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*Review*

# Nutritional Value of Dry Fish in Bangladesh and Its Potential Contribution to Addressing Malnutrition: A Narrative Review

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**Abstract:** Understanding the linkage between the nutrient composition of foods and individuals' recommended nutrient intake is important to address malnutrition. Despite it being a traditional and popular food item in Bangladesh, the nutrient composition of dry fish has not been reviewed yet. This study used a narrative review to assess the nutrient composition of dry fish and estimated its potential contribution to addressing some common nutritional deficiencies among children and pregnant and lactating women in Bangladesh. Records were collected from different databases, including the Web of Science, Google Scholar, PubMed, ScienceDirect, Banglajol, and ResearchGate. Data were extracted from 48 articles containing 1128 entries regarding nutrient composition. Most of the nutrient analyses estimated the proximate composition, whereas vitamin, mineral, amino acid, and fatty acid compositions were scarce in the literature. We found that dry fish has high protein and mineral content and could contribute highly to meeting the recommended nutrient intake of protein, iron, zinc, and calcium for children and pregnant and lactating women. The summarized nutrient composition data could be useful for further research to observe how dry fish could be best utilized to address malnutrition in Bangladesh. This narrative review recommends that further nutrient analysis, with emphasis on vitamin, mineral, and fatty acid compositions.

**Keywords:** Bangladesh; children; dry fish; malnutrition; minerals; nutrients; protein; vitamins; women

## 1. Introduction

Bangladesh is a riverine country, blessed with vast fishery resources, inland as well as marine [1]. From the viewpoint of the natural gift of aquatic resources, the aquatic food system plays a vital role in the food culture, eating habits, and lifestyle of the people. Fresh fish has versatile nourishing properties, which include highly bioavailable protein, essential fatty acids, macro- and micro-minerals, and vitamins; therefore, it undergoes rapid microbial spoilage [2]. Thus, various preservation techniques such as drying, salting, chilling, freezing, and smoking are used to prevent microbial spoilage and keep up the nutrient quality with a view to storing throughout the year [3,4]. Among these techniques, drying is the most traditionally used method of fish processing and preservation in developing countries, including Bangladesh [5,6]. From nutritive aspects, dry fish consist of high-quality proteins, healthy fatty acids, including long-chain omega-3 fatty acids such as eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA), and are a unique source of essential nutrients such as iodine, zinc, copper, selenium, and calcium [7]. Generally, dry fish is a delicious and gastronomically nourishing food that provides high protein and low calories compared to other animal protein such as beef. For example, 100 g of dry fish contains approximately 80 g of protein and 300 calories of energy, whereas animal meat contains almost two times more calories but low protein compared to dry fish [7]. Moreover, dry fish is considered a healthy food item for individuals and an entirely natural product that contains almost equivalent omega-3 fatty acid content and antioxidant properties to fresh fish [7]. Dry fish contributes a big share of micronutrients to the diet of the low socioeconomic population groups in South and Southeast Asia [8].

Dry fish (locally known as Shutki) is a popular and traditional food item among Bangladeshi people because of its high nutritional value, good taste, aroma, and distinctive flavor [9]. Moreover, people prefer some fish species, for instance, Bombay duck and ribbon fish, as dried rather than fresh for consumption. Evidence shows that people often find it reasonable to include dry fish in their diet to avoid heart diseases, diabetes, and obesity [7]. Dry fish is of low cost, affordable to low socioeconomic groups, and usually consumed with vegetables, oil, and spices in mixed dishes along with the major staple rice; thus, it helps improve individuals' dietary diversity and nutrition security [1,7].

Nowadays, there are different areas of Bangladesh, including Charfashion in Bhola, Dublar Chor in Khulna, Kutubdia, Khuruskul, Moheskhali, Sonadia, and St. Martin Island in Cox's Bazar, and Alipur, Mohipur, Rangabali, and Kuakata in Patuakhali, where dry fish is commercially produced [1,9]. Here, mainly three categories of fish, including large fish, elongated fish, and small fish, are used for dry fish production [10]. About 20% of the artisanal catch is processed for dry fish production by the sun-drying method [11]. In addition to fresh fish and seafood products, dry fish has created potential market demand in Bangladesh and abroad [12]. In 2018–2019, Bangladesh exported a total of 2339.36 metric tons of dry fish to different countries, including India, Singapore, Hong Kong, Malaysia, the UK, the USA, and the United Arab Emirates, and earned approximately USD 4 million [13].

In Bangladesh, dry fish has market demand all around the year although their availability is somewhat more seasonal, mostly during the winter. Market demand for dry fish is high during spring and early monsoon when the supply of fresh fish from capture fisheries and aquaculture is the lowest [9]. There are regional and cultural differences in dry fish consumption; for instance, the highest consumption occurs in the Chattogram and Sylhet divisions, followed by moderate in the Dhaka division, low in the Barishal and Rajshahi divisions, and rare in the Khulna division [9]. The choice of type of dry fish consumption also varies geographically. For example, people from the Chattogram region consume mainly dried fish of marine origin, while people from Sylhet and Dhaka consume dry fish of both freshwater and marine origin.

In recent decades, Bangladesh has stepped forward to achieve self-sufficiency in food production; however, food and nutrition insecurity and malnutrition remain major public health issues [14]. Moreover, a recent study reported a moderate level of nutrition literacy among Bangladeshi adults [15]. According to Bangladesh Demographic and Health Survey 2014, the prevalence of childhood malnutrition is high (for instance, stunting: 36.1%, wasting: 14.3%, and underweight: 32.6%) [16,17]. Micronutrient deficiencies (such as iron deficiency anemia and zinc and calcium deficiencies) are still highly prevalent among children and women of reproductive age [17]. Therefore, the choice of a diet with high nutritional value is important to prevent the malnutrition burden. In this aspect, the inclusion of dry fish in the diet could be a consideration for improving dietary diversity and nutrient supply to the body.

Although drying causes some changes in fish flesh, it is still an excellent source of essential nutrients [7]. However, the use of spoiled raw fish, insecticides, and pesticides, poor hygiene and sanitation during preparation, the traditional way of processing, and long-term traditional storage conditions may lead to the nutrient loss and quality deterioration of dry fish [18–20]. A previous investigation conducted in the Chattogram region of Bangladesh identified that the nutritional value of dry fish undergoes deterioration with high storage time [18]. Another study in Bangladesh reported that deteriorative changes in dried fishes may result in browning reactions and develop rancidity when the moisture content is comparatively high [21]. Therefore, sufficient precautionary measures such as using fresh raw fish, proper drying, maintaining personal hygiene and sanitation, and proper storage and packaging must be taken into consideration during dry fish production.

There is a lack of scientific documentation and quantitative information on the nutrient composition of dry fish prepared from fish species captured on the coast of Bangladesh. The "Food Composition Table for Bangladesh" prepared by the Institute of Nutrition and Food Science (INFS), University of Dhaka, Bangladesh, contains 381 food items but only four dry fish items [22]. Exploration of food composition data is essential for providing basic information on various aspects of nutrition, understanding dietary choices, and developing basic tools to improve food and nutrition security [23]. Therefore, the purpose of our study was to perform a narrative review on the nutrient composition of dry fish in Bangladesh, summarize quantitative data on the nutrient composition of dry fish, and observe their potential contribution to meeting the recommended nutrient intake (RNI) of some nutrients with high public health importance for children and pregnant and lactating women in Bangladesh.

## 2. Materials and Methods

### *2.1. Data Sources and Search Strategy*

To obtain the nutrient composition of dry fish prepared from fish species captured in Bangladesh, we conducted a narrative review with a literature search in the following databases: Web of Science, PubMed, Google Scholar, ScienceDirect, Banglajol (Bangladesh-based database), and ResearchGate. The following search strategy was used to collect records from the Web of Science and PubMed:

("Dried fish" OR "dry fish" OR fish) AND (Nutrient OR Composition OR "Nutrient composition" OR Vitamin OR Mineral OR Quality OR "Proximate composition" OR "Nutrient analysis") AND (Bangladesh)

Keywords, including "dry fish", "dried fish", nutrient composition, and Bangladesh, were used to conduct a manual record search in the databases of Google Scholar, ScienceDirect, Banglajol, and ResearchGate. No filter was applied while searching the Web of Science and PubMed. Database searching was conducted from June 2021 to December 2021. All citations were imported into Mendeley software and checked for duplication. Then, screening was conducted to identify eligible records.

### *2.2. Inclusion and Exclusion Criteria*

Initially, titles and abstracts were screened using a checklist. The checklist consisted of three questions: (i) Is the article original research? (ii) Does the article contain the nutrient composition of dry fish? (iii) Does the article consider dry fish produced from fishes available in Bangladesh? Articles that qualified for initial screening were screened for full text. The full-text screening was conducted considering several criteria, including the number of fish species analyzed, name of the species, place of sample collection, number and types of nutrients considered for analysis, methods for nutrient analysis, and statistical representation of the data. In addition, the following inclusion criteria were followed: (1) publication date: no time restriction was applied, (2) language: no language restriction was applied, (3) laboratory methods: no article was excluded due to the study design or the laboratory methods used for nutrient analysis, and (4) sample type: only articles with dry fish nutrient composition data were considered. We excluded records if irrelevant to the research question, and not peer reviewed. Finally, articles that met the inclusion criteria were considered for data extraction and analysis.

*2.3. Selection Process*

Four researchers independently conducted the literature search and screened titles and abstracts. They also conducted full-text screening according to the screening strategy. Another reviewer assessed the variance of the number of records at each stage of the selection process. To minimize the bias, any discord in the selection process, such as database searching and inclusion and exclusion of the articles, was settled through a discussion among all the researchers. At first, the literature search was performed in different databases and sites. Then, all the records were imported into Mendeley software for duplication checking. After excluding the duplicates, an initial screening was conducted using the checklist. Articles that qualified for initial screening were then screened for full text. Finally, articles that qualified for the screening process and inclusion criteria were considered for data extraction.

*2.4. Data Extraction*

Four reviewers independently conducted data extraction from the selected articles. Data were extracted in a Microsoft Excel spreadsheet and included the name of the species (local, common, and scientific names) and nutrient composition per 100 g of edible dry fish. Some articles presented nutrient composition per 1 kg of weight or in other units, such as ppm or percentage. In these cases, we converted the unit into per 100 g of edible dry fish. In the original articles, nutrient compositions were often represented in values with standard deviation, as several samples were analyzed. However, we did not consider standard deviation during data extraction and synthesis. Some common and commercially important dry fishes were analyzed by different researchers, but we considered all the findings and included them in the data extraction spreadsheet. This means that several entries were considered for a single dry fish if reported in different articles. Fatty acid and lipid profiles showed a wide range of variation in results: individual fatty acid content, total saturated fatty acid (SFA), monounsaturated fatty acid (MUFA), polyunsaturated fatty acid (PUFA), EPA, DHA, total cholesterol, etc. We considered total SFA, MUFA, PUFA, EPA, DHA, and cholesterol. In the data extraction spreadsheet, we kept the cells blank for the following: missing value, no result, trace, not detected, and unreported information (such as English name and local name of the species). The data extraction spreadsheet is provided as Supplementary Material.

*2.5. Assessment of Potential Contribution of Dry Fish to Addressing Malnutrition*

We focused on four nutrients based on the availability of nutrient composition data and the nutritional importance of nutrients in the Bangladesh context, including protein, zinc, iron, and calcium. Protein was considered because of low protein consumption among children in Bangladesh. Micronutrients such as zinc, iron, and calcium were considered based on data showing both national and global deficiencies [24,25]. For each of the four nutrients, we presented a calculation where we compared the nutrient content of a given uncooked dry fish item to the daily RNI for women and children at different life stages. These calculations highlighted the relative variation in the nutrient composition and density (nutrient content per unit of dry fish) among the dry fish items. For every calculation, we considered five dry fish species or items that have the highest nutrient content according to the data extraction and synthesis. We also used two reference fish for comparison: Tilapia (*Oreochromis niloticus*) and Thai pangas (*Pangasianodon hypophthalmus*). Tilapia and Thai pangas were selected because they are the most commonly consumed fish, with the highest market accessibility in Bangladesh. Nutritional values fluctuate during processing and cooking, and other dietary factors influence the absorption of particular nutrients. As a result, these calculations are not meant to provide any individual dietary advice. Rather, they help provide an estimate of how certain dry fish contributes nutrients to the diet. The percentage of what a serving of fish covers for the RNI was calculated for pregnant women, lactating women, infants 6–12 months old, and children 1–2 years old [26].

While calculating how one serving of dry fish could meet the RNI of certain nutrients for pregnant and lactating women and children, we considered a daily serving of 50 g for pregnant and lactating women and 25 g for children based on a previously used method [27,28]. We assumed 10% bioavailability for iron [26]. The RNI for iron for pregnant women was estimated based on the FAO/WHO (2004) [26] value for women aged 19–50 years old, as no specific value for pregnant women is given. The daily value of 29.4 mg closely aligns with the Institute of Medicine's recommendation of 27 mg and the Indian Council of Medical Research's (ICMR) recommendation of 35 mg for pregnant women [29,30]. The RNI for protein for children 12–23 months old and pregnant and lactating mothers was directly received from the ICMR (2011) [29]; however, the ICMR does not directly mention the RNI for protein for infants 6–12 months old. Because of this, we considered the median body weight of boys and girls at 9 months of age, which is the average and median value between 6 and 12 months, and then calculated the average standard body weight [31]. The standard body weight was then multiplied by 1.69 to obtain the recommended daily protein intake [29]. For zinc, moderate bioavailability was assumed [26]. We calculated the daily zinc requirement by averaging the requirement across the three trimesters of pregnancy and the first 12 months of lactation, using a value of 7.5 mg for pregnancy and 8.5 mg for lactation. For the calcium requirements of the target populations, the FAO/WHO (2004) recommendation was followed [26]. The calculation showing how one serving of dry fish could meet the RNI of the target group is provided as Supplementary Material.

## 3. Results

Our search yielded 2139 articles. After screening titles and abstracts, 1939 records were excluded. After a full-text screening of the 198 records, we finally included 48 articles that had a nutrient composition of 1128 entries on dry fish from Bangladesh (Figure 1). Characteristics of the included studies [18,21,22,32–76] such as the number of samples analyzed, sample collection location, etc., are summarized in Table S1 (Supplementary Material).

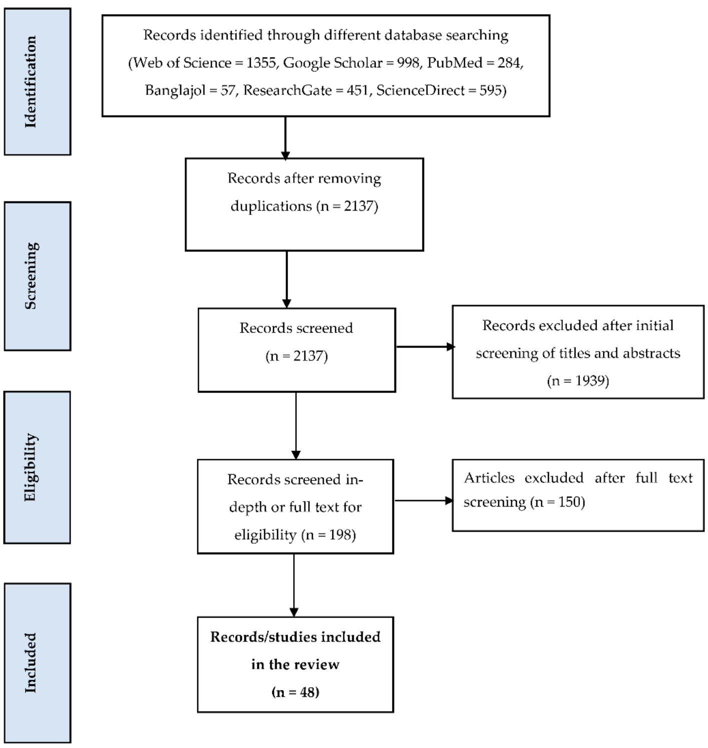


**Figure 1.** Selection process of the records.

### 3.1. Proximate Composition of Dry Fish Prepared from Fish Species Captured in Bangladesh

Of the total 1128 entries, 702 (62.23%) had the proximate composition of dry fish. Total protein content was determined in 14.54% ($n$ = 164) of entries, and it was found that the average protein content was 56.63 g per 100 g of dry fish with the highest (77.68 g) in Churi (*Trichiurus savala*) and the lowest (26.73 g) in Ilish (*Tenualosa ilisha*). Total fat and ash content were analyzed in 15.70% ($n$ = 177) and 15.25% ($n$ = 172) of entries, respectively, and showed that Rupchanda (*Pampus chinensis*) and Tengra (*Mystus tengra*) contained the highest amount of fat and ash, respectively (Table 1).

Protein deficiency malnutrition is still prevalent among nutritionally vulnerable population groups such as children and pregnant and lactating women in Bangladesh. Being a good source of high-quality animal protein, dry fish can contribute to meeting individuals' daily protein requirements. For example, a serving of Ribbon fish (Churi) could fulfill 49.79% and 54.70% of daily recommended protein intake for pregnant and lactating mothers, respectively, and provides 100% of the recommended protein intake for children up to two years old. The potential contribution of dry fish to individuals' recommended protein intake is higher than that of fresh Thai pangas and Tilapia in Bangladesh (Figure 2).

**Table 1.** Analyzed nutrients, average nutrient content, and name of dry fish species with the highest and the lowest nutrient content.

| **Nutrients (Unit)** | **Number of Entries or Results *** | **Nutrient Content per 100 g of Dry Fish **** | | | **Species with the Highest Value: Local Name (Scientific Name)** | **Species with the Lowest Value: Local Name (Scientific Name)** | **Reference(s) (Highest Value, Lowest Value)** |
|---|---|---|---|---|---|---|---|
| | | **Average Value** | **Highest Value** | **Lowest Value** | | | |
| **Proximate composition** | | | | | | | |
| Energy (KJ) | 9 | 362.67 | 412 | 318 | Chela (*Salmostoma acinaces*) | Vetki (*Lates calcarifer*) | [22] |
| Moisture (g) | 180 | 21.60 | 43.03 | 4.70 | Rupchanda (*Stromateus chinensis*) | Chela (*Salmostoma acinaces*) | [22,37] |
| Protein (g) | 164 | 56.63 | 77.68 | 26.73 | Churi (*Trichiurus savala*) | Ilish (*Tenualosa ilisha*) | [39,61] |
| Fat (g) | 177 | 9.73 | 27.74 | 0.47 | Rupchanda (*Pampus chinensis*) | Datina koral (*Lates calcarifer*) | [57,61] |
| Ash (g) | 172 | 14.29 | 36.20 | 0.16 | Tengra (*Mystus tengra*) | Chingri (*Macrobrachium dayanum*) | [41,58] |
| **Minerals** | | | | | | | |
| Iron (mg) | 50 | 13.15 | 45.10 | 2.80 | Olua (*Coilia neglecta*) | Shol (*Channa striata*) | [40,73] |
| Zinc (mg) | 38 | 4.31 | 19.30 | 0.23 | Tengra (*Mystus tengra*) | Vetki (*Lates calcarifer*) | [22,65] |
| Calcium (mg) | 44 | 954.61 | 3590 | 33.70 | Chela (*Salmostoma acinaces*) | Rita (*Rit rita*) | [22,73] |

**Table 1.** *Cont.*

| Nutrients (Unit) | Number of Entries or Results * | Nutrient Content per 100 g of Dry Fish ** | | | Species with the Highest Value: Local Name (Scientific Name) | Species with the Lowest Value: Local Name (Scientific Name) | Reference(s) (Highest Value, Lowest Value) |
|---|---|---|---|---|---|---|---|
| | | Average Value | Highest Value | Lowest Value | | | |
| Phosphorus (mg) | 23 | 810.08 | 2930 | 73 | Khailsa (*Colisa fasciata*) | Taki (*Channa punctata*) | [32,62] |
| Magnesium (mg) | 21 | 202.14 | 367.10 | 43.69 | Churi (*Trichiurus lepturus*) | Shol (*Channa striata*) | [40,73] |
| Sodium (mg) | 11 | 1133.91 | 3488 | 84 | Pangas (*Pangasius pangasius*) | Vetki (*Lates calcarifer*) | [22,73] |
| Potassium (mg) | 21 | 1060.56 | 1720.60 | 271 | Vetki (*Lates calcarifer*) | Vetki (*Lates calcarifer*) | [22,74] |
| Manganese (mg) | 21 | 0.58 | 1.11 | 0.15 | Bata (*Cirrhina reba*) | Maitya (*Scomberomorus guttatum*) | [73,74] |
| Copper (mg) | 39 | 0.26 | 1.11 | 0.02 | Gura Chingri (*Leander styliferus*) | Rupchanda (*Pampus chinensis*) | [61,74] |
| **Vitamins** | | | | | | | |
| Folate (µg) | 2 | 22 | 30 | 14 | Fesha (*Engraulis tellara*) | Vetki (*Lates calcarifer*) | [22] |
| Thiamine (mg) | 2 | 0.16 | 0.19 | 0.13 | Fesha (*Engraulis tellara*) | Vetki (*Lates calcarifer*) | [22] |
| Riboflavin (mg) | 2 | 0.68 | 0.86 | 0.50 | Fesha (*Engraulis tellara*) | Vetki (*Lates calcarifer*) | [22] |
| Vitamin $B_6$ (mg) | 2 | 0.43 | 0.48 | 0.38 | Fesha (*Engraulis tellara*) | Vetki (*Lates calcarifer*) | [22] |
| **Fatty acids** | | | | | | | |
| Lauric acid (g) | 13 | 6.21 | 11.80 | 2.50 | Tuna (*Tunnus albacores*) | Sundori (*Bodianus neilli*) | [57] |
| Myristic acid (g) | 14 | 10.15 | 18.80 | 0.17 | Rangachoi (*Lutjanus indicus*) | Kauwa fish (*Megalaspis cordyla*) | [57,72] |
| Palmitic acid (g) | 14 | 47.15 | 63.56 | 0.96 | Koladia (*Otolithoides pama*) | Kauwa fish (*Megalaspis cordyla*) | [57,72] |
| Palmitoleic acid (g) | 12 | 11.53 | 26.80 | 1.80 | Bol koral (*Lates calcarifer*) | Koladia (*Otolithoides pama*) | [57] |
| Stearic acid (g) | 14 | 7.07 | 16 | 0.64 | Rup chanda (*Pampus chinensis*) | Kauwa fish (*Megalaspis cordyla*) | [57,72] |
| Oleic acid (g) | 13 | 11.35 | 22.80 | 0.51 | Bol koral (*Lates calcarifer*) | Kauwa fish (*Megalaspis cordyla*) | [57,72] |

* Duplication (same species analyzed by several researchers) was considered. ** Values such as range, zero, not detected, missing values, and trace were not considered while calculating the average.

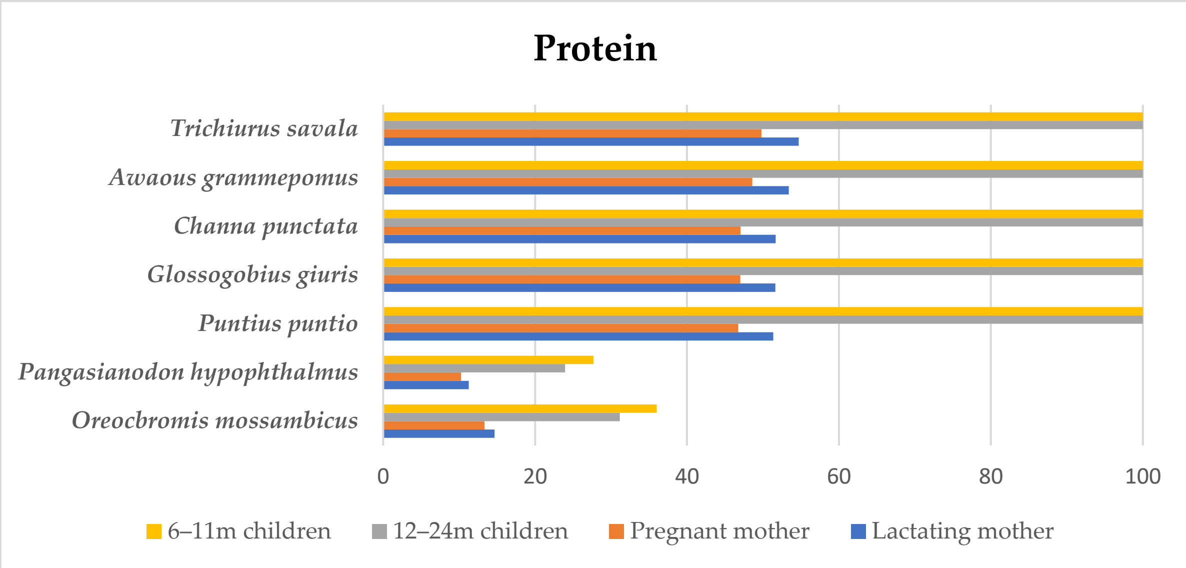


**Figure 2.** Potential contribution (%) of dry fish to the recommended nutrient intake (RNI) of protein for children and pregnant and lactating women in Bangladesh. Local names: Churi (*Trichiurus savala*), Bele (*Awaous grammepomus*), Taki (*Channa punctata*), Bele (*Glossogobius giuris*), Punti (*Puntius puntio*), Thai Pangas (*Pangasianodon hypophthalmus*), and Tilapia (*Oreocbromis mossambicus*).

### *3.2. Minerals*

The content of minerals such as iron, zinc, calcium, phosphorus, magnesium, sodium, potassium, manganese, and copper was assessed in 23.76% (*n* = 268) of entries. The average mineral content with the highest and the lowest values is presented in Table 1.

Iron (Fe) was estimated in 4.43% (*n* = 50) of entries. The average Fe content was 13.15 mg per 100 g of dry fish which ranged from 45.10 mg (*Coilia neglecta*) to 2.80 mg (*Channa striata*) (Table 1). The bioavailability of iron is the extent to which dietary iron is absorbed by the body; therefore, highly bioavailable iron is good for health. Iron from dry fish (i.e, haem iron) has more bioavailability than non-haem iron and can meet iron demands at critical stages of the life cycle. Our analysis shows that a daily serving of Olua, Bata, or Loitta could fulfill 100% of the recommended intake of iron for children up to two years and lactating mothers (Figure 3). For a pregnant woman, a daily serving of Olua, Bata, and Churi meets 76.70%, 68.03%, and 52.72% of her daily iron needs, respectively (Figure 3). According to our data, the potential contribution of dry fish to individuals' recommended iron intake is higher than that of fresh Thai pangas and Tilapia in Bangladesh (Figure 3).

Zinc (Zn) was analyzed in 3.37% (*n* = 38) of entries, and we found that the average zinc content of dry fish was 4.31 mg (per 100 g of dry fish). The zinc content ranged from 0.23 mg to 19.30 mg per 100 g, and the highest amount was identified in dried Tengra (*Mystus tengra*). In many low- and middle-income countries including Bangladesh, zinc is deficient in diets. Thus, zinc-rich dry fish can contribute to reducing the gap. As demonstrated in Figure 4, a daily serving of dried Tengra provides 100% of the recommended intake of zinc for children aged up to two years and pregnant and lactating mothers. Like other nutrients, dry fish contributes much more to individuals' recommended zinc intake compared to reference fresh fish (Figure 4).

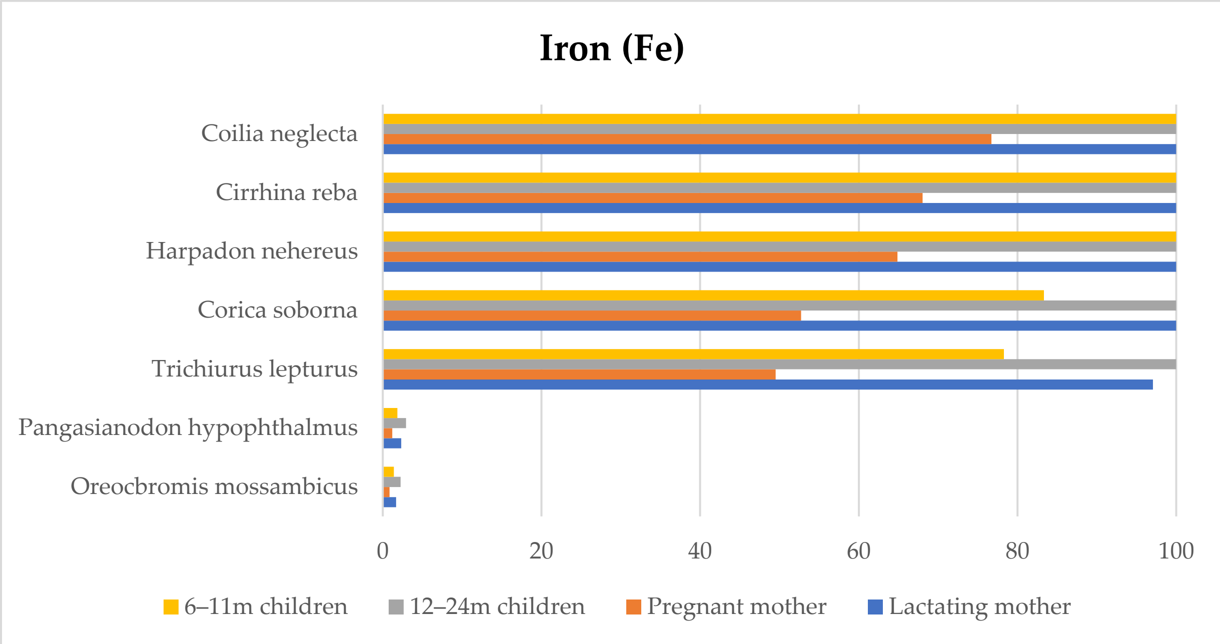


**Figure 3.** Potential contribution (%) of dry fish to the RNI of iron for children and pregnant and lactating women in Bangladesh. Local names: Olua (*Coilia neglecta*), Bata (*Cirrhina reba*), Loitta (*Harpadon nehereus*), Kachki (*Corica soborna*), Churi (*Trichiurus lepturus*), Thai Pangas (*Pangasianodon hypophthalmus*), and Tilapia (*Oreocbromis mossambicus*).

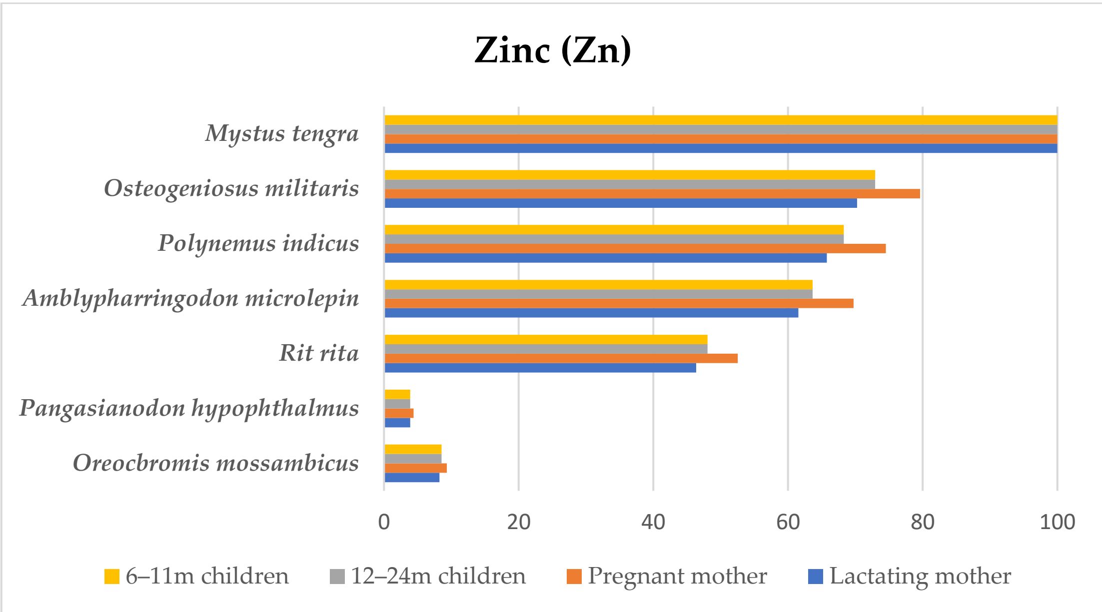


**Figure 4.** Potential contribution (%) of dry fish to the RNI of zinc for children and pregnant and lactating women in Bangladesh. Local names: Tengra (*Mystus tengra*), Kata mach (*Osteogeniosus militaris*), Lakhua (*Polynemus indicus*), Kachki (*Amblypharringodon microlepin*), Rita (*Rit rita*), Thai Pangas (*Pangasianodon hypophthalmus*), and Tilapia (*Oreocbromis mossambicus*).

In 3.90% ($n$ = 44) of the entries, calcium (Ca) content was reported. According to the data analysis, the calcium content of dry fish varied from 3590 mg (dry Chela) to 33.70 mg (dry Rita) per 100 g of dry fish with an average of 954.61 mg. (Table 1). Figure 5 represents how one serving of dry fish could cover the recommended calcium intake of the target population. The calculation shows that one serving of dry fish could significantly meet the calcium requirement for women and children. We found one serving of the respective dry fishes (i.e., Chela, Olua, Bata, Punti, and Khailsa) could meet 100% of the daily dietary calcium requirement of the women and children. Similarly, dry fish are ahead in the case of potential contribution to the recommended intake of calcium compared to the referenced raw fish (Figure 5).

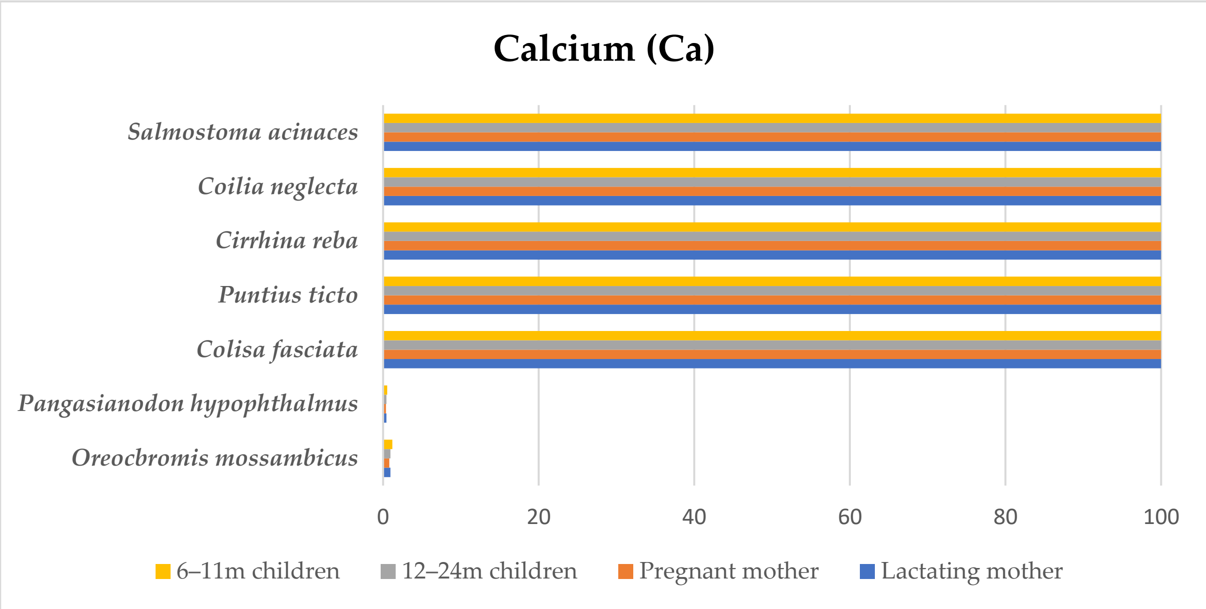


**Figure 5.** Potential contribution (%) of dry fish to the RNI of calcium for lactating and pregnant women and children in Bangladesh. Local names: Chela (*Salmostoma acinaces*), Olua (*Coilia neglecta*), Bata (*Cirrhina reba*), Punti (*Puntius ticto*), Khailsa (*Colisa fasciata*), Thai Pangas (*Pangasianodon hypophthalmus*), and Tilapia (*Oreocbromis mossambicus*).

### *3.3. Vitamins*

Only 0.71% ($n$ = 8) of entries were found to report the vitamin content of the dry fish. Data show that the average folate, thiamine, riboflavin, and vitamin $B_6$ content of the dry fish was 22 µg, 0.16 mg, 0.68 mg, and 0.43 mg per 100 g of dry fish, respectively. Based on the data, vitamin content was found to be higher in dried Fesha (*Engraulis tellara*) compared to other dried fishes. Moreover, a study reported that the vitamin D content of dried Giant sea perch (local name: Vetki) was 4.7 µg [22].

### *3.4. Fatty Acids and Amino Acids*

Major fatty acid and amino acid contents of the dry fish were found in 13.30% ($n$ = 150) of entries. The average fatty acid and amino acid content per 100 g of dry fish with the highest and lowest values is presented in Table 1. According to the data, the three most common fatty acids were palmitic acid, palmitoleic acid, and leic acid with an amount of 47.15 g, 11.53 g, and 11.35 g per 100 g of dry fish, respectively. The highest amount of palmitic acid and palmitoleic acid was found in the Koladia (*Otolithoides pama*) and Bol koral (*Lates calcarifer*) species, respectively (Table 1). Moreover, the PUFA content of dried Kauwa fish (*Megalaspis cordyla)* varied from 26.74% (traditional drying) to 30.45% (solar drying) in which docosahexaenoic acid and eicosapentaenoic acid were prominent [72]. The amino acid content of the dry fish shows that they contain all the essential amino acids, including sulfur-containing amino acids (e.g., methionine) which are lacking in plant protein and lysine which is absent in terrestrial meat proteins. According to the data, the highest amount of essential amino acids was found among three species, namely, Churi (*Lepturacanthus savala*), Coral (*Lates Calcarifer*), and Rupchanda (*Pampus chinensis*) (Table 1).

## 4. Discussion

The analysis of fish consumption data presented by the International Food Policy Research Institute (2006/7) shows that dried fish is one of the most frequently consumed categories of fish in Bangladesh [9]. Although dry fish plays a significant role in the diet and nutrition of the people in Bangladesh, there is a dearth of information about evidence-based documentation of the nutritive aspects of dry fish and its potential contribution to the recommended nutrient intake of vulnerable groups such as children and pregnant and lactating women. This study reviewed and accumulated the available nutrient composition data on dry fish produced in Bangladesh and represents its potential contribution to meeting the nutrient requirement of children and pregnant and lactating women. We found that most of the studies analyzed dry fish for proximate composition (i.e., moisture, protein, fat, and ash) rather than minerals, vitamins, and fatty acids. Our review suggests that future research should focus on the analysis of nutrients including vitamins, minerals, fatty acids, and amino acids. By documenting the available nutrient composition data on dry fish, our review provides a baseline resource for fisheries, nutrition researchers, and policymakers to better understand the need to include dry fish in food-based interventions to reduce malnutrition in Bangladesh.

Our analysis showed that different kinds of dry fish were able to meet the daily recommended intake of protein, iron, zinc, and calcium for children up to 2 years old and pregnant and lactating mothers. Additionally, dry fish contain more nutrients than the considered reference fresh fish (Thai pangas and Tilapia). A recent review, focusing on the global context, on fish nutrient composition conducted by Byrd et al. (2021) [28] also considered the RNI in the study. Generally, the RNI is a more conservative estimate than the estimated average requirement (EAR), which provides a concrete scientific basis for meeting the requirements of nearly all individuals in a group and the adequacy of diets [26].

The nutrient content of a particular fish species could vary from one habitat to another and season to season due to the variation in the amount and quality of food consumed by the fish and also their movement [77–79]. In our review, we found that the nutrient content of dried Loitta was analyzed in twelve studies; however, the crude protein content varied from 32.21 g to 67.21 g (per 100 g of dry fish). This inconsistency in the nutrient content of the same fish species might be due to the drying methods of raw fish (whether sun, solar, or mechanically dried), fish capture season, source of raw fish collection, and quality of the raw fish. Therefore, future comparative studies evaluating the effect of different drying techniques on nutrient composition are recommended to better understand the quantitative differences in the nutrient content of dry fish samples from the same species.

Evidence shows that the nutrient content of the dry fishes mainly varies due to the nutrient composition of their respective raw fishes and geographical differences [80]. According to the extracted data, dry fishes prepared from marine sources were more nutritious considering their proximate composition and fatty acid and amino acid contents. For instance, Churi (*Trichiurus savala*) had comparatively higher protein content, Rupchanda (*Pampus chinensis*) had higher fat content, Tuna (*Tunnus albacores*) had comparatively higher lauric acid content, and Churi (*Lepturacanthus savala*) had comparatively higher essential amino acid content than the other dry fishes. Marine fish species are rich in nutrients such as polyunsaturated fatty acids [81]; therefore, even after drying, they could retain a substantial amount of nutritive properties. A previous study reported no significant effect of drying on the fatty acid profile and composition of the dried cod heads [82]. Bangladeshi dry fish from freshwater sources contains higher protein than the respective freshwater dry fish in Northeast India as investigated by Ullah et al. (2016) [83]. Based on the extracted data, we found that mineral content was higher among small dry fish species, including Olua (*Coilia neglecta*), Tengra (*Mystus tengra*), Chela (*Salmostoma acinaces*), and Khailsa (*Colisa fasciata*), than the large dry fish. Several studies also reported that small fish and their dried products are good sources of minerals [28,84,85].

Sun drying is the most used fish drying technique in Bangladesh. It is a traditional preservation method of fish that is carried out in the open air using sunlight to evaporate the water and the airflow to carry away the vapor [86]. Though sun drying has several advantages, including a simple operation technique and economical convenience, it has some demerits too. The major constraints of traditional fish drying include dependency on weather, a long drying period (2–3 days), and the required hygienic handling of raw materials [86].

### 4.1. Hazards Associated with Dry Fish Production in Bangladesh and Some Recommendations

Dry fish is proven to have a higher nutritional profile that is important for public health. However, the quality of dried fish can be degraded due to various hazards in the production chain. Rasul and his colleagues (2020) [20] summarized the chemical and microbiological hazards of dried fish in Bangladesh. They reported that several dried fishes were contaminated with a high content of heavy metals (for example, Pb, Cd, and Cr) and pesticide residue (dichlorodiphenyltrichloroethane, heptachlor, endrin, aldrin, and dieldrin), and highly pathogenic *E. coli*, *Salmonella* sp., and *Vibrio* sp. were found in a few dried fish samples that may cause serious health hazards after consumption [20]. They also reported that lipid oxidation occurred in some dried fishes from Bangladesh which are responsible for the unpleasant flavors and odors. Sun-based drying affects polyunsaturated lipids and can promote lipid oxidation, which can reduce the nutritive value and functional quality and raise consumer health risks [7]. Two recent Bangladeshi studies conducted by Hoque et al. (2021) [87] and Rakib et al. (2021) [88] reported that heavy metals pose moderate-to-high health risks to the dry fish consumer. There are several factors associated with these health hazards which include traditional drying techniques, the use of harmful pesticides, anthropogenic contamination, atmospheric deposition, the lack of maintaining proper hygiene and sanitation, improper packaging and storage, and water pollution [20,88]. To minimize and prevent these hazards of dry fish production in Bangladesh, some recommendations include: (i) developing improved and cost-effective methods of fish drying [89], (ii) designing effective packaging and storage facilities, (iii) ensuring heavy metal decontamination strategies, (iv) organizing public health awareness programs for dry fish producers regarding basic hygiene and sanitation practices, the adverse effect of chemical contaminants in dry fish, and the importance of the quality of the raw materials used, and (v) providing training on safe dry fish production and waste management to dry fish producers.

The use of harmful chemicals in dry fish production is a special concern. In Bangladesh, dry fish producers usually use harmful chemicals (such as a mixture of organochlorine) to protect dry fish from insect infestation and to increase shelf life [19] without considering their deleterious impacts on human health. A study found the presence of harmful chemicals such as DDT and heptachlor in some dry fish samples in Bangladesh [90]. These pesticides are used to protect fish from insect infestation; however, they are associated with serious health problems, including cancer and non-allergic reactions, and environmental hazards [71]. Considering the situation, the following recommendations can be highlighted to prevent the use of harmful chemicals or insecticides during dry fish production: (i) Ensuring strict implementation of laws and policies related to harmful pesticide use. In many countries, including Sweden, Japan, and the USA, organochlorine chemicals have been banned due to their potential harm to human health. Therefore, the government of Bangladesh may strictly implement the updated pesticide legislation and policies for fishery products. (ii) Developing and implementing safe insect control strategies instead of using harmful insecticides. For instance, red pepper and turmeric (separately or mixed) have insect- and bacteria-repealing characteristics and thus can be used in fish drying. Evidence shows that the pretreatment of fish with 10–12% salt for 10–12 h can reduce infestation [91]. (iii) Sensitizing dry fish producers to the harmful impacts of pesticides on human health and the food system. (iv) Taking initiatives to prevent environmental pollution so that heavy metals and harmful chemicals cannot enter the aquatic ecosystem.

### 4.2. Implications for Practice

The findings of our study (i.e., up-to-date data on the nutrient composition of dried fish) can be useful to policymakers, public health practitioners, and nutrition experts for developing nutrition-based programs and interventions to improve the country's food and nutrition security. Such programs and interventions could encompass formulating dietary guidelines, updating the food composition table, promoting dry fish production and consumption, and formulating nutrition-education-related materials.

Again, an area that requires further exploration is assessing the shelf lives of dried fish during storage over a period of time to explore possible nutritional changes that may occur when dried fish is under storage. Assessing the impact of consuming dried fishes on growth and nutritional status among vulnerable populations is another key research area that has to be further explored.

Inclusion of nutritious food items in the diet is important for health and survival. Globally, the recent coronavirus (COVID-19) pandemic has imposed a new set of challenges on humans to maintain a diversified and healthy diet [92–94]. Energy, protein, and micronutrient (especially vitamin A, B complex, C, and D, zinc, iron, and selenium) deficiencies are associated with impaired immune function and an increased risk of infection and mortality among vulnerable populations as well as COVID-19 patients [94,95]. Evidence shows that zinc, magnesium, and vitamin C have a potential role in reducing the severity of the infection and inflammatory response associated with severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), while folate and vitamin D may have a role in antagonizing the entry of virus in host cells [96,97]. Zinc has the potential to reduce viral replication and increase immune responses as well as act as a prophylactic which might provide an additional shield against the initiation and progression of COVID-19 [98]. Since dry fish contain high nutritional properties, including protein and minerals (Fe, Zn, and Ca), the inclusion of dry fish in the diet could be a consideration especially for at-risk groups during this COVID-19 pandemic [99]. For instance, in Myanmar, the use of dry small fish powder provides an opportunity for accessible and acceptable forms of micronutrients required to improve the health status of young children during this pandemic [100]. The example from the Myanmar study [100] suggests the potential fortification of staple cereal and grain-based complementary foods with dried fish powder that can improve the nutrient quality of foods that are used to feed young children in most developing countries. A similar concept could also be replicated for Bangladesh. Dry fish of high nutritional quality could be considered for powder preparation and be used to improve the nutritional quality of complementary food for young children. Bangladesh is a disaster-prone country. As dry fish could be stored for a longer period of time, it could be included in the ration after any disaster, including floods and cyclones.

## 5. Conclusions

According to available information, dry fish possess high amounts of nutritional properties, especially protein, zinc, iron, and calcium. In particular, dry fish from marine sources and small fish species are high in protein, fatty acids, amino acids, and minerals. Dry fish significantly contributed to the recommended intake of protein, iron, zinc, and calcium for children up to two years and pregnant and lactating mothers. It is imperative that policymakers along with food and nutrition experts focus on promoting the nutritional value of dried fish and encouraging particularly vulnerable populations (children and pregnant and lactating women) to include dry fish in their diet. Further research in this area may emphasize analyzing vitamin and mineral composition rather than proximate analysis. Further research may highlight and analyze the essential fatty acid composition (omega-3, -6, and -9) of different species of fishes and its impact on improving the cognitive development and functioning/performance of children and the elderly, respectively.

**Supplementary Materials:** The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/fishes7050240/s1, Table S1: Characteristics of included studies (N = 48), data extraction file, and calculation of RNI.

**Author Contributions:** M.H.A.B.: conceptualization, study design, literature search and screening of articles, writing—original draft (Abstract, Introduction, Results interpretation, Discussion, and Conclusion) and editing. A.A.Z.: literature search and screening of articles, data management and analysis. N.R.: literature search and screening of articles, data curation. M.A.M.S.: literature search and screening of articles. M.A.B.S., J.E.H.J., C.N.A.N.-A., A.-A.S., B.O.A. and M.S.I.K.: visualization, validation, writing—reviewing and editing. M.A.R.: conceptualization and supervision, study design, visualization, validation, writing—original draft (Materials and Methods), critical review for intellectual content, editing. All authors have read and agreed to the published version of the manuscript.

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