Overview of Dried Fish

Subjects: Food Science & Technology

Contributor: Nursyah Fitri, Sharon Xi Ying Chan, Noor Hanini Che Lah, Faidruz Azura Jam, Norazlan Mohmad Misnan, Nurkhalida Kamal, Murni Nazira Sarian, Mohd Aizuddin Mohd Lazaldin, Chen Fei Low, Hamizah Shahirah Hamezah, Emelda Rosseleena Rohani, Ahmed Mediani, Faridah Abas

Fish is a good source of nutrients, although it is easily spoiled. As such, drying is a common method of preserving fish to compensate for its perishability. Dried fish exists in different cultures with varying types of fish used and drying methods.

Keywords: fish ; drying

1. Health Benefits of Dried Fish

Dried fish is widely consumed not only for enjoyment but also for its nutritional values and health benefits. Fish itself is known for its richness in proteins, healthy fats, and minerals. These properties are also well preserved in dried fish products, furthering the benefits by prolonging the shelf-life of the fish by drying them. In a past study, it was found that the protein content of sun-dried fish ranged from 49.23–62.85%, depending on the used type of fish [1]. According to that study, snake-headed fish (*Channa striatus*) charted the highest protein content (62.85%), while a type of catfish (*Wallago attu*) contained the least (49.23%). Essential amino acids absent in either plant or meat proteins like cysteine (28 to 25 mg/g), methionine (0.18–2.66 g/100 g) and (0.89–9.864 g/100 g) lysine were found in dried fish [2][3][4]. It is found out that cysteine and methionine are effective antioxidants in which cysteine prevents the build up of toxic metabolic wastes that accelerate ageing whereas methionine regulates nucleotide and redox statuses [5][6]. Additionally, it was stated that methionine metabolism could also be linked to tumour cell metabolism, making methionine possibly essential for cancer prevention [6]. As for lysine, one study that claims that L-lysine could have preventative and therapeutic effects on osteoporosis as lysine aids in the uptake of calcium in the body [7]. It mentioned that dried fish proteins contain essential amino acids for body growth, repairing functions and metabolism [2]. Hence, it can be concluded that the protein contents in dried fish aid in regulatory functions in the body and prevent various diseases .

The fat contents in dried fish are claimed to be healthy, especially when dried fish have lipid oxidation properties by omega-3 polyunsaturated fats (PUFA) [8]. For instance, eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) are long-chained omega-3 fatty acids that help in foetal development and the prevention of cardiovascular diseases [9]. Dried fish has been declared to be rich in calcium, phosphorus, and β vitamins, which aid in bone development and maintenance [10]. Another notable mineral present in dried fish is selenium, which is a nutrient that allows proteins to act as antioxidants and anti-inflammatory substances in the immune system by being the cofactor of glutathione peroxidase [11][12]. Since selenium was previously considered a toxin [12], moderate amounts of selenium should be taken to maintain the necessary levels. It was also concluded that niboshi, a type of dried anchovy product in Japan, was sufficient to sustain the dietary intake of selenium in Japan in which little to no deficiency cases were reported, at least back in 2007 [11]. Usually, dried fish is salted as part of the drying process to both hasten the drying process and add flavour to the product. In Sri Lanka, the maximum acceptable level of salt is 12% in dried fish as higher levels of salt could contribute to an increase in blood pressure for consumers [13]. However, studies are being done to reduce and even substitute salt in dried fish to cater to a healthier sodium level intake. For example, potassium chloride and potassium lactate can be used (up to 40%) to avoid the addition of sodium in dried fish, especially for prioritising those with hypertension [14]. Additionally, sodium levels as low as 5% can be used in dried fish, whereby microbial qualities are still maintained [13]. Interestingly, there seemed to be a bias toward lower salt levels (2%) in terms of sensory attributes, which urged future research [13].

2. Microbial Characteristics of Dried Fish

One of the most concerning factors when it comes to the edibility of dried fish is whether the microbial constituents in the products are at safe levels. This of course is highly dependent on the method of drying and the extent of dryness the fish is able to reach. Additionally, the ingredients added to the dried fish also play an essential role in managing the microorganisms in dried fish, as does the drying environment the fish is exposed to. In the case of sun-drying, the microbial characteristics of dried fish change due to the exposure of fish to high temperatures and ultraviolet (UV) radiation from the sun. It was revealed that *Escherichia coli* was found in naturally sun-dried fish whereas *Salmonella* spp. and *Vibrio* spp. were completely eliminated by sun-drying regardless of the presence of fish racks [15]. It was also found that fish racks mainly reduced the drying time from 3 to 2 days in comparison to sun-drying without the racks [15]. Nonetheless, sun drying keeps the dried fish products at risk of contamination by other elements like animals and insects since the dried fish are out in the open. As such, natural sun-drying is still less recommended, except when fish racks are used to not only reduce the time and cost of drying but also to minimise the risk of contamination [15]. In an alternate scenario, certain regions of the world are limited to only air-drying when putting out fish to dry in the sun because of seasonal and regional weather conditions. This is seen in Norway, where fish are usually dried in lower temperatures with minimal sunlight [16]. In Nigeria, the use of lower or ambient temperatures to dry fish is also observed as harmattan occurs late into the year, in which temperatures are cooler and wind speeds are higher [17]. This research showed that open-air drying in lower temperatures seemed to yield similar microbial results as in higher temperatures. On the other hand, smoke-drying fish can be said to be less effective at removing microorganisms compared to sun-drying as seen in a past study, where no significant difference in total plate count (TPC) was observed between fresh and smoke-dried fish [18]. However, smoke-dried fish was observed to contain no faecal coliform [18], indicating that smoke-drying could prevent issues in the digestive tract upon consumption of dried fish. *Bacillus, Klebsiella, Staphylococcus, Pseudomonas, Streptococcus* and *Proteus* bacteria could be found in smoke-dried fish, with *Bacillus* spp. being the most prominent (58.4%) at least in *Clarias angularis, Channa obscura and Chrysicthtys auratus* fishes [18]. At the same time, the diversity of fungal constituents of the fish in the study was also reduced by smoke-drying, in which only *Aspergillus, Fusarium and Penicillium* were isolated compared to the 7 isolated fungi strains from fresh fish (**Table 1**).

Table 1. Microbes found in dried fish along with their quantities according to their drying methods.

Drying Method	Type of Microbe Found in Dried Fish	Microbes Found in Dried Fish	TPC/TVC/TFC	References
Open-air drying • Sun-drying • Air-drying	**Bacteria**	***Escherichia coli***	**1.84 × 10^4/g to 5.3 × 10^6/g**	[1][15]
	Fungi	• Fusarium spp. • Penicillium spp. • Aspergillus spp.	• 1.00 × 10^2 to 2.11 × 10^4 cfu/g • 1.23 × 10^3 cfu/g to 3.67 × 10^3 cfu/g • 1.25 × 10^2 to 2.40 × 10^4 cfu/g	[10]
Smoke-drying	**Bacteria**	• Bacillus spp. • Klebsiella spp. • Staphylococcus spp. • Pseudomonas spp. • Streptococcus spp. • Proteus spp.	**4.0 × 10^8 to 2.30 × 10^{10} cfu/g**	[18]
	Fungi	• Aspergillus spp. • Rhizopus spp. • Penicillium spp. • Saccharomyces spp. • Fusarium spp.	**1.0 × 10^4 to 4.0 × 10^5 cfu/g**	

Drying Method	Type of Microbe Found in Dried Fish	Microbes Found in Dried Fish	TPC/TVC/TFC	References
Salt-drying	**Bacteria**	• Bacillus spp. • Micrococcus spp. • Coryneform bacteria	**6.5 × 10^4 to 1.4 × 10^8 cfu/g**	[19][20]
	Fungi	• Aspergillus spp. • Rhizopus spp. • Penicillium spp. • Absidia spp. • Mucor spp.	**0.72 × 10^1 to 1.8 × 10^1 cfu/g**	[19][21]
Hot-air drying	**Bacteria**	**Bacteria** • Salmonella spp. • Escherichia spp. • Shigella spp. **Fungi: N/A**	**2.87 × 10^5 cfu/g**	[22]
	Fungi		**1.9 × 10^5 cfu/g**	
Freeze-drying	**Bacteria**		**1.90 × 10^5 cfu/g**	
	Fungi		**0.63 × 10^5 cfu/g**	
Solar Convection Drying	**Bacteria**		**1.60 × 10^5 cfu/g**	
	Fungi		**0.53 × 10^5 cfu/g**	

For salted dried fish, the microorganisms present are usually halotolerant or halophilic, especially if the microbe is familiar with marine salinity conditions [19]. Not only could the microbes come from the fish itself, but also from salt. The presence of *Bacillus* spp., *Micrococcus* spp., and Coryneform bacteria in salt could be the cause of dried fish spoilage, especially when the fish is salt-dried [19]. Several fungi genuses like *Aspergillus, Rhizopus, Penecillium, Absidia* and *Mucor* are also found in salted fried fish as they possess halotolerant or halophilic properties [19]. From this, it can be concluded that mere salt-drying is inefficient to eliminate harmful microorganisms from dried fish products. As such, salted fish are normally sun-dried afterwards to achieve lower levels of water content and remove harmful microorganisms. More scientific methods of drying fish have been developed to hasten and improve the quality of dried fish. A critical bonus factor of modern drying methods is that dried fish can be beamed relatively safe from harmful microorganisms. Comparing solar conduction drying, hot air drying and freeze-drying techniques to traditional sun-drying, the total viable count (TVC) and total fungal count (TFC) of all modern techniques charted lower values [22]. Once again, the findings of the study emphasised the lack of hygiene while sun-drying fish because of the unenclosed drying environment of the fish. Nonetheless, **Table 1** shows that the number of microbes found in fish dried by advanced technologies are generally not lower than the other traditional methods. The quantification of microbes highly depends on the type of fish used and the surrounding environment, which differs from study to study. Alternatively, fish that are osmotically dehydrated with sugar beet molasses showed lower concentrations of bacteria (4.23 × 10^4 CFU/g) than with a salt and sucrose aqueous osmotic solution (7.33 × 10^4 CFU/g) [23]. Although the TVC in dried fish from this drying method still depends highly on the surrounding environment, its potential as a fish drying technique is undeniable and is worth looking into.

To summarise, dried fish is supposed to contain less microbial activity, and certain factors are still able to affect the presence of microorganisms in the products. In fact, some techniques could even draw in microbes from the environment, like with open-air sun-drying and halophile-attracting fish salting. Generally, it can be said that the key to reducing the microbial activity in dried fish would be to decrease the water activity in the product.

3. Safety Challenges of Dried Fish and Precautions to Prevent Side Effects

While dried fish is widely accepted and consumed by diverse communities, there have always been a few safety concerns circulating the dried fish industry. Fish itself is highly perishable due to its microbial and enzymatic compositions, even under refrigerated and frozen conditions [24]. Although drying the fish aids in prolonging shelf-life, drying alone is unable to fully preserve and protect the fish from hazardous components, nor is it enough for sellers to avoid adding harmful substances to further preserve the fish (**Figure 1**). As mentioned, the microbial characteristics of dried fish are, albeit lesser compared to fresh fish, still potentially harmful when consumed. The microbial contents of dried fish are also related to the total volatile base-nitrogen (TVB-N) [1]. TVB-N are biogenic amines that could be formed when foods are stored [25]. Excessive consumption of these biogenic amines can cause health issues like food poisoning in humans [26]. These biogenic amines are formed from the microbial decomposition of fish [27], explaining the relation between thriving bacteria and high concentrations of biogenic amines in a study by Mansur, Rahman, Khan, Reza, Kamrunnahar, and Uga [1]. Thus, it is extremely important to ensure that dried fish products are not contaminated, especially when toxic components could be released (**Figure 1**).

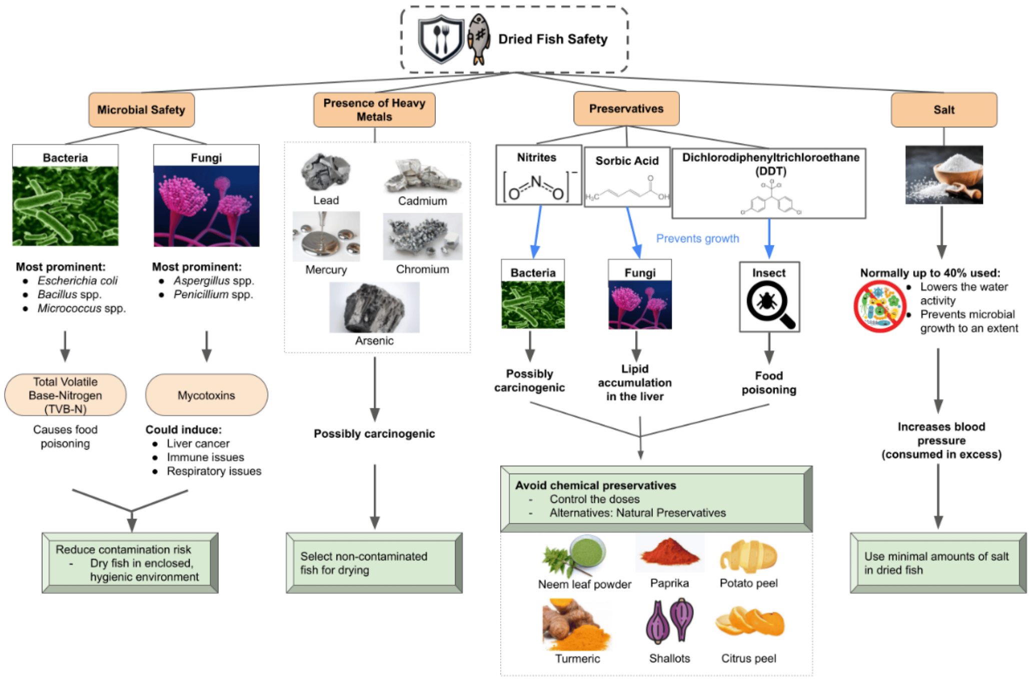

Figure 1. Significant safety aspects of dried fish along with their effects on human health and the prevention recommendations.

Furthermore, fungi should also be taken note of when avoiding contamination of dried fish. This is because harmful mycotoxins can be produced from fungal contaminations. From a study by Deng, Wang, Deng, Sun, Wang, Ye, Tao, Liao and Gooneratne [10], Aflatoxin B_1 (AFB_1), T-2 toxin (T-2), ochratoxin A (OTA), and deoxynivalenol (DON) were mycotoxins found to be released by fungi in dried fish products, dominantly by *Fusarium, Penicillium* and *Aspergillus* fungi. If consumed in excess, mycotoxins could cause major health problems like liver cancer, immune issues, and respiratory issues [28]. The study recommended that marketplaces and storage places for dried fish should have better fungal control to prevent mycotoxins from ruining the dried fish products. The challenge for preventing both bacterial and fungal contaminations is that most dried fish sellers do not have the means to afford, nor do they prefer, fish drying by machinery. Because of that, most dried fish are still mass produced by open-air sun-drying, which exposes the fish to contaminants and unpredictable humidity changes in the environment. Hence, it would be difficult to make dried fish completely safe from contamination. However, there have been more studies that focus on making financially friendlier drying methods for sellers. Sufi, et al. [29] were able to create a more economical and efficient drying method compared to the traditional sun drying with a solar tunnel dryer. This development could inspire more people to utilise cheap materials to ensure that safety measures can be taken for the production of dried fish. Other than that, the presence of heavy metals in fish has also been a significant concern for consumers when it comes to dried fish. Previously, lead, mercury, cadmium, chromium, and arsenic were found in dried fish sold in Bangladesh [30]. This was suspected to be caused by the bioaccumulation of heavy metals in aquatic environments [31]. It was found that the amount of chromium itself, along with the sum of other heavy metals in dried fish represent a possible carcinogenic threat in Bangladesh, especially in dried Bombay duck and ribbon fish [30]. Consequently, authorised personnel are pressured to tighten laws on aquatic pollution and regulations on dried fish production to ensure the health of the community [30]. Regarding small businesses, it would be wiser to simply select non-contaminated fish sources for dried fish production (**Figure 1**).

Like any other commercially packaged food product, dried fish also often contains preservatives. One of the substances used as preservatives for dried fish is nitrites for their inhibitory effects against *Clostridium botulinum*, which could cause food poisoning when ingested [32]. However, there is a limit to the amount of nitrite that can be consumed, especially when nitrites can be carcinogenic when combined with amines or amides [33]. Another commonly used preservative for dried fish is sorbic acid as it is effective against fungal growth, making it a good pair with nitrites since both substances each conquer either bacteria or fungi [32]. However, it was discovered that sorbic acid has adverse effects on hepatic lipid metabolism when consumed in excess, causing lipid accumulation in the liver [34]. Fortunately, there are natural alternatives available to replace chemical preservatives. For example, organic substances such as neem leaf powder and paprika could be used to control insect and fungal contaminations in dried fish [35]. Turmeric, shallots, potato peel, citrus peel, and pomegranate peels have also been said to have protective properties against microbes and oxidation, making them effective preservatives [35]. Hence, there are organic and economically available means of preservation for storing dried fish.

4. Advanced Technology in the Progress of Drying Fish and Fish Products

High-quality dried fish and fish products with minimal changes in nutritional and sensory characteristics are highly in demand among consumers. Advances in technology in fish drying are being implemented and explored as a way to serve a safe, fresh, and nutritive products with high quality and minimal changes in dried fish and fish products (**Table 2**). There are abundant emerging technologies that can be implemented in order to obtain a high quality of dried fish and fish products. For instance, a high-pressure processing, which is a new and novel technology has the potential to significantly increase shelf life of the products with little or no heat treatment [36]. It is a non-thermal process, where the food item to be treated, is put in a pressure vessel that can withstand the necessary pressure, and is submerged in a liquid that serves as the pressure transmission medium. The influence of high pressure on the products quality was evaluated through the sensory characteristics of cod (*Gardus morhua*) after storage up to six months [37]. Moreover, another non-thermal technology, pulse light technology has been implemented for the decontamination of products surfaces and packaging that incorporates of short time high-peak pulses of broad-spectrum white light [38]. This method had been implemented in preservation of fish products which then further analysed for its sensitivity effect on the fish products [39].

Table 2. Processing methods for preserving the quality of fish products.

Sample	Method	Technology	Reference
Cod (Gardus morhua)	High pressure processing	Non-thermal process with vessel pressure	Matser, Stegeman, Kals and Bartels [37]
Fish products	Pulse light technology	Non-thermal process with high peak pulses	Lasagabaster and De Marañón [39]
Atlantic salmon (Salmo salar)	Pressure shift freezing	High freezing rate	Zhu, Bail and Ramaswamy [40]
Sea bass (Dicentrarchus labrax)	Pressure assisted thawing	Non-thermal process with thawing conditions	Tironi, De Lamballerie and Le-Bail [41]
Sea bass	Pulsed electric field	Non-thermal process with electric pulses	Cropotova, Tappi, Genovese, Rocculi, Laghi, Dalla Rosa and Rustad [42]

Pressure shift freezing assists in reducing tissue deformation and shrinkage of the products. Based on the study conducted by Zhu, et al. [40], pressure shift freezing treated salmon showed that the muscle fibres of the salmon were well maintained. This has convinced researchers that pressure shift freezing can aid in preserving the quality of fish products. Furthermore, it is known that the success of freezing preservation of fish products depends on the preparation, freezing rate, storage conditions, and thawing conditions. Pressure shifting pressure and pressure assisted thawing that were conducted on sea bass demonstrated a promising result to preserve the products quality [41]. Additionally, pulsed electric field is a processing method that integrates the application of very short electric pulses at electric field intensities [43]. This technology is considered as non-thermal disintegration or preservation process, which is possible for the occurrence of rapid rapture with no effect on the entire cell membrane, depending on the electric field. Study on pre-treated sea bass using pulsed electric field-assisted brining seemed to show a promising technology due to its efficacy processing and preserving fish products [42].

Understanding the molecular levels may assist in enhancing the quality of dried fish and fish products. Advancement in omics analysis, which includes genomics, transcriptomics, proteomics, and metabolomics that holistically integrate the study of genes, transcripts, proteins, and metabolites in an organism are useful in understanding the mechanisms that are involved while drying the products (**Figure 2**). The emerging of technological advancements such as next-generation sequencing technology (Illumina, PacBio and Nanopore) and mass spectrometry coupled with gas and liquid chromatography can provide a high-throughput data generation [44]. The information from the data generation is crucial in determining the best quality of the dried fish and fish products as well as prolonging the shelf-life of the products. Additionally, integrating these emerging technologies may help ensure the safety aspects for consumption.

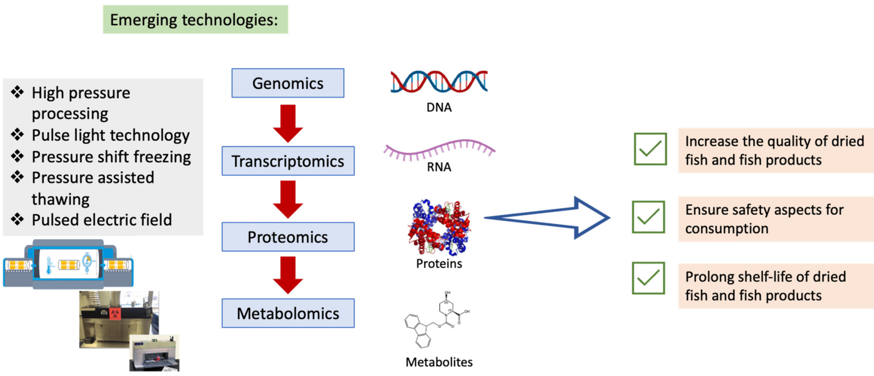

Figure 2. Emerging technologies in enhancing the quality of dried fish products.

References

1. Mansur, M.A.; Rahman, S.; Khan, M.N.A.; Reza, M.S.; Kamrunnahar; Uga, S. Study on the quality and safety aspect of three sun-dried fish. Afr. J. Agric. Res. 2013, 8, 5149–5155.
2. Rasul, M.G.; Yuan, C.H.; Azad Shah, A.K.M. Chemical composition and nutritional value of dried fish in Bangladesh. Egypt. J. Aquat. Biol. Fish. 2021, 25, 379–399.
3. Hussain, B.; Sultana, T.; Sultana, S.; Mahboob, S.; Farooq, M.; Al-Ghanim, K.; Nadeem, S. First report on fish cysteine as a biomarker of contamination in the River Chenab, Pakistan. Env. Sci Pollut. Res. Int. 2016, 23, 15495–15503.
4. Siddhnath; Ranjan, A.; Mohanty, B.P.; Saklani, P.; Dora, K.C.; Chowdhury, S. Dry Fish and Its Contribution Towards Food and Nutritional Security. Food Rev. Int. 2022, 38, 508–536.
5. Piste, P. International journal of pharmaceutical, chemical and biological sciences cysteine–master antioxidant. Int. J. Pharm. Chem. Biol. Sci. 2013, 2013, 143–149.
6. Sanderson, S.M.; Gao, X.A.-O.; Dai, Z.A.-O.X.; Locasale, J.A.-O. Methionine metabolism in health and cancer: A nexus of diet and precision medicine. Nat. Rev. Cancer 2019, 19, 625–637.
7. Civitelli, R.; Villareal, D.T.; Agnusdei, D.; Nardi, P.; Avioli, L.V.; Gennari, C. Dietary L-lysine and calcium metabolism in humans. Nutrition 1992, 8, 400–405.
8. Nordvi, B.; Langsrud, O.; Egelandsdal, B.; Slinde, E.; Vogt, G.; Gutierrez, M.; Olsen, E. Characterization of volatile compounds in a fermented and dried fish product during cold storage. J. Food Sci. 2007, 72, S373–S380.
9. Swanson, D.; Block, R.; Mousa, S.A. Omega-3 fatty acids EPA and DHA: Health benefits throughout life. Adv. Nutr. 2012, 3, 1–7.
10. Deng, Y.; Wang, Y.; Deng, Q.; Sun, L.; Wang, R.; Ye, L.; Tao, S.; Liao, J.; Gooneratne, R. Fungal diversity and mycotoxin contamination in dried fish products in Zhanjiang market, China. Food Control 2021, 121, 107614.
11. Haratake, M.; Takahashi, J.; Ono, M.; Nakayama, M. An Assessment of Niboshi (a Processed Japanese Anchovy) as an Effective Food Source of Selenium. J. Health Sci. 2007, 53, 457–463.
12. Rocourt, C.R.; Cheng, W.H. Selenium supranutrition: Are the potential benefits of chemoprevention outweighed by the promotion of diabetes and insulin resistance? Nutrients 2013, 5, 1349–1365.
13. Nuwanthi, S.G.L.I.; Madage, S.S.K.; Hewajulige, I.G.N.; Wijesekera, R.G.S. Comparative Study on Organoleptic, Microbiological and Chemical Qualities of Dried Fish, Goldstripe Sardinella(Sardinella Gibbosa) with Low Salt Levels and Spices. Procedia Food Sci. 2016, 6, 356–361.
14. Osheba, A.S. Technological Attempts for Production of Low Sodium Smoked Herring Fish (Renga). Adv. J. Food Sci. Technol. 2013, 5, 695–706.
15. Immaculate, J.; Sinduja, P.; Jamila, P. Biochemical and microbial qualities of Sardinella fimbriata sun dried in different methods. Int. Food Res. J. 2012, 19, 1699–1703.
16. Bao, M.; Cipriani, P.; Giulietti, L.; Roiha, I.S.; Paoletti, M.; Palomba, M.; Levsen, A. Air-dried stockfish of Northeast Arctic cod do not carry viable anisakid nematodes. Food Control 2020, 116, 107322.

17. Udeinya, B.C.; Ojike, O.; Okonkwo, W.I.; Abada, U.C. Performance evaluation of mixed mode passive solar stock fish dryer. Niger. J. Technol. 2022, 40, 1104–1109.

18. Oku, I.; Amakoromo, E.R. Microflora of fresh and smoke-dried fish in Yenagoa metropolis, Nigeria. Afr. J. Microbiol. Res. 2013, 7, 4451–4456.

19. Sivaraman, G.K.; Siva, V. Microbiological spoilage of dried fishes. SSRN Electron. J. 2015, 38, 508–536.

20. Vijayan, P.K.; Surendran, P.K. Quality aspects of dried fish marketed in the north eastern states of India. Fish. Technol. 2012, 49, 167–171.

21. Gore, S.B.; Relekar, S.S.; Kulkarni, A.K.; Joshi, S.A.; Pathan, J.G.K.; Telvekar, P.A.; Bankar, S.S. Quality of traditionally salted and dried fishes of ratnagiri fish market, Maharashtra. Internafional J. Sci. Environ. Technol. 2019, 8, 663–673.

22. Nagwekar, N.; Tidke, V.; Thorat, B.N. Microbial and biochemical analysis of dried fish and comparative study using different drying methods. Dry. Technol. 2017, 35, 1481–1491.

23. Lončar, B.; Filipović, V.; Nićetin, M.; Knežević, V.; Pezo, L.; Plavšić, D.; Šarić, L. Microbiological profile of fish dehydrated in two different osmotic solutions. Acta Univ. Sapientiae Aliment. 2014, 7, 73–80.

24. Tavares, J.; Martins, A.; Fidalgo, L.G.; Lima, V.; Amaral, R.A.; Pinto, C.A.; Silva, A.M.; Saraiva, J.A. Fresh Fish Degradation and Advances in Preservation Using Physical Emerging Technologies. Foods 2021, 10, 780.

25. Idakwo, P.Y.; Negbenebor, C.; Bullet, M.; Badau, M.; David, b.; Gbenyi, D.I. Total volatile base nitrogen (TVBN) and trimethylamine (TMA) content of “Bunyi youri” as influenced by the addition of glucose and clove during storage. Int. J. Biotechnol. Food Sci. 2016, 4, 81–85.

26. Wójcik, W.; Łukasiewicz, M.; Puppel, K. Biogenic amines: Formation, action and toxicity—A review. J. Sci. Food Agric. 2021, 101, 2634–2640.

27. Prester, L. Biogenic amines in fish, fish products and shellfish: A review. Food Addit. Contam. Part A 2011, 28, 1547–1560.

28. Freire, F.D.C.O.; da Rocha, M.E.B. Impact of Mycotoxins on Human Health. In Fungal Metabolites; Mérillon, J.-M., Ramawat, K.G., Eds.; Springer International Publishing: Cham, Switzerland, 2016; pp. 1–23.

29. Sufi, G.B.; Morshed, M.; Wahed, M.A.; Khaleque, M.A.; Rafique, S. The performance of a solar tunnel dryer and evaluation of the quality of dried and dehydrated fish. Dhaka Univ. J. Biol. Sci. 2005, 14, 169–176.

30. Hoque, M.S.; Tamanna, F.; Hasan, M.M.; Al Banna, M.H.; Mondal, P.; Prodhan, M.D.H.; Rahman, M.Z.; van Brakel, M.L. Probabilistic public health risks associated with pesticides and heavy metal exposure through consumption of common dried fish in coastal regions of Bangladesh. Environ. Sci. Pollut. Res. 2022, 29, 20112–20127.

31. Saha, N.; Zaman, M.R. Evaluation of possible health risks of heavy metals by consumption of foodstuffs available in the central market of Rajshahi City, Bangladesh. Environ. Monit. Assess. 2013, 185, 3867–3878.

32. Syamdidi, M. The Use of Chemical Additives for Fisheries Product Preservation. Squalen Bull. Mar. Fish. Postharvest Biotechnol. 2013, 7, 79.

33. Bedale, W.; Sindelar, J.J.; Milkowski, A.L. Dietary nitrate and nitrite: Benefits, risks, and evolving perceptions. Meat Sci. 2016, 120, 85–92.

34. Chen, C.H.; Ho, S.N.; Hu, P.A.; Kou, Y.R.; Lee, T.S. Food preservative sorbic acid deregulates hepatic fatty acid metabolism. J Food Drug Anal. 2020, 28, 206–216.

35. Islam, M.N.; Kabir, M.A. Application of organic preservatives for sustainable storage of dried fishes. Int. J. Fish. Aquat. Stud. 2019, 7, 40–43.

36. Tewari, G.; Juneja, V. Advances in Thermal and Non-Thermal Food Preservation; John Wiley & Sons: Hoboken, NJ, USA, 2008.

37. Matser, A.M.; Stegeman, D.; Kals, J.; Bartels, P.V. Effects of high pressure on colour and texture of fish. Int. J. High Press. Res. 2000, 19, 109–115.

38. Palmieri, L.; Cacace, D. High intensity pulsed light technology. In Emerging Technologies for Food Processing; Elsevier: Amsterdam, The Netherlands, 2005; pp. 279–306.

39. Lasagabaster, A.; De Marañón, I.M. Sensitivity to pulsed light technology of several spoilage and pathogenic bacteria isolated from fish products. J. Food Prot. 2012, 75, 2039–2044.

40. Zhu, S.; Bail, A.L.; Ramaswamy, H. Ice crystal formation in pressure shift freezing of Atlantic salmon (Salmo salar) as compared to classical freezing methods. J. Food Processing Preserv. 2003, 27, 427–444.

41. Tironi, V.; De Lamballerie, M.; Le-Bail, A. Quality changes during the frozen storage of sea bass (Dicentrarchus labrax) muscle after pressure shift freezing and pressure assisted thawing. Innov. Food Sci. Emerg. Technol. 2010, 11, 565–

573.

42. Cropotova, J.; Tappi, S.; Genovese, J.; Rocculi, P.; Laghi, L.; Dalla Rosa, M.; Rustad, T. Study of the influence of pulsed electric field pre-treatment on quality parameters of sea bass during brine salting. Innov. Food Sci. Emerg. Technol. 2021, 70, 102706.
43. Nagarajarao, R.C. Recent advances in processing and packaging of fishery products: A review. Aquat. Procedia 2016, 7, 201–213.
44. Fondi, M.; Liò, P. Multi-omics and metabolic modelling pipelines: Challenges and tools for systems microbiology. Microbiol. Res. 2015, 171, 52–64.