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RESEARCH PAPER

Marine Fish Drying in Major Drying Yards: An Explorative Study in the Bay of Bengal of Bangladesh

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Abstract

The study investigated detailed drying yard infrastructures, processing conditions, raw materials quality, spot quality defect point, packaging, storage, marketing, profit margin and production of commercially important marine fish species in major drying hubs of Cox's Bazar district. In Moheshkhali, Thakurtala (0.81 ha), Ghotibhanga (47.5 ha), and Sonadia yards (250 ha) identified 19±4, 71±3, and 250±11 active processors respectively. Shaporirdip (28.25±6.13 ha) and Shamlapur yards (21±5 ha) had 38±2 and 45±2 active processors respectively from Teknaf, and Chowfalldandi drying yards covered 97.5±13.23 ha, with 143±10 active processors from Cox`s Bazar sadar area. The Nazirertek area included two drying yards: Nazirertek, the largest at 2259.26 ha with 1328±75 active processors, and Nunierchara, a smaller yard (0.340±09 ha) with 3±0 active processors used for processing of dry fish. For 1 kg of finished dried products, the average quantity of raw fish required were 3.25±0.3 kg for pomfret, 3.7±0.25 kg for jewfish/croaker, 2.8±0.02 kg for mackerel, 4.5±0.2 kg for sardine, 4.01±0.2 kg for anchovy, 5.5±0.3 kg for Bombay duck, 3.9±0.2 kg for shrimp, 4.04±0.3 kg for skipjack tuna, 3.7±0.3 kg for sea catfish, 3.7±0.3 kg for shark, and 3.6±0.1 kg for other small pelagic species. The percentage of salt used ranged from 3% to 16%, and the average freshness quality defect point of raw material fish ranged between 1.38 to 3.3 depending on species. Dried fish processors used mostly traditional methods for raw material handling, processing, packaging, storage, and marketing of dried fish products. A total of 42,566 metric tons (MT) of marine dried fish production was recorded in the surveyed Cox's Bazar region. The average profit margins (%) of major sun-dried fish species were as follows: for pomfret 26 ±3, jewfish/croaker 25±1, mackerel 26±2, sardine 24±2, anchovy 25±5, bombay duck 28±3, ribbon fish 33±13, shrimp 14±0.3, shark 12±4 and for other species 11±6. The government and policymakers may find the results useful in planning and implementing the subsequent phases required for development and for the stakeholders in improving the quality, processing, storage, marketing and export of dried fish. Furthermore, this research may contribute to understanding the dynamics of Bangladesh's fish drying industry and its potential for sustainable development.

Introduction

Bangladesh possesses a wide variety of fisheries resources. The country ranks second in inland open-water capture production and fifth in global aquaculture production, making it one of the top fish producers in the world accounting for 4.91 million tonnes of fish production (FAO, 2024). Bangladesh produced 69866.52 MT of dried fish, accounting for approximately 15% of total fish production. Marine dried fish production contributed 59487 MT, with Cox's Bazar district accounting for 48285 MT. Bangladesh exported 2224.62 metric tonnes of dried fish, generated more than 48.72 core BDT in the 2022-2023 fiscal year (DoF, 2024).

Fish are preserved using conventional drying, smoking, and salting methods. The oldest traditional method of preserving fish was to expose it to the wind and sun for sundrying. Drying food is the world's oldest known preservation technology, and dried fish can be stored for many years (Doe and Olley, 2020). The method is cheap and effective in suitable climates; the fisherman and family can do the work, and the resulting product is easily transported to the market. It remains a core component of diets and cuisines across much of the world and is one of the main forms in which fish is sold and eaten in regions including Sub-Saharan Africa (e.g. Liverpool-Tasie et al., 2021) and Southeast Asia (Hortle, 2007). In Bangladesh, sun drying is the most common method of fish preservation.

The conventional sun drying procedure for fish takes 3-7 days, based on species, to completely dry (Balachandran, 2001). Dried fish is easy to transport, market, and store. These are often processed at cheap cost, are easily transportable, marketable, and storable, and have a high market demand (Nowsad, 2007, Nowsad, 2022). In Bangladesh, sun drying preserves a significant number of fresh fish from both freshwater and marine sources. It is a low-cost dietary protein source that is utilized as a substitute for fish when fresh fish is scarce in Bangladesh (Khan and Khan, 2001).

Cox’s Bazar of Bangladesh presents one of the most prominent marine fish drying in Bangladesh. Commercial fish drying mainly takes place in seven regions of Cox's Bazar District, as well as in Charfashion in Bhola, Alipur-Mohipur in Patuakhali, Rangabali, and the Dublarchar in the Sundarbans. Kutubdiapara and Nunierchara of Cox’s Bazar Sadar Upazila, Dhalghata-Matarbari, Ghotibhanga and Sonadia of Moheshkhali, and Shaporirdip and Zingira of Teknaf are the seven most important locations in Cox's Bazar (Nowsad, 2007). Traditional drying is still practiced in every coastal fishing town. Dhalghata-Matarbari in Moheshkhali and Kutubdiapara in Cox's Bazar Sadar are the two largest fish drying facilities. (Nowsad, 2004). The dried fish are then distributed throughout Bangladesh. It is also provided to overseas markets such as Singapore, Hong Kong, Malaysia, the United Kingdom, the United States of America, and the United Arab Emirates (Kleih et al., 2003).

Cox's Bazar has the longest coastline, roughly 120 kilometers. Fishing and drying are traditional practices in Cox's Bazar. The islands of Sonadia and Moheshkhali played an important role in drying this exportable commodity. Several drying industries have been created and operated in Sonadia, Moheshkhali, Cox's Bazar, and Teknaf (Nowsad, 2004)).

Several fish species such as Bombay duck (*Harpodon nehereus*), pomfret (*Stromateus chinensis* and *Parastromateus niger*), jewfish (*Johnius argenteus*, *Otolithoides argenteus* and *Otolithoides brunnes*), ribbon fish (*Trichiurus haumela*), anchovy (*Setipina taty*) and shrimp (*Penaeus spp*.) are used for commercial production of dried fish between October and March in the coastal districts of Bangladesh (Nowsad 2007; Amin et al. 2012).

Generally, dried fish and fishery products are marketed through many different channels and outlets in Bangladesh (Nowsad, 2022; Nayeem et al., 2010; Reza et al., 2005). Several studies on dried fish and its marketing system and profit margin in Bangladesh have been conducted by many researchers (Fersoushi et al., 2015; Amin et al., 2012; Monir et al., 2012; Flowra et al., 2012; Nayeem et al., 2010). Amin et al. (2012) found that the producers carried 70% of their dried fish to Asadganj market. Besides, some dried fish were also exported to the neighboring countries. Most dried fish producers market their products every 2-20 days, with 95% going to Chittagong and

the rest of the other districts like Syedpur, and Dhaka (Al Mehedi et al., 2020). The seasonal income of the drying enterprise might vary from area to area. This variation was due to the raw material availability, size, and quality of the fish species, processing cost, and demand of the consumer (Marine, 2014; Purkait et al., 2018). But high-priced fish demanded high marketing costs resulting in higher marketing margins and profit compared to low-priced fish (Faruque et al., 2012; Haque et al., 2015). Many actors are involved in dried fish marketing such as beparies, arathdars, wholesalers, and retailers (Haque et al., 2016).

The current study was undertaken to assess the present condition of fish drying activities, including existing yard infrastructure, along with the activities at several marine fish landing sites, and commercially important dried fish processing sites in Cox's Bazar district. The study was conducted in three upazilas of the district: Moheshkhali, Teknaf, and Cox's Bazar Sadar. Nazirertek, Chowfalldandi, Khurushkul, and Nunierchara in Cox Bazar upazila; Thakurtala, Ghotibhanga, Sonadia in Mohakhali upazila; and Shaporirdip, Shamlapur in Teknaf upazila were targeted landing places and significant fish drying sites.

Materials and methods

Location

The survey was carried out in three upazilas of Cox's Bazar district and targeted specific fish landing places such as Nazirertek, Chowfalldandi, Khurushkul, Nunierchara (Cox Bazar Sadar upazila), Thakurtala, Ghotibhanga, Sonadia (Moheshkhali upazila), Shaporirdip, and Shamlapur (Teknaf upazila) (Figure 1).

Study time and target group

The data was collected in response to survey goals over six months in the year 2024, from January to June. The target groups were dried dish processors, entrepreneurs, fishermen, and other employees, both male and female, engaged in fish drying.

Sample size

About 500 data samples were recorded regarding fish drying yards, infrastructure, processing conditions, species, raw material quality, packaging, storage, marketing, profit margins, and production.

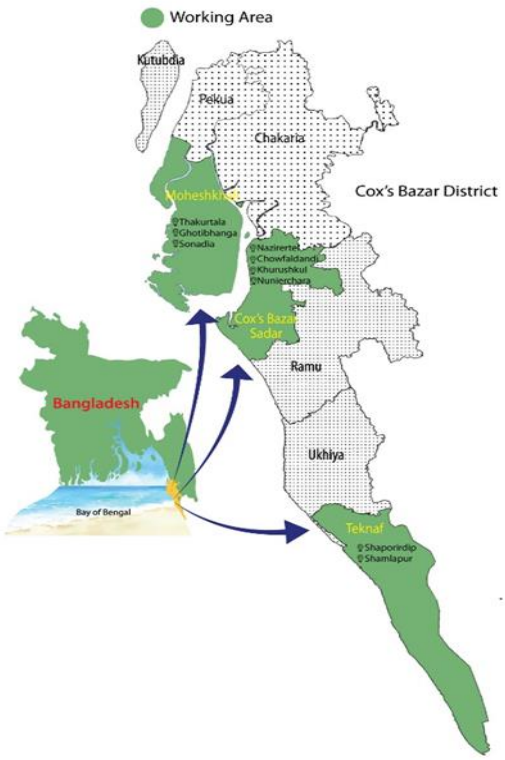

Figure 1. Location of the studied major marine fish drying yards and landing centers (drawn in Adobe illustrator, 2020 version)

Participatory Rural Appraisal (PRA)

For stakeholder involvement, semi-structured survey questionnaire and focus group discussions (FGDs) as PRA tool were used.

Key Informant Interview (KII)

Primary data generated by the survey and FGDs were varied with Key Informants Interviews with Department of Fisheries (DoF) officials, local government personnel, civil society men and Non-government Organization (NGO) personnels.

Questionnaire for data collection

Design and formulation of the questionnaire

A semi-structured questionnaire was designed to collect data from various drying sites and processing stakeholders depending on the study's objectives. Throughout the processes, the survey forms were checked, changed, and reviewed several times until a functional final form was achieved. The questionnaire was designed in such a way that stakeholders could answer it easily and

logically once completed. Field data were acquired through face-to-face interviews.

Data collection methods

All data was collected in multiple stages to improve both reliability and coverage. First, questionnaires in structured and semi-structured forms were administered to the dried fish processors and employees. Secondly, FGDs were conducted with the intermediaries and other actors in the value chain to obtain qualitative data relating to practices, livelihoods and socio-economic factors. In the last step, these findings were validated through KIIs with district fisheries officer (DFO) and upazila fisheries officers (UFOs), assistant field officers, local leaders and members of NGOs.

Fish quality defect point (DP) analysis

Sensory quality defect points of raw material fish were determined by the fish freshness assessment method (Nowsad, 2014) with slight modification. Sensory analysis of raw materials for dry fish was evaluated by trained personnel using the sensory method (Table 1 and 2). Color, odor, texture, or muscle consistency of raw fish samples were also observed.

Data analysis

The data was collected and analyzed in descriptive statistics for accuracy. Tools were used in Microsoft Office 2019 for descriptive analysis; percentage, mean ($\bar{x}$) and standard deviation (SD).

Table 1. Determination of defect points for freshness test of raw fish

Characteristics	Defects	Defect points	Grade
Odour of broken neck	a) Natural odour b) Faint or sour odour	1 5	Acceptable Rejected
Odour of gills	a) Natural odour b) Faint sour odour c) Slight moderate sour odour d) moderate to strong sour odour	1 2 3 5	Excellent Acceptable Acceptable Rejected
Colour of gills	a) Slight pinkish red b) Pinkish red to brownish c) Brown or grey d) Bleached colour, thick yellow slime	1 2 3 5	Excellent Acceptable Acceptable Rejected
General appearance	a) Full bloom, bright, shining, iridescent b) Slight dullness and loss of bloom c) Definite dullness and loss of bloom d) Reddish lateral line, dull, no bloom	1 2 3 5	Excellent Acceptable Acceptable Rejected
Slime	a) Usually clear, transparent and uniformly spread b) Becoming turbid, opaque and milky c) Thick sticky, yellowish or green colour	1 2 5	Excellent Acceptable Rejected
Eye	a) Bulging with protruding lens, transparent eye cap b) Slight cloudy of lens and sunken c) Dull, sunken, cloudy d) Sunken eyes covered with yellow slime	1 2 3 5	Excellent Acceptable Acceptable Rejected
Consistency of flesh	a) Firm and elastic b) Moderately soft and some loss of elasticity c) Some softening d) Limp and floppy	1 2 3 5	Excellent Acceptable Acceptable Rejected

Table 2. Grading of fish with grade points

Grade	Points	Comments
A	< 2	Excellent/ Acceptable
B	2 to < 4	Good / Acceptable
C	4 to 5	Bad / Rejected

Results

Fish drying activity

Fish drying yard

Dried fish processors employed sun drying for two main reasons: demand for consumption, which was primarily driven by the demands of businesses and household consumption, as documented from the study data. In Moheshkhali, around 340 fish processors with an area covered 298.31 hectares (ha) in three fish drying yards; in Teknaf, 83 fish processors with an area covered 49.5 ha in two drying yards; at Chowfalldandi, 143 processors with an area covered 97.5 ha and in Nazirertek, found 1331 processors with the area covered of 225.34 ha recorded in two drying yards used as processing of dried fish (Table 3).

These findings revealed a variety of sizes of drying yards, all are privately operated and situated on the seashore except for Nazirertek's yard, with significant variation in the number of active processors between locations (Table 3).

Table 3. Existing fish drying yards under different landing centers in Cox's Bazar

Sl. no.	LC	Drying yards	Area (ha)	Type of yard	No. of active processor	Managed by
1	Moheshkhali	TT	0.81±0	Onshore	19±4	Private
		Gbh	47.5±5		71±3	Private
		Sd	250±0		250±11	Private
2	Teknaf	Slp	28.25±6.13	Onshore	38±2	Private
		Spd	21±5		45±2	Private
3	BFDC	Cd	97.5±13.23	Onshore	143±10	Private
4	Nazirertek	Nt	225±9.26	Approved & organized*, onshore	1328±75	Private
		Nc	0.34±0.09		3±0	Private

LC-Landing Center, TT-Thakurtala, Gbh- Ghotibhanga, Sd-Sonadia; Slp- Shamlapur, Spd- Shaporirdip; Cd-Chowfalldandi; Nt-Nazirertek, Nc-Nunierchara.

* Only one drying center in Nunierchara named Sagar Fish Exports and it is FDA-approved and certified.

Infrastructures of sun-drying yard

The present infrastructure and facilities in sun-drying yards of various landing centers are depicted in Table 4. Sun drying in the Cox's Bazar district was carried out by bamboo-fenced, elevated bamboo rack or pole-based fish drying yards called as "*killa" or "basha*". The quantity of fish in killa was difficult to assess because it varied depending on the availability of raw material quantity and the specific fish drying procedures prevalent in that geographical area. However, some important features were noticed.

Thakurtala, Ghotibhanga, and Sonadia Island were the most widespread sun-drying regions in Moheshkhali upazila. Out of 459 killas, 410 have sheds to keep dry fish, and 448 have tube wells for washing and drinking. Split bamboo mats were used to elevate 1,361 drying racks, while 691 were covered by black polythene sheets. During the course of the study, the author did not come across any yards that used mosquito netting, mechanical solar dryers with exhaust fans, electric dryers, ice boxes, huge sheds, particularly during wet or foggy weather, hoover packaging, or covered plastic buckets. However, all processors used bamboo parallel or vertical drying poles, split-bamboo elevated racks for processing and polythene sacks for packaging. The drying yards have electricity and Pucca road connections except for Sonadia Island, although there was one ice factory existing but other one was under construction at Ghotibhanga.

Sun-drying places in the Teknaf upazila included Shaporirdip and Shamlapur, having a total of 95 killas. There were 94 storage sheds and 66 tube wells. The total numbers of drying racks identified were 369 with bamboo mats and 187 with black polythene sheets. The survey found no mosquito nets, electric dryers, ice boxes, or huge sheds in Shamlapur, however, there were 22 mechanical sun dryers with exhaust fans. Where processors used drying bamboo poles and polythene sacks for storage with good electricity and road networks were provided. There were two ice factories nearby (Table 4).

A total of 165 killas were detected in Khurushkul and Chowfalldandi of Cox's Bazar sadar upazila, of which 143 had the capacity for storage sheds and 14 had the capacity for tube wells. Black polythene sheets were found on 295 drying racks, but bamboo mats were present on 598 of them in 165 killas. This indicates that no evidence of the use of improved facilities such as electric dryers, ice boxes, mosquito netting, or other advanced methods for preparing and storing dried fish was found. However, all processors have access to a good road, electricity, drying poles and elevated racks, and polythene sacks for the processing and storage. About 22 ice factories were located in the region.

With 2,681 killa, Nazirertek is the largest sun-drying site in Cox's Bazar area. There are 572 tube wells, and 2,719 storage structures have existed at the site. There were 2,599 drying racks that were wrapped in black polythene sheets and 5,223 drying racks with bamboo mats. In addition, 210 large open shelters are found to protect fish from inclement weather, thirteen fish-drying yards used mosquito nets, thirteen mechanical sun dryers, one electric dryer, one vacuum packing equipment, and four basic sealer machines. There was no covered plastic storage container, no ice plant nearby, and no ice box for transporting raw materials. The processors utilized drying poles and polythene sacks as a last resort. The killas were connected to the electricity grid, but the road to Nazirertek was still under construction, they could still find it difficult to reach the yard for raw material collection and processed product transportation (Table 4)

Table 4. Infrastructures and facilities in sun-drying yards of different landing centers

Sl.no.	Infrastructure	Number ($\bar{x}$ ±SD)			
		Moheshkhali	Teknaf	BFDC	Nazirertek
1	Fish drying establishments (killa/basha)	459±16	95±5	165±13	2681±129
2	Raised drying rack wrapped with split bamboo mat	1361±50	369±24	598±17	5223±285
3	Raised drying rack wrapped by black polythene sheet	691±37	187±11	295±13	2599±71
4	Fish drying yards covered with mosquito net	-	-	-	13±2
5	Mechanical solar dryer with exhauster fan	-	22±3***	2±0	13±3
6	Electric fish dryer	-	-	-	1±0
7	Vacuum packaging machine	-	-	-	1±0
8	Traditional polythene sac to store dry fish (%)	100	100	100	100
9	Connection to Pucca Road (%)	100	100	100	100**
10	Municipal water supply	-	-	-	-
11	Ice factory in the vicinity	1±0	2±0	22±1	-
12	Shed in killa for storage of dry fish	410±18	94±4	143±10	2719±79
13	Large open shed for drying during rainy/foggy weather	--	--	--	210±10
15	Uprisen drying poles/bars (%)	100	100	100	100
16	Simple sealer packaging machine	-	-	-	4±1
17	Covered plastic container to store	-	--	-	--
18	Electricity supply (%)	100	100	100	100
19	Tube well	448±15	66±2	14±2	572±58
20	Icebox	-	-	-	-

*1±0 means have a connection to the pucca road and electricity supply except Sonadia drying yard of Moheshkhali.
** Only Nunierchara is present and Nazirertek is under construction. *** Present in Shamlapur

Processing conditions of fish drying

The processing condition of fish drying at different landing centers is shown in Table 5. Drying methods were varied with the type or size of fish to be dried. Both bamboo-made racks (0.40 – 0.90 m above ground)) and mats were used for spreading fish. In most places, fish spread on the mat directly on the earth without using any bamboo rack. Each entrepreneur had a well-

marked territory, fenced by bamboo with elevated bamboo racks, poles, and bars where the fish is dried. The present study was carried out to know the % of the compliance of processing conditions of fish drying at different landing centers. The study included parameters for processing and method of fish drying at the studied place and found results that are shown in Table 5. The landing center's processors used an elevated drying rack, a mosquito net-covered elevated rack, an exhaust fan-covered fish drying room, potable water for washing raw materials, ice or re-ice fish while sorting, traditional polythene sac storage, covered containers for storage, receiving raw materials with ice in an ice box, sorting/grading raw fish before washing/drying, washing raw fish before spreading, handling fish with bamboo baskets, using salt before sorting and using salt in fish before spreading for the production of dried fish.

Table 5. Processing condition of fish drying of different landing centers

Sl. no.	Parameters	% Compliance ($\bar{x}$ ±SD)							
		Moheshkhali			Teknaf		BFDC	Nazirertek	
		TT	Gbh	Sd	Slp	Spd	Cd	Nt	Nc
1	Elevated drying rack	100	38±3	100	77±5	22.4±3	66±5	100	100
2	Having an elevated rack covered by mosquito net	-	26±5	-	22±2	-	-	22±4	100
3	Mosquito net-covered fish drying room with exhaust fanning	-	-	-	4±1	-	1.4±0.1	3±1	100
4	Using potable water for raw material washing	100	100	100	84±4	47±3	7±0.2	94±4	100
5	Ice or re-ice fish while sorting	-	-	-	-	-	-	-	-
6	Using traditional polythene sac storage	100	100	100	100	100	100	100	-
7	Using a covered container for storage	-	-	-	-	-	-	-	-
8	Receiving raw material in ice condition in the ice box	-	-	-	--	-	-	-	-
9	Sorting/grading raw fish before washing/drying	100	100	100	100	100	100	100	100
10	Washing raw fish before spreading	-	-	-	-	-	-	-	84±4
11	Using canal/ditch water for fish washing	41±5	35±1	-	-	46±4	93±3	-	-
12	Using bamboo baskets while handling	36±6	26±6	18±4	66±3	78±3	26±4	90±6	47±6
13	Using salt in fish before sorting	--	-	-	-	-	-	-	83±6
14	Using salt in fish before spreading	100	100	100	100	100	100	100	100

TT-Thakurtala, Gbh- Ghotibhanga, Sd-Sonadia; Slp- Shamlapur, Spd- Shaporirdip; Cd-Chowfalldandi; Nt-Nazirertek, Nc-Nunierchara. *Compliance means following a rule or order.

Raw materials quality

The study area was recognized to harbor many species of marine fish. Monthly availability of species during different seasons was also well recorded. The winter season has more variation in terms of species availability compared to the summer or other seasons. In Cox's Bazar cost, due to relative abundance in landing, a variety of fish species, including pomfret (*Stromateus chinensis* and *Parastromateus niger*), jewfish/croaker (*Johnius argenteus, Johnius belangerii, J. elongates, J. dussumieri and Otolithes cuvieri*), mackerel (*Scomber australasicus* and *Rastrelliger brachysoma*), tuna (*Thunnus albacares* and *Euthynnus affinis*), sea catfish (*Tachysurus thalassinus* and *Rita rita*), sardine (*Sardinella*

longiceps), anchovy(*Setipina taty*, *Coilia ramcarati* and *Setipinna phasa*), bombay duck (*Harpodon nehereus*), ribbon fish (*Trichiurus haumela*), small shrimp (*Peneaeus indicus*, Mixed shrimp), and others species (Spotted sea fish-*Scomberomorus guttatus*, Four thread tassel fish-*Eleutheronema tetradactylum*, Pale edged stingray- *Himantura bleekeri*, Indian River shad-*Gudusia chapra*, Yellowtail mullet-*Sicamugil cascasia*, Indian salmon- *Polynemus tetradactylum* and so on) are used for the commercial production of dried fish during October and April.

Spot quality defect points of raw materials

The raw material (species) used during the current study were subjected to organoleptic testing and sensory evaluation to determine the freshness quality.

The study found that the average quality defect points for pomfret, jewfish/croaker, mackerel, tuna, sea catfish, sardine, anchovy, bombay duck, ribbon fish, mola, small shrimp, and others species of raw materials were 2.25±0.3, 2.06±0.09, 2.1±0.03, 2.06±0.21, 2.4±0.19, 2.13±0.59, 2.08±0.19, 2.14±0.03, 2.13±0.77, 2.37±0, 2.22±0.18, 1.96±0.07 at Moheshkhali area, 2.5±0.46, 2.06±0.09, 2.1±0.03, 1.73 ±0.27, 2.4±0.53, 2.19±0.27, 2.13±0.27, 1.38±0.53, 1.67±0.34, 2.21±0.31, 2.02±0.03, 2.67±0.14 in Teknaf, 2.6±0.3, 2.5±0.1, 2.5±0.05, 2.56±0.4, 2.83±0.3, 2.9±0.1, 3.3±0.4, 2.97±0.5, 2.5±0.5, 2.7±0.2, 2.4±0.14, 2.5±0.2 in BFDC landing site area, and 2.18±0.34, 2.06±0.08, 2.10±.03, 2.15±0.08, 2.20±0.32, 2.10±0.30, 2.20±0.5, 1.81±0.14, 2.14±0.03, 2.7±0.19, 2.02±0.03, 2.7±0.14 in Nazirertek respectively (Figure 2). The quality of all the raw fish remained an acceptable range (within grade A to B). Anchovy was highest in terms of quality defect point recorded in BFDC.

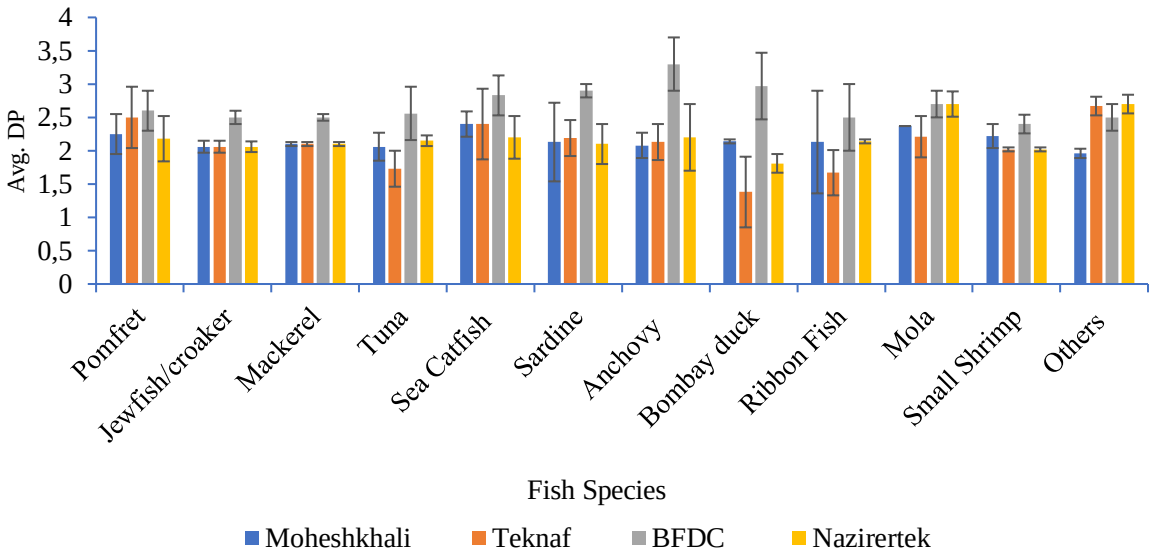

Figure 2. On-spot quality defect points of sampled raw materials fish for drying

Quantity of raw materials for each kg dry fish drying

The present study calculated raw materials required for 1kg production of dried pomfret, jewfish/croaker, mackerel, sardine, anchovy, Bombay duck, ribbon fish, shrimp, tuna, sea catfish, shark, and others mixed species were 3.25±0.3, 3.7±0.25, 2.8±0.02, 4.5±0.2, 4.01±0.2, 5.5±0.3, 3.2±0.08, 3.9±0.2, 4.04±0.3, 3.7 ±0.3, 3.6±0.1, 3.6±0.3kg at Moheshkhali's drying yards; 3.5±0.5, 3.02±0.3, 2.7±0.3, 3.5±0.6, 3.2±0.2, 6.1±0.1, 2.9±0.4, 3.9±0.5, 3.6±0.6, 3.5±0.5, 2.6±0.25, 3.3±0.2kg at Teknaf's fish drying yards; 3.5±0.6, 3±0.7, 2.75±0.3, 4±0.2, 3.4±0.5, 4.6±0.7, 3.75±0.5, 3.5±0.9, 3.25±0.3, 4.13±0.3, 3.5±0.6, 3.4±0.5 in BFDC landing site's drying yards and 3.45±0.01, 3.4±0.3, 2.65±0.02, 3.8±0.5, 3.42±0.7, 6.4±0.1, 2.9±0.4, 4.12±0.5, 3.6±0.02, 3.6±0.06, 3.4±0. 3, 2.8±0.3kg at Nazirertek fish drying yards respectively (Figure 3). Highest raw material needed to prepare 1 kg dry fish was Bombay duck in Nazirertek.

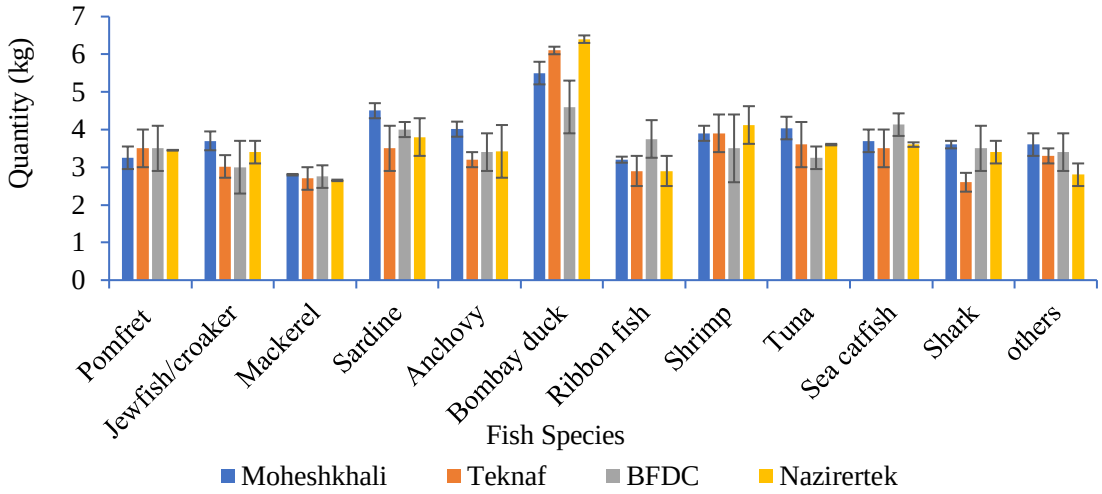

Figure 3. Raw fish used/kg for dried fish production of different landing centers

Salt use with raw fish for salted fish drying

Table 4 displays the percentage of salt used for the major species of fish dried in the study areas. It was found that fish farmers in the locations under study used salt with raw fish before drying, but they did not keep fish and salt at a set ratio.

In Moheshkhali Upazila fish drying centers, the study found that the percentage of salt used varied from yard to yard and species to species. Here the salt used ranged as follows: pomfret was only found with 3%, jewfish/croaker with 8-13%, mackerel with 3-6%, sardine with 4-7%, anchovy with 3-9%, bombay duck with 5-10% and ribbon fish with 4-23%, sharks being with 2-4%, shrimp with 5-6%, and others mixed species with 4-13%. Salt used in Teknaf was: pomfret 3–4%, jewfish/croaker 8–15%, mackerel 3–8%, sardine 5–8%, anchovy 3–10%, bombay duck 5–13%, ribbon fish 6–23%, shark 2–4%, shrimp 5–6%, and others 4–13%. At Chowfalldandi (BFDC ghat area) fish drying yards the percentage of salt used was found for pomfret, jewfish/croaker, mackerel, sardine, anchovy, bombay duck, ribbon fish, shark, shrimp, and other species were 4,15, 8, 8, 10, 13, 6, 4, 5 and 10% respectively. In Nazirertek fish drying yards, the percentage of salt used depended on the production capacity and target of marketing. The study found the salt used was: for pomfret- 3%, jewfish/croaker- 6.5-33%, mackerel- 4.5-7%, sardines- 4-5%, anchovy- 6-7%, Bombay duck- 7-16%, ribbon fish- 4-7%, shark- 2%, shrimps- 4.5% and other fish- 10-16% (Table-6).

Table 6. % of salt used in fish drying operation of different landing centers

Sl. no.	Species	% of salt used in fish before drying ($\bar{x}$ ±SD)							
		Moheshkhali			Teknaf		BFDC	Nazirertek	
		TT	Gbh	Sd	Slp	Spd	Cd	Nt	Nc
1	Pomfret	3±1	3±1	3±1	3±1	-	4±1	3±0.35	3±1
2	Jewfish/ croaker	11±1	13±2	8±1	13±1	13±1	15±1	6.5±2	25±8
3	Mackerel	6±1	5±1	3±1	5±.1	5±1	8±2	4.5±1	-
4	Sardine	4±1	7±1	5±.1	6±1	5±1	8±0.1	4±1	-
5	Anchovy	7±1	9±1.3	3±0.1	10±2	8±1	10±2	6±1	7±1
6	Bombay duck	9±2	10±1	5±1	4±02	4±2	13±1	7±1	5±1
7	Ribbon fish	4±1	6±2	3±0.3	4±1	3±1	6±1	4±1.6	7±1
8	Shark	3±0.3	2±1	2±1	2±1	6±2	4±2	2±1	--
9	Shrimp	6±1.	5±2	5±1	4±1	6±1	5±1	4.5±1	-
10	Others	8±4	13±7	4±1	8±3	7±1	10±3	10±4	16±2

TT-Thakurtala, Gbh- Ghotibhanga, Sd-Sonadia; Slp- Shamlapur, Spd- Shaporirdip; Cd-Chowfalldandi; Nt-Nazirertek, Nc-Nunierchara.

Packaging of dry fish

Upon sorting, the dried fish were placed in jute and plastic bags for convenience of handling. Bamboo baskets were occasionally employed for the same function. The size varied according to the volume of product to be stored. The processors in Moheshkhali, Teknaf, and the BFDC landing site area used traditional gunny sacks or baskets for packaging. In Nazirertek, 87% of the processors used gunny sacks, 10% used simple sealing in plastic pouches, and 3% utilized HDPE pouches. In Nazirertek, there was no vacuum packaging, whereas, in Nunierchara, only 10% to 15% of dried fish were vacuum packaged (Figure 4).

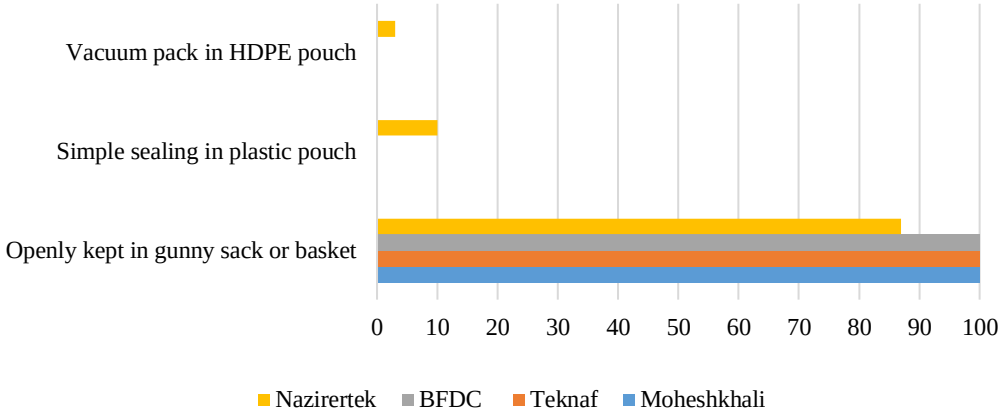

Figure 4. Compliance packaging (%) condition of different landing centers

Storage of dry fish

In Moheshkhali, dried fish openly kept in the sack on the floor or rack was about 72.73%, sealed in a plastic pouch and kept on rack was 27.27%, while in the drying yards of the BFDC landing site, processed dried fish openly kept in a sack on the floor or rack was 47.62%, sealed in a plastic pouch and kept on rack was 52.58%. These findings are consistent with the findings of the current study on the storage percentage of dried fish in other locations. Vacuum packed in cardboard carton was 14.28% (only at Nunierchara) at Nazirertek; openly kept in a sack on the floor or rack was 57.14%; sealed in a plastic pouch and kept on rack was 42.86%; and openly kept in the sack on the floor or rack was 57.15%; sealed in a plastic pouch and kept on rack was 28.57% (Figure-5).

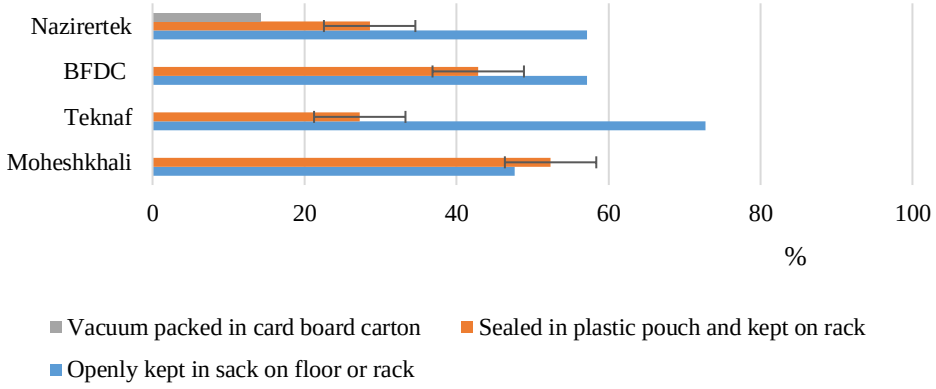

Figure 5. Storage of dry fish (%) in drying yards under different landing centers

Marketing of dry fish

The dried fish from Moheshkhali was marketed by 42.1% as retail and 57.89% as wholesale; at Teknaf 27.27 % retail and 72.73% wholesale; at BFDC landing site's drying yards - 50 % retail and 50% wholesale while in Nazirertek 23.1% retail and 76.92% wholesale (Figure-6). Highest wholesale marketing was recorded in Nazirertek and lowest in BFDC, whereas retail marketing was found highest in BFDC and lowest in Teknaf.

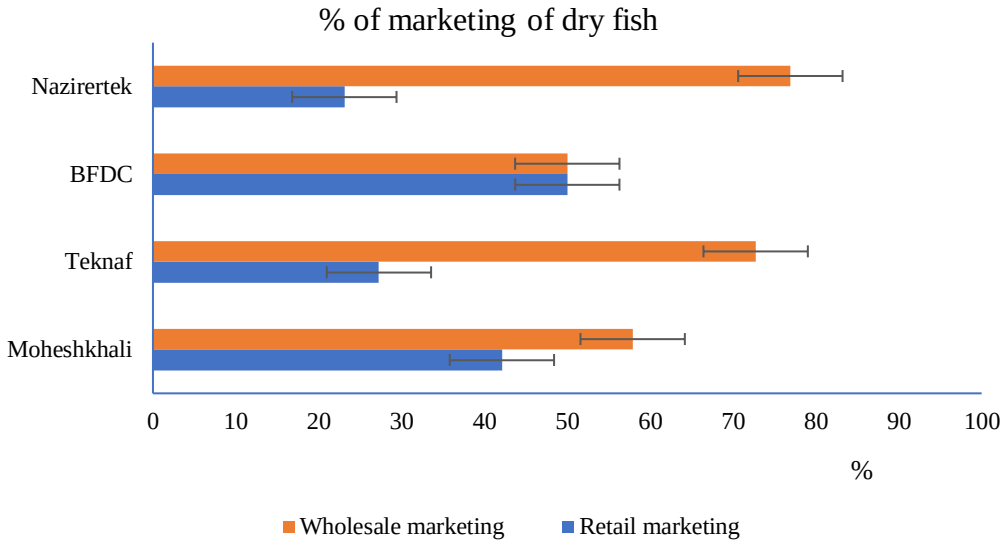

Figure 6. % Marketing of dry fish in drying yards under different landing centers

Profit margin

Species often to determine the profit margin for a fish-drying business. During the present investigation, key processors' profit margin data was obtained based on their quantity of dried fish operation. The percentage of profit margin for pomfret, jewfish/croaker, mackerel, tuna, sea catfish, sardine, anchovy, bombay duck, ribbon fish, mola, small shrimp, and other mixed species were 26 ±3, 25±1, 26.±2, 24±2, 25±5, 28±3, 33±13, 14±0.3, 12±4, 11±6 at Moheshkhali yards, 26±1, 19±2, 20±5, 26±2, 24±2, 21±3, 26±2, 15±4, 15±2, 15±2 in Teknaf yards, 24±1, 25±7, 25±5, 23±4, 22±2, 25±6, 21±14, 14±3, 12±2, 12±1 in BFDC landing site yards, and 27±4, 32±3, 23±3, 25±5, 23±5, 22±3, 23±3, 14±2, 11±2, 16±2 in Nazirertek yards, respectively. Figure 7 illustrates the profit margins of sun-dried major fish species in the study area. Jewfish/croaker earned highest profit from Nazirertek compare to other drying sites.

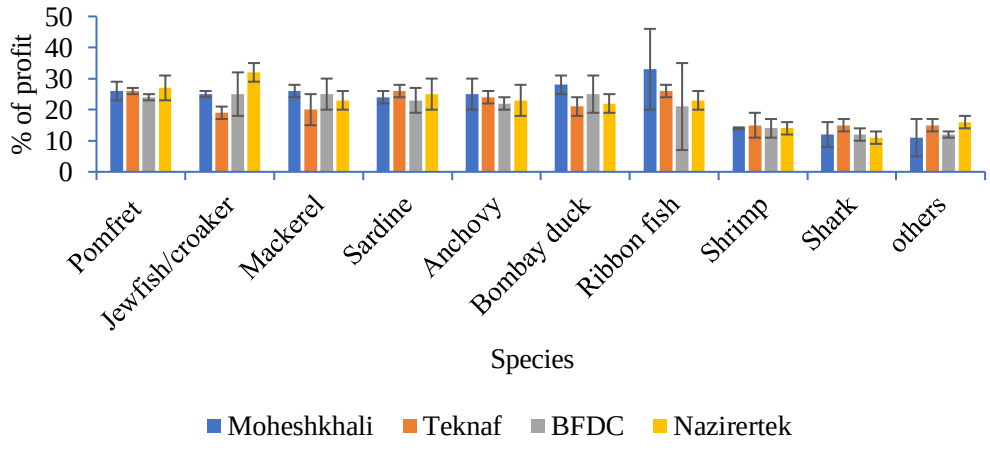

Figure 7. Profit margin (%) of dried fish of different landing centres

Quantity of sun-dried fish (MT) by species

The total marine dried fish production at Cox's Bazar drying area under the study period was 42566 MT (Table-5). While in the Moheshkhali area, total production was 3875.8±36.9 MT, in Teknaf 2422.2±81.3 MT, in BFDC landing yard 2376.3±121.1MT and Nazirertek yards 33892.5±34 MT. The production of dried fish by major species is shown in Table 7.

Table- 7. Quantity of sun-dried fish (MT) by species of drying yards under different landing centers

Sl. no.	Name of species	Quantity of sun-dried fish ($\bar{x}$ ±SD)			
		Moheshkhali	Teknaf	BFDC	Nazirertek
1	Pomfret	214.5±3	33±3	46.2±1.5	9.9±1.5
2	Jewfish/croaker	40±3	230±3	20±1.2	3430±30
3	Mackerel	77±0.6	80.5±6	24.5±3	80.5±6
4	Tuna	90±1.5	33±3	30±3	57±4
4	Sea catfish	24.2±1.6	94.6±3	8.8±3	81.4±6
5	Sardine	105±6	122.5±7	63±7	465.5±21
6	Anchovy	246.4±9	294.4±21	268.8±6	8968±24
7	Bombay duck	1155±41	445.5±16	561±4	9075±32
8	Ribbon fish	1310.4±34	603.2±15	780±11	9937.2±32
9	Shark	80.5±3	25.3±3	41.4±4	18.4±3
10	Brown shrimp	82.8±3	205.2±13	57.6±3	543.6±10
11	other	450±21	255±6	475±8	1225±18
Subtotal		3875.8±36.9	2422.2±81.3	2376.3±121.1	33892.5±34
Total		42566			

Discussion

Fish drying activity

Fish drying yard

The majority of fish species in Cox's Bazar were produced in dried form and sold for both domestic and commercial purposes. All of these major fish drying yards are located in different landing centers of Cox's Bazar district: in Cox's Bazar upazila, mostly Nazirertek, Chowfalldandi, Khurushkul, and Nunierchara; in Moheshkhali upazila, in Thakurtala, Ghotibhanga, and Sonadia; and finally, and in Teknaf upazila, in Shaporirdip and Shamlapur. New drying entrepreneurs have emerged, and some of them are operating in Nazirertek, Sonadia, Moheshkhali, Cox's Bazar, and Teknaf. Nowsad (2004) and Hossain et al. (2015) identified large-scale commercial marine fish drying yards were in Nazirartek, Chowfalldandi, Khurushkul, Moheshkhali, and Teknaf area. According to Hossain et al. (2015), Nazirertek covered 682 acres (276 ha) and 2,200 Khola while 784 acres (317 ha) were recognized by Belton et al. (2018). Hossain et al. (2022) highlighted that Nazirartek, the largest fish drying centre, has an increased number of Khola, while Teknaf dry fish yards have declined in the past 4–5 years. Our study findings recorded more than 220 ha area for drying yards at Nazirertek.

Infrastructures of sun-drying yard

Sun drying in Cox’s Bazar was done in killa or basha (fish drying yards) and these yards had different structures in different areas. The study found raised drying rack wrapped in split bamboo mats, a raised drying rack wrapped by black polythene sheet, fish drying yards covered with mosquito net, mechanical solar dryer with an exhauster fan (Nazirertek), an electric fish dryer (Nazirertek), vacuum packaging machine, traditional polythene sac to store dry fish (%), connection to pucca road (%), ice factory in the vicinity, shed in killa for storage of dry fish, large open shed for drying during rainy/foggy weather, up risen drying poles/bars (%), simple sealer packaging machine (in Nazirertek), electricity supply (%) and tube well in fish drying establishments (killa/basha) in the study area. Most of the sites have poor-quality equipment. Few have advanced ones; actually, most of them don't had mosquito nets, ice boxes, vacuum

packets, etc., they were so traditionally oriented. This result also agreed with studies by Nahiduzzaman et al. (2020), Kubra et al. (2020), Rahman et al. (2017), and Nowsad (2004), which stated that sun drying for commercial purposes is typically done on an elevated bamboo rack constructed of splits and poles, for domestic use is done on a smaller scale using bamboo baskets and hanging small earthen pots. Paul et al. (2018) and Al Mehedi et al. (2020) reported that marine fish were dried by hanging over bamboo bars and hung similarly over bamboo poles. Hamja et al. (2024) suggested the establishment of ice plants, tube well facilities, improved technology and equipment that should be used for drying.

Processing conditions fish drying

The study found that elevated drying rack, using potable water for raw material washing, using traditional polythene sac storage, sorting/grading raw fish before washing/drying, using bamboo baskets while handling and using salt in fish before spreading for processing in all drying sites.

An elevated rack covered by a mosquito net was found in Ghotibhanga, Shamlapur and Nazirertek area, mosquito net-covered fish drying room with exhaust fanning was found in Shamlapur, Nazirertek and Chowfalldandi. washing raw fish before spreading and using salt in fish before sorting practice only in Nunierchara and canal water was utilized for washing purposes in Moheshkhali, BFDC and Teknaf. Ice or re-ice fish while sorting, using a covered container for storage and receiving raw material in ice condition in ice boxes were not found at any of the drying sites. All in all, a high level of compliance was not uniform across the regions, especially in the areas of infrastructure and processing. Reza et al. (2005) reported on the traditional fish drying system in Cox's Bazar, Bangladesh, where fish is dried on bamboo mats, concrete floors, raised platforms, or poles. The result aligned with other studies: Paul et al. (2018), Rahman et al. (2017), and Hossain et al. (2015), who reported bamboo mats or racks for dry fish. Samad et al. (2009) and Shamim et al. (2014) reported similar sun-drying methods, though Soegiyono (1994) added that fish was put on trays for sun drying.

Raw materials used for drying

The current study was discussed with 10 major species that were used for sun-drying. Hossain (2015) identified the ten primary species used in dry fish production by volume and abundance, including Bombay duck, ribbon fish, croaker, white sardine, anchovy, shrimp, pomfret, river shad, flatfish, and rays. Payra et al. (2016) reported 19 species, with 16 finfish and the rest were shellfish. Shuchi et al. (2022) documented 23 dry fish species and one shrimp species, while Al Mehedi et al. (2020) identified 21 species, categorizing them into major species (80% of total dried fish, e.g., Loittya, Faissa, Churi) and minor species (20%, e.g., Shapla pata, Poa, Chingri, Koral, Ramsos, Rupchanda, Lakkha, Rupsha, Bhata).

Spot quality defect points of raw materials

Quality defect points (DP) were studied for different fish species across four locations. The average DP was 1.38 to 3.3: These defects point values indicate that all raw materials are good and acceptable. The raw material quality was excellent as those were freshly landed. Raw fish are processed quickly by yard area temperature at Sonadia Island's sandy beach yard. Bulk harvests of large boats are unloaded on a mat of split bamboo kept on sand. Proper icing is not done after the landing of the raw fish. Overall, the study found that the raw materials quality' an average of 2-3 DP. The present study results coincided with both the study of Nowsad (2004) and Reza et al. (2005). However, it was well documented that the quality of raw material used for traditional drying was of poor quality primarily due to insufficient icing during harvest (Nowsad, 2007; Al Mehedi et al., 2020).

Quantity of raw materials for each kg dry fish drying

The quantity of raw materials for each kg of dry fish drying varies according to the different species under study. The average quantity of raw materials for each kg of dry fish was found to be 2.6 to 6.5 kg. It also varies in raw fish quality, temperature rate, fish drying process practice and so many factors related to fish drying. According to Hossain et al. (2015), to produce 1 kg of dried lotya, ichhiri, small chhuri, pata, large chhuri, tak chanda, phaisa, poa and olua - 5.97, 4.24, 3.17,

3.06, 3.00, 2.69, 2.68, 2.17 and 1.92 kg fresh fish was needed. Normally, dry fish producers get 30-35 kg of dry fish from 100 kg of raw fish (Al Mehedi et al., 2020). Current studied findings more or less similar with above author's results.

Salt use with raw fish for salted fish drying

The present study revealed that on average, the percentage of salt used in the fish drying yards at Cox's Bazar area were- 3-5% for pomfret, 7-13% for jewfish/croaker, 3-8% for mackerel, 4-8% for sardine, 7-8% for anchovies, 5-8% for bombay duck, 3-7% for ribbon fish, 3-6% for shark, 4-6% for shrimp and a range of 5-16% for other species (table-4). All the fish farmers used non-branded commercial salt for this purpose. According to Nowsad (2004), the fish undergoes salt preparation before being sun-dried. However, the salt content of the uncooked fish does not go above 3-4%. according to Sugathapala et al. (2012) consumers like goods with minimal or no salt content. However, fish needs to be salted by 10–15% on overcast or wet days. Fish were carefully cleaned and salted at a ratio of 1:3 (salt: fish) after dressing. Nahiduzzaman et al. (2020) and Rahman et al. (2017) discovered that processors blended 1 kg of salt for every 20 kg of raw fish.

Packaging of dry fish

The study found that at Moheshkhali, Teknaf, and BFDC landing site areas, processors completely use traditional gunny sacks or baskets for packaging dried fish. But at Nazirertek, 87% of processors use gunny sacks, 10% use simple sealing in plastic pouches, and 3% use vacuum packs in HDPE pouches (Nunierchara) only for packaging dried fish. Nahiduzzaman et al. (2020), Al Mehedi et al. (2020), Islam et al. (2020), Paul et al. (2018) and Rahman et al. (2017) reported that after sorting, the dried fish were packed into plastic and jute bags for easy handling. Sometimes bamboo baskets are also used for this purpose. Hossain et al. (2015) reported that almost 85-90% of dried products were simply packed in a plastic pouch and exported to Hong Kong or other countries. The study also relevant to Chattopadhyay et al. (2024), also claimed the main goal of packaging innovations is to maintain the traditional essence of dry fish.

Storage of dry fish

The study found the following storage methods for dried fish: Moheshkhali used open sack 47.62% and sealed pouch 52.58%; Teknaf open sack 72.73% and sealed pouch 27.27%; Khurushkul open sack 57.14% and sealed pouch 42.86% and vacuum packed 14.28% and Nazirertek open sack 57.15% sealed pouch 28.57%. Nahiduzzaman et al. (2020), Rahman et al. (2017), and Samad et al. (2009) reported that well storage is a system prerequisite for quality products and also for shelf life. Storage of dried fish is found to be done in a tent made of thin plastic sheets and bamboo split for temporary storage until sold or sold. Packed dried fish were kept in these tents for temporary storage until marketing or selling. (Nowsad, 2007; Al Mehedi et al., 2020).

Marketing of dry fish

The study showed dried fish marketing distribution in Bangladesh: Moheshkhali (42.1% retail, 57.89% wholesale), Teknaf (27.27% retail, 72.73% wholesale), Khurushkul (50% retail, 50% wholesale), and Nazirertek (23.1% retail, 76.92% wholesale). Generally, dry fish and fishery products are marketed through many different channels and outlets in Bangladesh (Paul et al., 2018; Reza et al., 2005 Nayeem et al., 2010). The marketing channel for dry fish starts with the producer and then goes to the reader, wholesalers, and retailers and finally up to consumers or from the producer to the retailer and finally up to consumers. The present result is similar to Samad et al. (2009) and more or less similar findings were also found by Flowra et al. (2012), Marine et al. (2014), Shamim et al. (2011), and Al Mehedi et al., (2020). In domestic marketing, marine dry fish producers sell fish mainly to beparis (69%) via aratdar, 19% to Faria, and 12% to inter-district aratdar agents. On the other hand, especially for export marketing, marine dry fish producers sell the entire amount (100%) to fish-drying factories/ processing plants (Haque et al., 2016).

Profit margin

The study identified that there were profit differences in dried fish between four drying centers (Moheshkhali, Teknaf, BFDC and Nazirertek) based on species. The maximum profit percentages were achieved for ribbon fish

(33%), bombay duck (28%), and pomfret (27%), and finally, the minimum values of 12% for shark and 14% for shrimp were observed for two species. There were also great differences in profit margins in different regions, and they were generally higher in Moheshkhali. Net profits per species varied between 11% and 33%, with ribbon fish and Bombay duck having the highest percent margin. The profit margin of processors for dried pomfret, Indian salmon, Bombay duck, ribbon fish (small size), Indian piker, Spanish mackerel, and big eye croaker was 10.52 %,17.33 %, 11.83 %, 11.83 %, 13.15 %, 12.27 %, and 5.23 % respectively reported by Amin et al. (2012) and Haque et al., (2016). More or less similar profit margins were reported by Ahsan et al. (2016), Faruque et al. (2012), and Biswas et al. (2006), which showed 35% and 19% marketing margins respectively, for dried products of bombay duck and ribbon fish in Cox's Bazar. The highest estimated net profit was recorded for dry Churi (large) at $0.57 per kg (Dey et al., 2024).

Quantity of sun-dried fish (MT) by species

The survey observed that Cox's Bazar dried fish production was 42,566 MT in the four major study locations. In 2022-2023, a total of 69,866.52 MT of dried fish were processed out of which Cox's Bazar produced 48,285 MT (FRSS, 2023). The studied findings from major drying locations are more or less like FRSS (2023). Bangladesh exported dried fish, 2224.62 MT, and earned more than 48.72 crore taka or USD 6,52,000 per annum (FRSS, 2023). Hossain et al. (2015) observed that 204,000 MT of marine and 36,000 MT of freshwater fish were required to produce 51,000 MT of marine and 9,000 MT of freshwater dried fish. According to the studied findings the highest dry fish production was recorded in Nazirertek and lowest in Teknaf. Nazirertek is the largest marine fish drying facilities of the country noted by Hossain et al. (2022). In terms of species production, Ribbon fish was recorded the highest and shark was the lowest. Matching to FRSS (2023) shark was the lowest in species-wise annual production of Bangladesh.

Conclusion

The article highlighted the significance of marine dried fish production and trade in Cox's Bazar district, which plays a crucial role in the economy through food production, employment, and product diversification. Key fish drying centers in Cox's Bazar sadar upazila include Nazirertek, Chowfalldandi, Khurushkul, and Nunierchara, while other centers are in Moheskkhali and Teknaf Upazila. The dry fish industry in Cox's Bazar holds significant economic and cultural importance, providing livelihoods to thousands of coastal communities and contributing to the region's economy. Despite its potential, the industry faces challenges such as outdated processing methods, poor infrastructure, market inefficiencies, and environmental concerns. Addressing these issues through modernization of drying techniques, improving supply chain management, sanitary and epidemiological standards, organizing joint product storage, and sale and ensuring environmental sustainability can greatly enhance production quality and market competitiveness. Additionally, government and private organization support, proper regulations, and community engagement are crucial for transforming the dry fish sector into a more profitable and sustainable industry, ultimately boosting local employment and contributing to national economic growth.

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Ethical approval

The study was done following the ethical guidelines of the Department of Fisheries Technology of Bangladesh Agricultural University.

Informed consent

Not available.

Conflicts of interest

The authors declare no conflicts of interest.

Data availability statement

The data presented in this study are available in the article.

Author contribution

Author 1: Field data curation and analysis and thesis/report writing
Author 2: Conceptualization, planning, supervising, writing, and revising the original manuscript
Author 3: Field data curation and analysis, writing original manuscript and corresponding author

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