0 kg of dried fish is higher than 1.0 kg of chicken in wet weight (Koralagama *et al*, 2021).

As an animal origin protein source, protein in dried fish is known as more easily digestible than plant protein while improving the digestibility of plant protein (Emmanuel *et al*., 2019). Dried fish is rich in all essential amino acids, especially methionine and cysteine which are less available in plants. Further, the digestibility of fish protein is higher nearly 85-95% than other sources of proteins (Balami *et al*., 2019, Jag Pal *et al*., 2018).

A large portion of fish lipids contains unsaturated fatty acids and lipid-soluble vitamins (A and D). Omega 3 and omega 6 are two types of essential fatty acids and cannot be efficiently synthesized in the human body (Pal *et al*., 2018). Polyunsaturated fatty acids make fish a nutritionally important food.

Table 1. Marine and freshwater fish varieties used to produce dried fish in Sri Lanka

Scientific name	English name	Sinhala name	Expenditure on dried fish (LKR)†	Dried fish consumption (g)‡
Marine fish				
Stolephorus sp.	Anchovy species (sprats)	Haalmessa	77.90	128.15
Amblygaster cluepeoides	Smoothbelly sardinella	Keerameen	13.26	20.11
Amblygaster sirm	Trenched sardinella (herring)	Hurulla	3.22	6.01
Leiognathus sp.	Pony fish species	Karalla	-	-
Rastrelliger kanagurta	Indian mackerel	Kumbalava	-	-
Decapterus macrosoma	Shortfin scad	Linna	-	-
Katsuwonus pelamis	Skipjack tuna	Balaya	22.19	29.77
Scombroides lysan	Double-spotted queen fish	Katta	19.85	19.69
Carcharhinus sp.	Shark	Mora/Keelan	19.85	22.15
Clarias thalassinus	Giant catfish	Anguluwa	7.75	10.85
Scomberomorus commersoni	Narrow-barred Spanish mackerel (Seer)	Thora	-	-
Harpadon nehereus	Bombay duck	Bombili	-	-
Dasyatis sp.	Sting ray	Maduwa	-	-
Caranx ignobilis	Giant trevally	Parawa	1.11	1.51
Penaeus sp.	Shrimp/prawn	Issa	1.94	2.41
	Krill	Kooni	-	-
Freshwater Fish			2.22	3.86
Oreochromis mossambic	Tilapia	Mozambique Tilapiya	-	-
Clarias sp.	Catfish	Magura	-	-
Puntius filamentosus	Filamented barb	Pethiya	-	-
Etroplus suratensis	Pearl spot cichlid	Koraliya	-	-
Oreochromis niloticus	Nile tilapia	Batta	-	-
Glossogobius giuris	Bar eyed goby	Weligouwa	-	-
Channa striatus	Murrel	Loola	-	-
Hyporham	Half beak	Morella	-	-

†*Average monthly expenditure per person in 2016*

‡*Average monthly consumption per person in 2016*

(Source: Department of Census and statistics - 2016, Fisheries Statistics -2019, Koralagama et al, 2021).

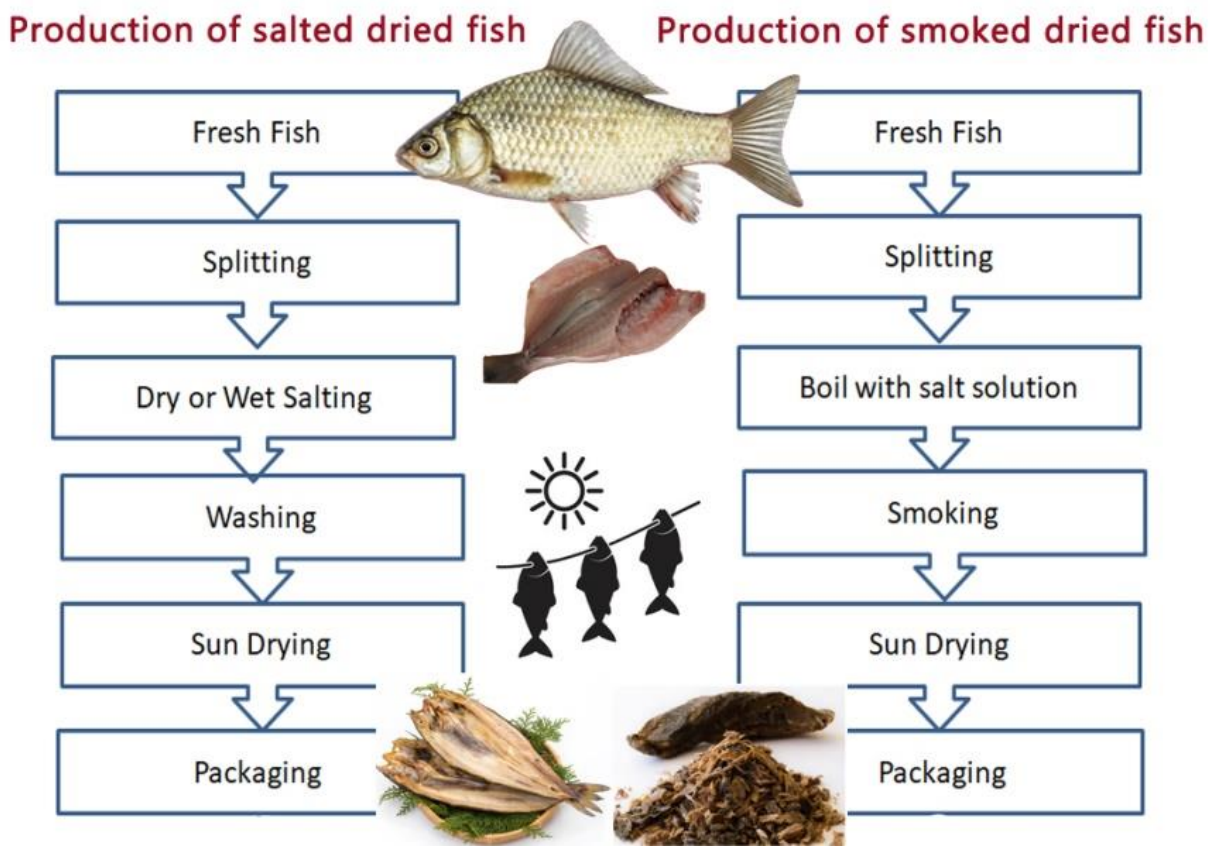

Figure 2. Overview of processing methods of dried fish

Fish including Trenched sardinella, Gold-striped sardinella, other *sarinella sp*., and Mackerels supply sufficient amounts of omega-3 fatty acids by eating them at least twice a week (Ministry of Health Sri Lanka, 2011). Polyunsaturated fatty acids are very crucial during the pregnancy period to improve the cognitive development of the child.

Docosahexaenoic acid (DHA) has been found to be essential for the development of the brain and central nervous system in children while eicosapentaenoic acid (EPA) is important in cardiovascular health (Balami *et al*., 2019, Ministry of Health Sri Lanka, 2011). Fat in fish is helpful for the prevention of cancer, depression, and atherosclerosis. They are known to prevent many diseases such as skin diseases, asthma, arthritis, diabetes, autoimmune disorders, and enhance the immune system (Pal *et al*., 2018, Ministry of Health Sri Lanka, 2011).

Dried fish, more particularly small fish are rich in bioavailable minerals and these minerals are easily absorbed by the body. Calcium, iron, iodine, zinc, and selenium are the main minerals in fish. Other than these, phosphorus, sodium, potassium, and fluorine are present in fish and dried fish products. Calcium is a crucial mineral for bone health, and it is supplemented during the pregnancy period to maintain the health of both fetus and mother (Kwasek *et al*., 2020). Small fish can be added to meals as fried fish which are rich in calcium. Calcium is a key component for the formation and the maintenance of teeth and bones and helpsto minimize the risk of osteoporosis in adults and rickets in children (Ministry of Health Sri Lanka,

2011). Further, it is important for the proper functioning of

Table 2. Proximate composition values for dried fish

Fish species considered	Crude protein (%)	Crude fat (%)	Total minerals (%)	Reference
Dried haddock	75-80	0.6	5.6 Salt - 1.2	Jonsson *et al*., 2007
Dried sprats	-	-	Salt - 11.78	Surendra *et al*., 2015
Dried catfish	-	-	Salt - 12.48	
Dried tuna	-	-	Salt - 14.01	
Dried fish (Using 17 species)	40-50	Over 4	16.1 - 30.6	Sachithananthan, 1977
Sardinella sp	46.7	1.1	17.8	Sachithananthan, 1977 (Proximate composition of dried fish)
Amblygaster sirm	46.3	4.4	21.3	
Tachysurus sp.	45.1	2.9	21.1	
Exocoetus sp.	44.9	6.5	27.9	
Chorinemes lysan	44.2	2.3	21.1	
Tilapia mossambica	41.4	3.3	40.6	
Rastrelliger kanagurta	45.3	2.0	22.5	
Katsuwonus pelamis	45.0	1.7	17.6	
Dussumieria acuta	43.5	5.4	18.4	
Anchoviella indica	52.8	5.8	25.2	
Dried fish (using 14 species)	40.69 - 68.09	2.97 - 26.13	5.08 - 16.02	Azam *et al*., 2003
Dried fish (using five species)	53.45 - 76.39	2.31 - 21.54	11.21 - 28.15	Flowra *et al*., 2012
Dried fish (using four species)	32.02 - 41.38	3.21 - 14.03	20.14 - 24.40	Islam *et al*., 2013
Dried krill / "Kooni"	54.6 - 71.6	4.5 - 9.2	22.0 - 40.7	Abeywickrama and Attygalle, 2014

nervous system and muscles (Pal *et al*., 2018). All red fish, sardinella, and dried fish supply heme iron which shows a better absorption compared to plant-origin non-heme iron (Ministry of Health Sri Lanka, 2011). It facilitates hemoglobin synthesis and useful in the prevention of anema (Kwasek *et al*., 2020, Pal *et al*., 2018; Abeywickrama *et al*., 2018). Dried fish also counteracts the effect of inhibitors, such as phytates, and thus co-ingestion enhances the absorption of non-heme iron and zinc from plant foods.

Small marine fish is an excellent natural source of iodine, zinc, and selenium. The purposes of iodine for humans are balancing thyroid function and regulation of body metabolism. Selenium is a trace element with antioxidant properties (Pal *et al*., 2018) and important in preventing cardiovascular diseases. Prevention of cancers and stimulation of the immune system are the other important roles of selenium. Zinc is necessary for the growth and the proper functions of immune system (Kwasek *et al*., 2020).

High levels of vitamins including fat-soluble (i.e., Vitamins A and D) and water-soluble (i.e., Vitamin B12) vitamins are present in dried fish. However, the bioavailability of vitamin varies among fish species. Large amounts of vitamins A and D are known to be stored in the liver of many fish species (Balami *et al*., 2019). Fatty fish have high amount of vitamin D than lean fish due to their fat-soluble nature (Kwasek *et al*., 2020, Jag Pal *et al*., 2018). Vitamin A is sensitive to sunlight and heat (Abraha *et al*., 2018). However, the effect of processing methods on micronutrient levels in fish is yet to be thoroughly elucidated. To maximize the utilization of dried fish in Sri Lanka, both selection of the fish species and the processing methods are important factors which determine the nutrient density and preservation. However, research findings on this area is still not well-established.

Contribution of fish to nutrition security in Sri Lanka

There are many dried fish recipes in Sri Lanka, which mainly include dried fish curry with coconut sauce (karawala/halmessan hodi), deep frying, stir-frying and pickling etc. (Koralagama *et al*., 2021). Dietary enrichment of toddlers, adolescents, pregnant and lactating mothers as well as elderly people's main meals with dried fish products is a common practice in Sri Lanka. However, scientific literature on the topic remains scarce. According to research conducted in Bangladesh, fish-based complementary food (i.e., dried fish chutney, dried fish powder) supply desirable amount of nutrients including iron, zinc, essential fatty acids, and protein for infants, young children, pregnant and lactating women (Islam *et al.*, 2013). For instance, one serving (10 g) of fish powder in the diet supplies more than 20% of recommended daily calcium requirement and 37% of DHA. One serving (30 g) of fish chutney gives more than 40% and 50% of recommended daily calcium requirement for pregnant women and lactating women, respectively. Research in Africa showed, dried small fish-based recipes can deal with micronutrient deficiencies that occur during the first 1000 days of life (Byrd *et al*., 2021).

Quality and safety aspects of dried fish

While dried fish contains a wide array of nutrients, they are also a source of contaminants. Dried fish have recently been identified and confirmed as a significant source of pathogens and chemical contaminants that pose a potential threat to human health in Sri Lanka (Surendra *et al*., 2015). Microplastic contamination (Reksten, *et al*., 2020), the presence of mycotoxin / aflatoxin (Deng *et al*., 2020), histamine (Ginigaddarage *et al*., 2018, Surendra *et al*., 2015), accumulation of heavy metals (Hg, Pb, Cd) and residues of agrochemical substances (Jinadasa *et al*., 2018) and formalin contaminations (Hanayani and Mutiara, 2020) have been identified as major health hazards associated with dried fish. Government has enacted laws and regulations to ensure standard production of dried fish to make those safe for human consumption (Food Regulations, 2020). Sri Lanka Standards Institution (SLSI) has prepared national-level specifications for dried fish (SLS 643: 1984 (Surendra *et al*., 2015) and Maldive Fish (SLS 811: 1988). However, locally produced dried fish are identified as safe for human consumption than imported products (Surendra *et al*., 2015).

Apart from contaminants, salt concentration of salted dried fish is critical for human health because overconsumption of salt beyond the recommended levels can have a direct impact on the development of non-communicable diseases including hypertension, strokes, and cardiovascular diseases. According to the CODEX recommendation (2013) for salt concentration in dried fish, the content should be close to 12% (Dharshini *et al*.,

2018). Maximum salt content recommended by Sri Lanka's Food (Fish and Fish Products, 2020) Regulation was 12-30% for whole dried fish, 10-35% for split dried fish, and 2-16% for dried fish fillets. It has been reported that 91% of imported dried fish contained higher amount of salt compared to local products (54%). This problem can be avoided by soaking dried fish well before cooking (Ginigaddarage *et al*., 2018).

Nutritional constituents and sensory properties of fish can be changed due to drying and smoking of fish mainly through denaturation of protein and loss of vitamin A (Abraha *et al*., 2018). If protein denaturation and lipid oxidation take place, it eventually reduces the nutritional value of dried fish, especially PUFAs (Boziaris, 2014, Guizani *et al*., 2008). Sun-dried fish are slightly less quality due to the breakdown of certain nutrients in sunlight and direct exposure to contaminants. Due to the quick drying in initial stage, a relatively moisture impermeable layer is formed on the surface of fish and inner moisture of the fish may cause rapid spoilage. On the other hand, artificial drying methods contribute to preserve the dried fish in good quality and safety under controlled temperature conditions (Boziaris, 2014).

Stability of dried fish supply in Sri Lanka

Dried fish production in Sri Lanka is seasonal due to seasonal variations in fish availability. This led to price fluctuations of dried fish, which has the greatest impact on poor inland dried fish consumers. Additionally, seasonal fluctuations in fish availability have a considerable, cascading effect on economic stability and the livelihoods of dried fish producers in the marine and inland sectors (Wickrama *et al*., 2021).

Climatic changes and manmade disasters impose a significant impact on the livelihood (Rabbani *et al*., 2010) of coastal dried dish producers which affects the continuous supply of dried fish and the income of fishermen. For instance, the lowest Sri Lankan dried fish production was recorded in 2005, following the devastation of tsunami in December 2004. The destruction caused to the fisheries industry drastically reduced the overall fish production in 2005. Moreover, it was reported that people in the costal belt refrained from consuming fresh fish for some time after the tsunami (Jayantha and Hideki, 2006). Moreover, in early 2021, an environmental disaster caused by the slow sinking of a fire-ravaged cargo ship that had been loaded with chemicals was also affected the fishing community, especially in Colombo and Gampaha districts in Sri Lanka. As a result of this disaster, Sri Lankan consumers refused to consume fish and dried fish.

Role of dried fish during the Covid-19 pandemic in human nutrition and health

Marine fishery takes a major role in local fish consumption. The availability of fresh fish is an issue when fishing activities are disturbed by unexpected situations. Therefore, dried fish is used as one of the best nutritional alternatives for fresh fish to fulfill human nutritional requirements (Flowra *et al*., 2012, Jonsson *et al*., 2007). Covid-19 pandemic situation impacts almost all the sectors in the world disrupting the continuous supply of food. During the lockdown period people faced difficulties to access the nutritious food sources. Nutritionists encourage people to consume healthy foods rich in omega-3 fatty acids, minerals (zinc, selenium, iron etc.), and vitamins (A, B, C, and D) for the proper functioning of immune system (Coelho-Ravagnani *et at*., 2021). Continuous supply of fresh fish to inland areas was disturbed and people were reluctant to dealing with outsiders frequently during the pandemic. Therefore, rural poor mostly moved towards dried fish instead of fresh fish, because of the easy storage of dried fish.

Dried fish is recommended as a nutritious food, a rich source of protein and micronutrients and had been used frequently during the quarantine period by confirming food and nutrition security in the country (Khan *et al*., 2021).

CONCLUSIONS

Dried fish provides a significant proportion of affordable and readily available animal protein to a large segment of the people in the country. More emphasis should be given to enhance domestic dried fish production. However, to secure dried fish availability, investments should be made in the fish value chain. Initiatives must be taken to improve the productivity as well as quality and safety standards of the local dried fish industry to ensure the continuous supply of safe and nutritious dried fish. Upgrading of processing systems should address the areas of using of high-quality fish, suitable fresh fish storage facilities, practicing cutting, cleaning, and drying under hygienic and controlled conditions, proper packaging and storage of finished products. Effective management of dried fish industry is essential for food, economic, and nutritional security in Sri Lanka.

CONFLICT OF INTERESTS

The authors declare that they have no conflict of interest.

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