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Mapping the Landscape of Dry Fish Research in the World vis-a-vis India (1990–2022)

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Abstract

The fisheries industry has long relied on dried fish as a pivotal commodity for trade and consumption, significantly contributing to economic, nutritional, and cultural sectors. Despite its importance, a comprehensive analysis of the research landscape, particularly concerning India, has been lacking. Therefore, this study aims to fill this gap by conducting a scientometric analysis of global and Indian dry fish research from 1990 to 2022 using the Publish or Perish application. Keywords such as 'dry fish', 'dried fish', and 'fish drying' were used to identify 1,502 relevant articles. The findings reveal that Asia leads in dry fish research, accounting for 66.33% (977 articles) of the total, with India emerging as a major contributor, representing 21.75% (320 articles) of the global output, followed by Bangladesh (16.38 % - 241 articles) and Nigeria (13.26% - 195 articles). Notably, Kerala contributes significantly to India's research with 20.5% (64 articles). The articles garnered 23,074 citations, averaging 699 citations per year, with research papers constituting 73.5% of the publications. "Fishery Technology" stands out as the leading journal in this field, publishing 35 articles. Collaborative efforts are evident, with an average collaboration index of 3.10 and 21.24% of articles featuring three authors. The primary focus was on "dried" products (72.4%), followed by "smoked" products (11.15%). Articles were categorized into "Food value" (1,242), "Economic value" (218), and "Cultural heritage value" (42). The study further delves into sub-themes such as food and nutrition, food safety and microbiology, food engineering, economics and marketing, value chain, labour, gender, and history and change. This analysis underscores Asia's, particularly India's, significant contributions to global dry fish research and offers valuable insights into the multifaceted dimensions of this vital industry.

Keywords: Dry fish, Scientometrics, Publish or Perish, Fishery Technology, India

Introduction

Dry fish, encompassing various preservation methods such as curing, salting, fermenting, and smoking, plays a crucial role in the global food landscape (FAO, 2024). It is a catchall term for aquatic animal products that have undergone processing, enabling them to be stored at room temperature for prolonged periods without specialized industrial packaging. Historically, before the advent of ice-making technologies and cold chains, dry fish held a prominent position in trading and consumption, with evidence of its production, storage, trade, and consumption dating back millennia (Fagan, 2017; Belton et al., 2022). Among the various preservation techniques, traditional sun-drying methods have long been recognized as the most cost-effective preservation technique, particularly in rural areas where access to specialised processing techniques is limited (Horner, 1997). In addition to its practicality, dried fish is rich in protein and other essential nutrients; dried fish consumption and trade thrive in low-income countries, serving as a vital source of food and nutrition in coastal and arid mountainous regions (Belton & Thilsted, 2014). Even today, dried fish remains a core component of diets and

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cuisines across various regions, including Sub-Saharan Africa and Southeast Asia (Liverpool-Tasie, Sanou, Reardon, & Belton, 2021; Saha, Rima, Haq, & Sultana, 2022). The ease of storage and transportation enables dried fish to reach hinterland areas where fresh fish may not be readily available. Furthermore, its preservation facilitates the mitigation of seasonal fluctuations in fish abundance, ensuring a consistent supply throughout the year. The unique attributes of dried fish, such as its ready divisibility into small portions, intense flavour, and affordable prices per unit of nutrients, make it widely accessible, particularly for vulnerable populations (Kawai & Sakaguchi, 1996).

Despite constituting approximately 12% of global fish production, dry fish has been largely overlooked in international, regional, and national analyses, hindering a comprehensive understanding of its economic, nutritional, and social contributions. This oversight is especially notable in low-income countries, where dried fish consumption can account for up to 36% of total fish consumption, making it a vital source of sustenance and food security (FAO, 2015; Pradhan, Nayak, & Armitage, 2022). Beyond its role as a sustainable protein source, dried fish holds substantial cultural and gender-related importance. Remarkably, about half of those involved in dried fish production and marketing are women, underscoring its importance in livelihoods and gender dynamics. Despite its wide consumption and contribution to the well-being of vulnerable populations, dried fish, as a subsector of small-scale fisheries (SSF), has received minimal attention from academia and policymakers (Singh et al., 2014; Geethalakshmi, Chandrasekar, & Gopal, 2022). Moreover, while the significance of dried fish in both global and local contexts is evident, a comprehensive analysis of its research landscape, particularly in India, has been lacking. Therefore, the study examined global and Indian dry fish research (1990-2022) using scientometrics to gain a comprehensive understanding of the research landscape on dry fish. Scientometrics, a quantitative method for investigating the development of science as an information process, enables the analysis of scientific articles to uncover patterns, trends, and thematic focuses in research (Nalimov & Mulchenko, 1969; Velumani, Ananthan, Krishnan, & Chrispin, 2019).

Materials and Methods

The study followed a systematic approach to retrieve and analyze scientific articles pertaining to dry fish. To collect a comprehensive range of relevant literatures, the open-source software Publish or Perish (PoP) desktop application was used, employing various combinations of search terms such as "Dry fish", "Dried fish", and "Fish drying". The search was conducted at five-year intervals from 1990 to 2022 during May 2023. A total of 5,990 articles were initially collected, including patents and citations. Irrelevant articles and duplicates were then eliminated by assessing their titles, abstracts, and keywords. After this elimination process, 1,502 articles were selected for analysis. Data visualization software tools such as MS Excel, Rstudio, VOSviewer, and ArcGIS were employed to generate graphical representations of the findings.

The publication trends (number of articles and growth rate), citations (total citations and average citations per paper/ACPP) and collaboration metrics (collaboration index, degree of collaboration, and modified collaborative coefficient) were used to evaluate the annual research productivity on dry fish. The increase or decrease in the number of articles was measured using the relative growth rate (RGR) (Bhoomaiah et al., 2022). The following equation was used to calculate the mean RGR for the particular time period of the interval:

$$1 - 2R = Log_e2W - Log_e1W / 2T - 1T$$

Where,

1-2R = Mean relative growth rate over the specific period of time interval

Log_e1W = log of the initial number of articles or pages

Log_e2W = log of the final number of articles or pages after a specific period of time interval

2T - 1T = Unit difference between initial and final time

Doubling Time in years (DT) = 0.693/RGR

Doubling Time (DT) for articles, representing the time taken for the number of articles to double, fluctuates across different years.

To determine the trend in collaborative research from 1990 to 2022, the year-by-year authorship patterns of dry fish publications were examined. The degree of collaboration was determined based on the authorship information of these publications using a variety of indices, including the Modified

Collaborative Coefficient (MCC), a numerical indicator of collaborative strength; Collaborative Index (CI), an estimate of the mean number of authors; and the Degree of Collaboration (DC), which measures the proportion of multiple-authored papers (Savanur & Srikanth, 2010).

Degree of collaboration (DC) = $1 - f_i/N$

Collaborative Index (CI) = $\frac{\sum_{j=1}^{A} jf_j}{N}$

Modified Collaborative Coefficient (MCC) =

$$\frac{A}{A-1}\left\{1 - \sum_{j=1}^{A}\frac{(1/j)f_j}{N}\right\}$$

where,

f_i = Number of papers having 'j' authors in 'collection/year (K)'

N = Total number of papers in 'K'. N = " j f_i

A = Total number of authors in collection 'K'

The data collected for various features, such as the number of publications and papers with multiple co-authors, and different measures of collaboration (CI, DC, MCC) and growth (RGR, DT) were statistically analyzed using trend analysis techniques. Additionally, the correlation between annual publication count, citations, number of authors, and collaboration index were analysed.

Results and Discussion

The research landscape of dry fish revealed a significant focus on dry fish research in Asian countries (66.33%), followed by Africa which accounts for 22.20% (327 articles), highlighting a substantial contribution from these regions. This dominance is likely due to their heavy reliance on dry fish as a staple in aquatic food systems and traditional diets, as well as their significant share in aquatic food production, which relies heavily on traditional preservation methods due to their importance in ensuring food security and supporting cultural practices (FAO, 2022).

Europe contributes 6.25% of the articles, while South America and North America have a relatively lower research outputs, with 1.15% and 2.85%, respectively. Australia's contribution stands at 1.22%, suggesting a comparable level of research activity. No articles were found from Antarctica (Fig. 1). This pattern of article distribution aligns with findings by Seenivasan, Ankush, Janarthanan, and Velumani (2024), whose scientometric study on fish icing that colder climate countries predominantly rely on chilling as the primary method of fish preservation, which may explain their limited engagement in dry fish research.

Fig. 1. Geographical coverage of the dry fish publications

India emerges as the leading contributor to dry fish research, with 320 articles accounting for 21.75% of the total research articles. Bangladesh follows with 241 articles (16.38%), reflecting a significant research interest in dry fish. Nigeria also shows a strong presence, contributing 195 articles (13.26%). Other notable contributors include Indonesia (75 articles, 5.10%), Japan (51 articles, 3.47%), and China (48 articles, 3.26%). Sri Lanka, Thailand, and Korea each contribute around 3%, indicating a moderate level of engagement in dry fish research. Several other countries, such as Kenya, Malaysia, USA, Ghana, UK, and Oman, exhibit smaller yet significant research outputs, each contributing around 1% of the total articles (Fig. 2). Countries with low per capita income, high dry fish consumption, and

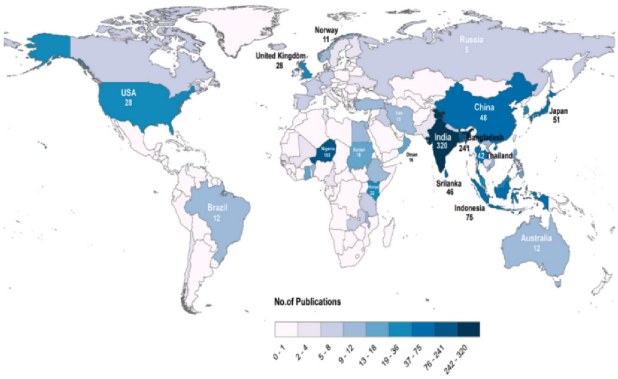


Fig. 2. Country-wise dry fish publications

strong dietary preferences for dried fish have been primary contributors to the dry fish research pool of publications (Ghosh et al., 2022; Wickrama, Koralagama, & Sandika, 2023). Low and middle-income countries consume more than 20% of fisheries products in cured form. Among them, India a major fish-producing nation, uses 17% of its total catch for drying, surpassing the global average of 12% (FAO, 2024).

Among Indian states, Kerala emerges as the leading contributor to dry fish research, with 64 articles (20%). Tamil Nadu follows with 37 articles (11.6%), while Assam and Maharashtra show similar research engagement, contributing 36 (11.3%) and 34 articles (10.6%), respectively. West Bengal and Andhra Pradesh also exhibit notable research output, with 29 articles (9.1%) and 21 articles (6.6%), respectively. Odisha and Karnataka each contribute 18 articles, accounting for 5.6%. Other states making contributions to dry fish research include Tripura (15 articles, 4.7%), Gujarat, and Manipur (14 articles each, 4.4%). Several inland states, such as Chhattisgarh, Meghalaya, Uttar Pradesh, Jharkhand, Arunachal Pradesh, Pondicherry, Jammu & Kashmir, Nagaland, Telangana, Uttarakhand, Bihar, Rajasthan, and Mizoram, exhibit smaller research outputs, ranging from 0.3% to 1.3% (Fig. 3). With the exception for Assam, which shows a higher share of dry fish publications, the dominating states are coastal, where higher fish production positively correlated with dry fish production. This trend can be attributed to underdeveloped cold chain infrastructure in middle and low-income countries, which limits the use of advanced preservation

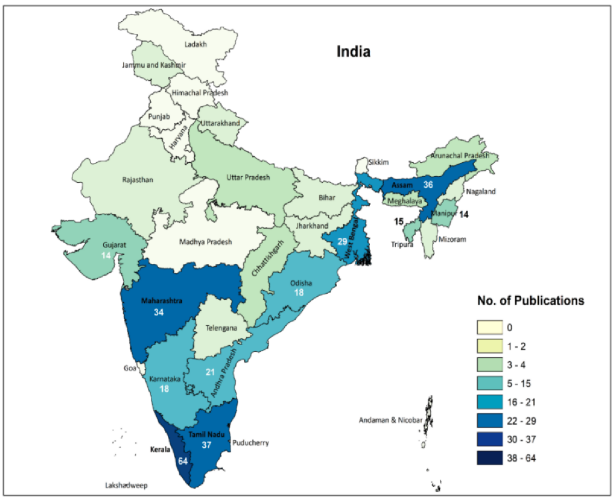


Fig. 3. State-wise dry fish publications from India

methods. As a result, marine fishers heavily rely on ice for preservation, with fish drying serving as a critical alternative to further mitigate post-harvest losses (Reza, Bapary, Islam, & Kamal, 2009; Seenivasan, et al., 2024).

Globally, research articles account for the majority, with 1104 publications (73.5%). India stands out as a key contributor, with 271 research articles (24.55% of the country's overall research output). Conference/workshops contribute 140 articles (9.32% globally), while reports/manuals and review articles account for 7.86% and 4.99%, respectively. Dissertations represent 2.73% of global publications, with India contributing 2.19% of these. Popular articles/magazines and patents make smaller contributions (Fig. 4).

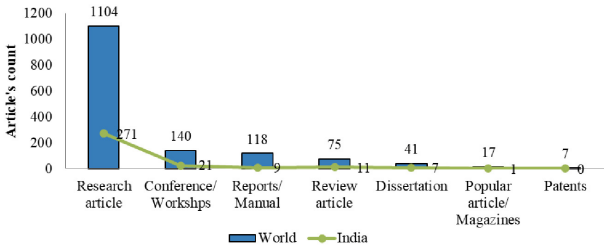


Fig. 4. Distribution of publication types on dry fish research (1990–2022)

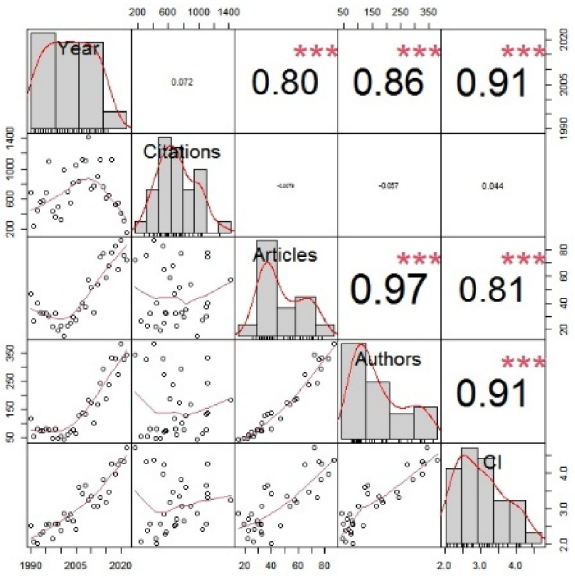
The number of dry fish articles has exhibited a fluctuating trend over the years, ranging from 15 articles in 2001 to a peak of 87 articles in 2020. The compound annual growth rate stands at 4%, indicating a steady overall increase in publications. The early years, from 1990 to 1999, witnessed relatively fewer publications, ranging from 19 to 47 articles, marking the formative phase of dry fish research. Notably, in India, earlier years saw a low average of 4 articles annually, with a spike in 1996. Following this, there was a resurgence, with an average of 8 articles per year between 2009 and 2012. The peak year for India was 2018, with 26 articles, and 2016 also stood out, with 25 articles, doubling the count from the previous year. Overall, dry fish research in India has seen rising interest, with a compound annual growth rate of approximately 6.23%. The number of articles published on dry fish has been steadily increasing over time with the Pearson correlation of 0.80* (Fig. 5). The higher ACPP values indicate a stronger impact per

Table 1. Year-wise research productivity of dry fish publications (n = 1502)

	Articles		RGR		DT		Authors		Citations		ACPP	
Year	W	I	W	I	W	I	W	I	W	I	W	I
1990	47	4	0.00	0.00	0.00	0.00	342	7	686	44	14.60	11.00
1991	26	3	-0.26	-0.12	-2.70	-5.55	327	6	237	17	9.12	5.67
1992	40	2	0.19	-0.18	3.70	-3.94	381	5	447	7	11.18	3.50
1993	33	7	-0.08	0.54	-8.29	1.27	274	19	556	37	16.85	5.29
1994	32	7	-0.01	0.00	-51.86	0.00	328	18	570	74	17.81	10.57
1995	32	5	0.00	-0.15	0.00	-4.74	332	14	687	39	21.47	7.80
1996	30	9	-0.03	0.26	-24.72	2.71	236	23	1096	115	36.53	12.78
1997	22	3	-0.13	-0.48	-5.14	-1.45	187	9	435	20	19.77	6.67
1998	32	9	0.16	0.48	4.26	1.45	293	30	361	41	11.28	4.56
1999	19	3	-0.23	-0.48	-3.06	-1.45	244	11	499	186	26.26	62.00
2000	23	5	0.08	0.22	8.35	3.12	166	18	328	107	14.26	21.40
2001	15	1	-0.19	-0.70	-3.73	-0.99	101	1	977	56	65.13	56.00
2002	23	3	0.19	0.48	3.73	1.45	173	9	701	6	30.48	2.00
2003	25	7	0.04	0.37	19.14	1.88	184	15	548	54	21.92	7.71
2004	29	5	0.06	-0.15	10.75	-4.74	135	9	806	209	27.79	41.80
2005	27	8	-0.03	0.20	-22.33	3.40	136	14	1049	15	38.85	1.88
2006	35	2	0.11	-0.60	6.15	-1.15	126	5	830	32	23.71	16.00
2007	40	9	0.06	0.65	11.95	1.06	65	27	1116	80	27.90	8.89
2008	37	7	-0.03	-0.11	-20.47	-6.35	78	20	1104	157	29.84	22.43
2009	57	9	0.19	0.11	3.69	6.35	71	31	1420	326	24.91	36.22
2010	52	6	-0.04	-0.18	-17.38	-3.94	62	13	740	26	14.23	4.33
2011	33	4	-0.20	-0.18	-3.51	-3.94	43	12	777	56	23.55	14.00
2012	54	8	0.21	0.30	3.24	2.30	55	24	895	134	16.57	16.75
2013	74	17	0.14	0.33	5.06	2.12	49	54	1115	225	15.07	13.24
2014	77	16	0.02	-0.03	40.15	-26.32	82	61	763	114	9.91	7.13
2015	59	15	-0.12	-0.03	-5.99	-24.72	47	44	615	130	10.42	8.67
2016	68	25	0.06	0.22	11.24	3.12	77	71	654	330	9.62	13.20
2017	78	23	0.06	-0.04	11.63	-19.14	81	96	1115	228	14.29	9.91
2018	83	26	0.03	0.05	25.68	13.02	75	119	528	79	6.36	3.04
2019	65	11	-0.11	-0.37	-6.53	-1.86	75	49	543	72	8.35	6.55
2020	87	19	0.13	0.24	5.47	2.92	81	72	410	25	4.71	1.32
2021	76	18	-0.06	-0.02	-11.80	-29.51	54	68	310	12	4.08	0.67
2022	72	24	-0.02	0.12	-29.51	5.55	118	90	156	32	2.17	1.33
Sum	1502	320					5078	1064	23074	3085	15.36	9.64

*Note: W- World; I - India

publication. For instance, in 2001, India had a relatively high ACPP of 56.00, indicating a significant average number of citations per paper pub-



*Note: *** 0.1% level of significance*

Fig. 5. Correlation matrix of dry fish publications

Citations trends in dry fish publications

Dry fish articles have accumulated a total of 23,074 citations between 1990 and 2022, with an average of 699 citations per year. In comparison, dry fish articles from India received a total of 3,085 citations (13.37% of the total citations), with an average of 93 citations per year. The average citation per article is approximately 15, while for India, it is 9, indicating that the articles on dry fish has had a moderate impact on the research community. In the early 1990s, citations count ranged from 237 to 687, with a notable spike in 1996, when the citations count reached 1,096. The year 2009 saw a significant increase, with 1,420 citations, suggesting growing interest in dry fish research (Fig. 6). The sustained average citation per year over the 33 years suggests that the relevance of the research on dry fish has remained consistent over time, with rising citation counts reflecting a broader research landscape and greater global engagement.

Country-wise citation analysis

India has the highest number of published articles on dry fish (320), and also received the highest

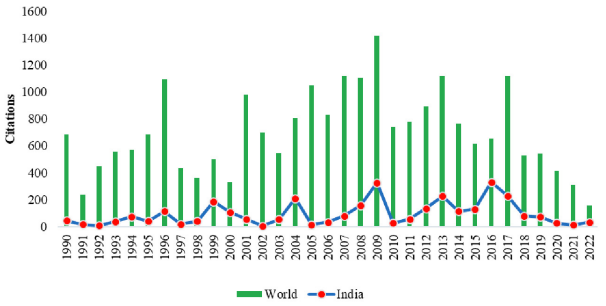


Fig. 6. Citation analysis of dry fish publication from the world and India (1990-2022)

number of citations (3,129), resulting in an average of 9.78 citations per article. A study by Seenivasan et al. (2024) also highlighted that India and Indonesia have the highest number of articles and citations on fish dryer aspects. Nigeria and Bangladesh followed closely, with 2,666 and 2,489 citations, respectively, both having a higher average citation per article than India. The USA, despite having only 18 published articles on dry fish, received the highest average citation per article, at 93.17, indicating the high impact and significance of its research. Similarly, Ireland with only 2 published articles on dry fish, received a remarkably high number of citations, with an average of 203.50 citations per article, indicating the significance and impact of its research (Table. 2).

Top journals publishing dry fish-related studies

The journal Fishery Technology from India has the highest number of articles, with 35 publications,

Table 2. Country-wise citation analysis

Country	Citations	Articles	Citation/Article
India	3129	320	9.78
Nigeria	2666	195	13.67
Bangladesh	2489	241	10.33
USA	1677	18	93.17
China	1604	48	33.42
Japan	1232	51	24.16
Thailand	757	42	18.02
Korea	442	36	12.28
Ireland	407	2	203.50
UK	398	17	23.41

followed by the International Journal of Fisheries & Aquatic Studies with 23 articles. Drying Technology and Food chemistry contribute 18 and 17 articles, respectively. Other journals in the list include the Journal of the Science of Food and Agriculture, the Journal of Entomology and Zoology Studies, and the Journal of Food Science and Technology (Fig. 7).

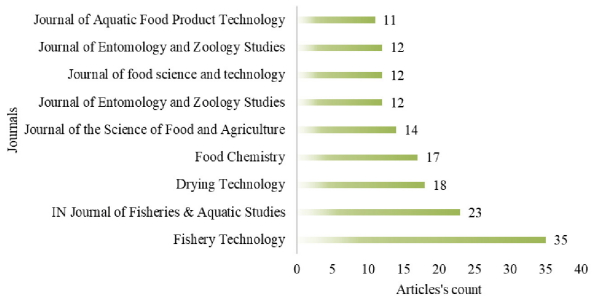


Fig. 7. Top journals publishing dry fish publications

Number of authors in dry fish publications

The authorship count ranged from 1 to 13 authors. Globally, the highest number of articles is authored by three authors (319 articles, 21.24%), closely followed by articles with two authors (315 articles, 20.97%). The number of articles decreases gradually as the number of authors increases, with the lowest count observed for articles authored by 13 authors, totaling just one article. In the Indian context, a similar pattern is observed, with the highest number of articles also authored by three authors (76 articles, 23.75%). Articles authored by two individuals follow closely, with 67 articles (20.94%). This highlights that a substantial portion of the dry fish articles, both globally and in India, are authored by 1 to 4 individuals, highlighting a prevalent trend of

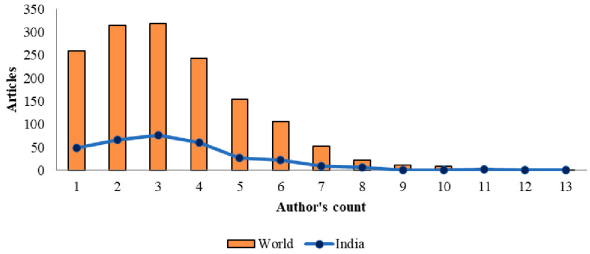


Fig. 8. Authorship pattern of dry fish publications from the world and India (1990-2012)

collaboration among a small number of authors in this research field (Fig. 8).

Co-authorship analysis of the world and India

In the global network, international collaboration among authors in dry fish research was relatively low. However, foreign authors demonstrated stronger connections among themselves, forming larger clusters within the network. The 1,499 authors analyzed were grouped into 51 clusters, with four major clusters standing out. In contrast, Indian authors exhibited a higher number of publications and citations in dry fish research. Despite this, collaborative research efforts among Indian researchers were limited. Among the 299 Indian authors analysed, only 18 met the threshold of a minimum occurrence of two, indicating a relatively lower degree of collaboration (Fig. 9).

Fig. 9. Co-author network map of dry fish research in the World and India

Collaborative measures in the dry fish publications (1990-2022)

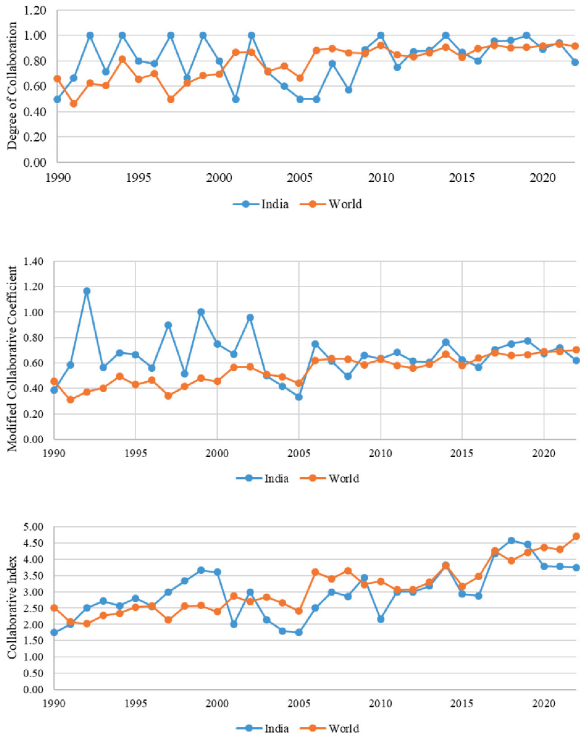


Fig. 10. Collaborative measures in dry fish research (1990-2022)

India's degree of collaboration (DC) slightly exceeds the global average, standing at 0.85 compared to the global average of 0.83, whereas the DC of ICAR Fisheries Research Institutes was 0.95 (Bhoomaiah et al., 2022), indicating a notably high level of collaboration. India's MCC averages at 0.58, indicating a moderate level of collaboration, while the global MCC stands at 0.57, reflecting a similar moderate level of global collaboration. The collaboration index for India ranges from 1.75 to 4.58, with an average of 3.33. Globally, the collaboration index ranges from 2.03 to 4.71, with an average of 3.38, highlighting the overall level of collaboration worldwide (Fig. 10).

Co-network analysis of the world and India

The co-network analysis of global dry fish research, based on keyword occurrence data, extracted resulting a total of 1,924 keywords. Among these, 83 keywords that appeared at least five times were selected for generating network visualization maps. The top 5 keywords with highest link strength were 'dry fish' (110), 'India' (73), 'dried fish' (58), 'Bangladesh' (50), and 'species' (49). These keywords reflect the strong association and emphasis on dry fish research globally, particularly concerning India and Bangladesh, as well as the exploration of different species. For the co-network analysis specific to India, 43 keywords out of 409 met the minimum occurrence threshold of five times. The prominent keywords in the clusters were 'effect' (33), 'sun' (27), 'dry fish market' (23), 'processing' (22), and 'West Bengal' (15). This indicates that Indian researchers have been particularly interested in studying the effects of various factors, such as sunlight, along with exploring the dry fish market, processing techniques, and the specific context of West Bengal (Fig. 11).

Major research areas in dry fish-related research

The most commonly researched area in fish processing is drying, which accounts for 73% of the total, indicating that it is a prevalent preservation method

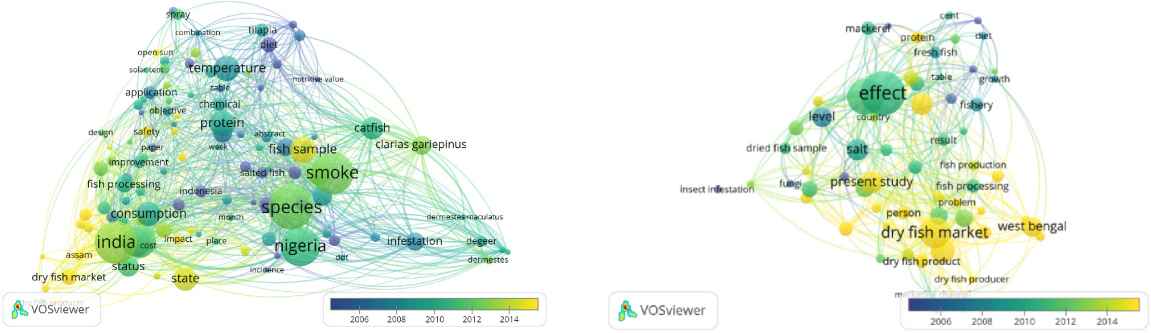


Fig. 11. Keywords overlay map of dry fish-related research

in the fishing industry. Smoking (11%) and salting (9%) techniques were the next major research areas in fish curing methods. Other processing methods, such as fermentation (4.13%), freeze-drying (1%), spray-drying (1%), and irradiation (1%), each account for less than 2% of the total research (Fig. 12).

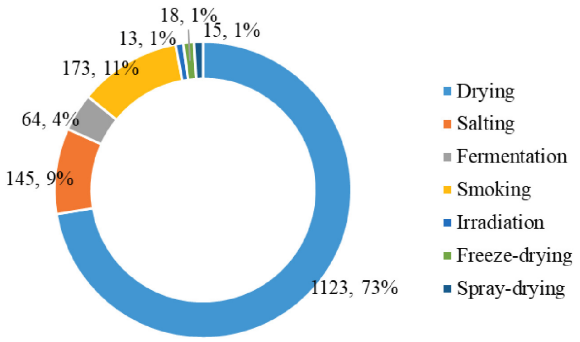


Fig. 12. Major research areas in the dry fish-related research

Most published thematic areas within dry fish

The food value is represented in 1,242 publications (83%), highlighting the perceived importance of the food item/group as a source of nutrition or sustenance. The economic value is reflected in 218 publications (14%), focusing on the perceived importance of the food item/group in terms of market value, employment opportunities, or other related economic benefits. The cultural value is represented in 42 publications (3%), emphasizing the perceived importance of the food item/group as a part of the cultural heritage or identity of a particular group of people (Fig. 13).

Food and nutrition

The food and nutrition theme, comprising 590 articles, accounts for 39.28% of the total. As a traditional food item, dry fish serves as a vital source of protein, especially in regions where fresh fish may be scarce. It is rich in essential fatty acids, such as omega-3 and omega-6, which are crucial for cardiovascular health and brain function. Additionally, dry fish provides vitamins B12 and D, as well as essential minerals like calcium, phosphorus, and iron, all of which support nerve function and bone health (Singh, Sarojnalini, & Vishwanath, 1990; Majumdar, Afrin, Rasul, Khan, & Shah, 2017).

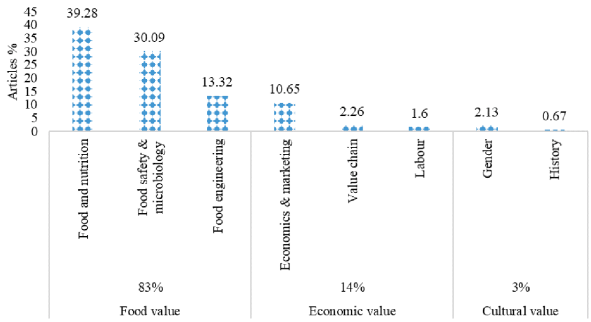


Fig. 13. Thematic intersection of dry fish publications

However, ensuring safety and quality through proper processing, handling, and storage practices is essential.

Food safety and microbiology

The food safety and microbiology theme comprises 452 articles (30.09%), highlighting the significant concern for the safety and quality of dry fish as a food product, particularly regarding microorganisms such as bacteria (*Salmonella*, *Staphylococcus aureus*, *Escherichia coli*, *Vibrio cholera*, *Listeria*), fungi (aflatoxins and *Aspergillus)*, and viruses, all of which can contaminate dry fish (Prasad, Rao, & Gupta, 1994; Vijayan & Surendran, 2012). Research conducted in India and Bangladesh has revealed high rates of bacterial contamination in dry fish samples, with associated risks of foodborne illnesses (Sivaraman et al., 2018; Hoque et al., 2022). Traditional drying methods, such as sun-drying and smoking, have been identified as potential sources of microbial contamination (Nath & Majumdar, 2013; Dhar, Karthikeyan, & Roy, 2014). However, various preservation methods, involving salt, radiation, smoking, and freezing, have shown promise in reducing microbial contamination. It is essential to adhere to proper processing and storage practices to minimize the risk of foodborne illnesses associated with dry fish consumption (Shiriskar, Khedkar, & Sudhakara, 2010).

Food engineering

The theme of applying engineering principles to design and develop food processing and preservation systems, which comprise 200 articles (13.32%). This theme focuses on the various technologies and processes involved in the production of dry fish, including drying, smoking, and packaging. Sun drying is a traditional and inexpensive method, but

it is slow, weather-dependent, and susceptible to contamination (Bala & Mondol, 2001; Reza et al., 2009). Smoking, another traditional method, not only dries the fish but also imparts a smoky flavor, though it can introduce potentially harmful compounds. Air drying, which involves hanging fish in a well-ventilated area, is faster than sun drying but is still influenced by weather conditions and contamination risks (Delfiya et al., 2022). Freeze drying is a modern technique and produces high-quality, long-lasting dry fish, but is costly and requires specialized equipment (Duan, Zhang, Li, & Mujumdar, 2008). Drum drying, which uses a heat pump with a rotating drum and steam, is a fast and efficient method, though it demands specialized equipment and is relatively expensive. Different drying methods are employed, each with its own advantages and disadvantages (Mustapha, Ajibola, Salako, & Ademola, 2014) and the choice of method depends on factors such as fish type, desired product, and available resources.

Economics and marketing

A total of 160 articles (10.65%) focused on the economic and commercial aspects of dry fish production and consumption, including market trends, pricing, and trade. Economic studies have shown that dry fish production is financially beneficial, with sun drying being the most cost-effective method compared to smoking and other techniques (Nanlohy Apituley, Tapotubun, Reiuwpassa, & Matrutty, 2017). Marketing channels for dry fish vary by region, ranging from direct sales by small-scale fishermen to local markets, to large-scale processing companies involved in mass production and international export. The export of dry fish has significantly contributed to the economies of developing countries, including India, Bangladesh, Thailand, and Sri Lanka, from where it is exported to Europe, the Middle East, and Southeast Asia (Shamsuzzaman, Mozumder, Mitu, Ahamad, & Bhyuian, 2020). Dry fish production can be economically profitable, particularly in regions rich in fish resources where drying is a traditional preservation method. However, profitability varies depending on factors such as raw material costs, labour, and energy expenses (Salim, Rahman, & Nashad, 2016; Madan et al., 2018).

Value chain

The value chain theme consists of 34 articles (2.26%) that focus on the various stages involved in the production and distribution of dry fish, including processing, transportation, marketing, and distribution. The value chain analysis of dried fish considers three major aspects: structure, conduct, and performance (Kaplinsky, 2000). The structure of the value chain is divided into upper, middle, and lower segments, encompassing fishers, processors, workers, commission agents, traders, wholesalers, exporters, and retailers (Belton, Hossain, & Thilsted, 2018, Belton et al., 2022; Pradhan et al., 2022). Conduct refers to the provision of goods and services and the relationships among the actors in the value chain (Rosales et al., 2017). Value chain analysis has been effective in fostering relationships between specific links, such as buyers and suppliers, with key considerations for factors like price, convenience, and product hygiene. Performance in the value chain focuses on value addition across the entire value stream, emphasizing the vertical interactions between actors and nodes (Berenji, Nayak, & Shukla, 2021). The dry fish value chain can be divided into different stages: in the production stage, fish are caught using various techniques, in the processing stage, fish are cleaned, gutted, and dried using traditional methods (Pradhan, Nayak, & Haque, 2023); and in the marketing stage, dried fish is graded, packaged, and branded to attract customers and establish brand loyalty (Upadhyay, Pandey, & Dhar, 2017).

Labour

Articles focusing on labour practices in the dry fish production industry, including employment conditions, work safety, and workers' rights account for 24 publications (1.60%). The dry fish industry provides livelihood opportunities, especially in coastal regions. However, labourers often face poor working conditions, low wages, and a lack of benefits. Many of these workers are unskilled and come from disadvantaged backgrounds (Kayamba-Phiri, Synnevåg, & Limuwa, 2020). They are typically employed on a daily wage basis, without access to health insurance or pensions. Working conditions in the industry are often unsanitary and unsafe, with workers exposed to harmful chemicals, gases, and extreme temperatures. Wages are generally low, and workers may not receive overtime pay or bonuses, sometimes earning less than the minimum wage (Belton et al., 2018). Resolving labour-related challenges is crucial for the sustainability and well-being of workers in the dry fish industry (Upadhyay, Pandey, Chauhan, & Pal,

2021). The dried fish economy faces sustainability challenges, such as the exploitation and vulnerability of marginalized labourers, widespread pesticide use with associated health risks (Hoque et al., 2022), poor sanitary conditions (Amuna, 2014), threats to the ecological integrity of fisheries (Hall, Hilborn, Andrew, & Allison, 2013), diversion of fish resources for non-food purposes, and a lack of formal governance and political representation (Hossain, Belton, & Thilsted, 2015).

Gender

The theme explores the role of gender in dry fish production and consumption, with a particular focus on the involvement of women in the industry, comprising 32 articles (2.13%). Women make up about half of the workforce in dried fish production and marketing. However, their participation in the sector is often informal, and they are not recognized as key stakeholders in the value chain. These women face challenges such as limited access to credit, information, and markets. Despite these obstacles, studies have shown that women's participation in the dry fish sector is crucial for their economic empowerment and decision-making power within their household (Singh et al., 2014; Geethalakshmi et al., 2022). Women are predominantly engaged in the post-harvest and marketing stages, including sorting, cleaning, processing, packaging, and selling fish in local markets (Galappaththi, Collins, Armitage, & Nayak, 2021). However, women traders encounter obstacles like lack of access to credit, inadequate infrastructure, and limited market information. Efforts are being made to enhance women's participation in the value chain through training, access to credit, and better information (Hapke, 2001). Achieving gender equity in the dry fish sector is essential, and measures should be taken to recognize women's contributions while improving their access to resources and markets (Bhatta & Rao, 2003).

History and change

There are only 10 articles on the history and change of dry fish, which has long been valued for its extended shelf life and nutritional value. Originating in ancient times, dry fish has evolved and spread across cultures, becoming a staple in many regions. Modern production methods employ technology for faster and more consistent drying. Despite these changes, dry fish remains significant, particularly in areas where fresh fish is scarce (Clarke, 2004; Neer, Wouters, & Mouton, 2013; Maltin & Jonsson, 2018). Known by various names, such as sukha machli and karawala, dry fish holds cultural significance in different countries. From India to Nigeria, it connects people through shared culinary traditions, making it a cherished part of global culinary history.

A total of 1,502 articles were authored by 5,078 researchers, showcasing a remarkable growth rate of 4%. Among the articles, 73.5% were research articles, while only 5% were review articles. The majority of dry fish studies originated from Asia, which accounted for 66.33% of the articles, and India led with 21.75% of the publications. Within India, the state of Kerala contributed the highest number of articles, representing 20.5% of the total. The articles collectively received 23,074 citations, signifying a moderate impact within the research community, with an average citation count of 699 per year and approximately 5 citations per article. Notably, the journal Fishery Technology had the highest number of publications, followed by the International Journal of Fisheries & Aquatic Studies. Collaborative research efforts were evident, as the most common number of authors per article was three, accounting for 21.24% of the articles, and the average collaboration index stood at 3.10. In terms of product types, "dried" products dominated at 72.4%, followed by "smoked" products at 11.15%. This scientometric assessment offers valuable insights into the dry fish research landscape, facilitating further collaboration and understanding within this field.

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