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Sun-Dried Fish: Bridging Food Science and Cultural Significance of Traditional Knowledge

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ABSTRACT

Nutritionally significant fish species undergo different post-harvest changes that render fish unfit for consumption. A traditional method used to preserve fish for extended periods is sun-drying. For millennia, sun-dried fish have been used as a staple food and are believed to offer therapeutic benefits in many civilizations across the globe. Ethnomedicine, which encompasses traditional healing practices based on indigenous knowledge, often incorporates sun-dried fish into remedies for various ailments. The present study aimed to subject the role of sun-dried fish *Puntius sophore*as an important zootherapy by emphasizing a comparative account of the nutritional profile of the species in both fresh and sun-dried conditions. In the present study, moisture content was found to be significantly higher (P<0.05) in the fresh fish samples, while the crude protein, crude fat, ash, and carbohydrate were found to be significantly higher (P<0.05) in the sun-dried samples. The predominant essential amino acids (EAA) in fresh and sun-dried samples of *P. sophore* were lysine and histidine, respectively. However, the non-essential amino acid (NEAA) found was glutamic acid in both fresh and sun-dried samples. Significant changes were observed in the amino acid content of the fish species in the two conditions. In the sun-dried condition of *P. sophore*, a significant increase (P<0.05) was detected in vitamin D content, sodium, potassium, iron, and zinc, aligned with a significant decrease in vitamins A, E, K, calcium, and magnesium. The present generation's attitude toward traditional medicine as being unscientific and acculturation are indeed significant factors contributing to the decline of such practices. Hence, the purpose of this study was to demonstrate the nutritional value of sun-dried fish species as a supplemental food source in the global fight against nutritional deficiencies worldwide and highlighting its implications in the field of ethnomedicine.

INTRODUCTION

Fish serve as an important source of animal protein in the routine diet of about one billion people in developing countries **(Mohanty, 2010)**. It is also a significant source of micro-nutrients in addition to amino acids and polyunsaturated fatty acids (PUFAs). India is considered one of the 17 mega diverse countries of the world and harbors about 2,246 indigenous finfish species, of which, 765 are from freshwater and out of these 450 species are categorized as small indigenous fishes (SIFs) **(Lakra, 2010; Mohanty, 2010; Joshi, 2019)**. SIFs are important sources of both macro and

micronutrients and are considered particularly important for nutrition because they are eaten as a whole with bones, head and eyes **(Kongsbak *et al.*, 2008)**. In relation to their affordability to the Indian major carps, they are also regarded as affordable source of animal protein.

Assam, the second-biggest state in northeast India, is home to several “beels”, wetlands, and significant river systems, all of which contribute to the region's huge inventory of ichthyofaunal diversity. Following the retreat of periodical floods and also during ‘Jeng fishing’, which is a community fishing method practiced in Assam, abundant quantity of fish with varied sizes are widely captured and sold at a lower price. However, a lion’s share of the fish collected is preserved by various methods amongst which sun-drying is one of the oldest and commonest methods **(Paul *et al.*, 2018)**. Sun-drying method basically implies the removal of water from fish flesh through evaporation with the effect of the sun and wind which imparts a characteristic color, texture, and flavor to the fish products **(Nowsad, 2005)**. Studies suggest that sun-dried fish are rich in protein such that protein level in sun-dried fishes are nearly twice as high as those in fresh fish, if not in quality but quantity **(Rasul *et al.*, 2021)**.

An essential method for comprehending the knowledge that communities have about the living and non-living things in their environment is ethno-science **(Ramires *et al.*, 2015)**. The study of ethno-ichthyology has gained importance across the globe, as it attempts to comprehend how fish are used and what they symbolize to various ethnic groups and local communities **(Da Silva *et al.*, 2021)**. In addition to being a means of healing, traditional medicine plays a significant role in the people's religion and culture. In terms of contemporary medicine, it is said that over half of all medications on the market today have biological origins, and of the 252 substances recognized by the World Health Organization as vital to human health, 8.7% of them originate from animal sources **(Lohani, 2010)**. The ethnic people of Assam traditionally use different varieties of small indigenous fish species as medicine for curing different kinds of ailments **(Borah & Bordoloi, 2023)**. Sun-dried fish, although considered a delicacy amongst different ethnic communities of Assam, yet most of the people in the urban setting are averse to the idea of consuming sun-dried fish. This is in part because of the characteristic smell the sun-dried fishes impart and relatively due to dearth of information regarding its nutritional significance. Owing to the modern means of living along with the use of modern drugs, the traditional knowledge system is fast eroding due to urbanization. The new generation is reluctant to learn the conventional knowledge leading to an accelerating disappearance of traditional knowledge. Hence, before the ancient cultures are entirely lost, it is imperative to keep track of and systematically document such priceless ethno-biological information among various ethnic groupings.

Although some aspects of nutritional composition of sun-dried *P. sophore* are available, yet complete nutritional profile is very few. Moreover, nutritional composition

of fish species varies with respect to zoo-geography, size, season, etc. The present study is an illustrated account on the traditional implications of sun-dried *P. sophore* in the field of ethnomedicine by generating a comparative account of the nutrient profile of *P. sophore* available in the Brahmaputra River system in both fresh and sun-dried conditions.

MATERIALS AND METHODS

Study area

Guwahati lying on the geographical coordinates of 26° 11' 0" N, 91° 44' 0" E is the capital city of the state of Assam in North-East India. It is located on the south bank of the River Brahmaputra and is a significant a riverine port city.

Sample collection

Fresh fish samples of *Puntius sophore* were collected from different markets of Guwahati City. For further analysis, the samples collected were transported to the laboratory in ice box to restrict microbial growth.

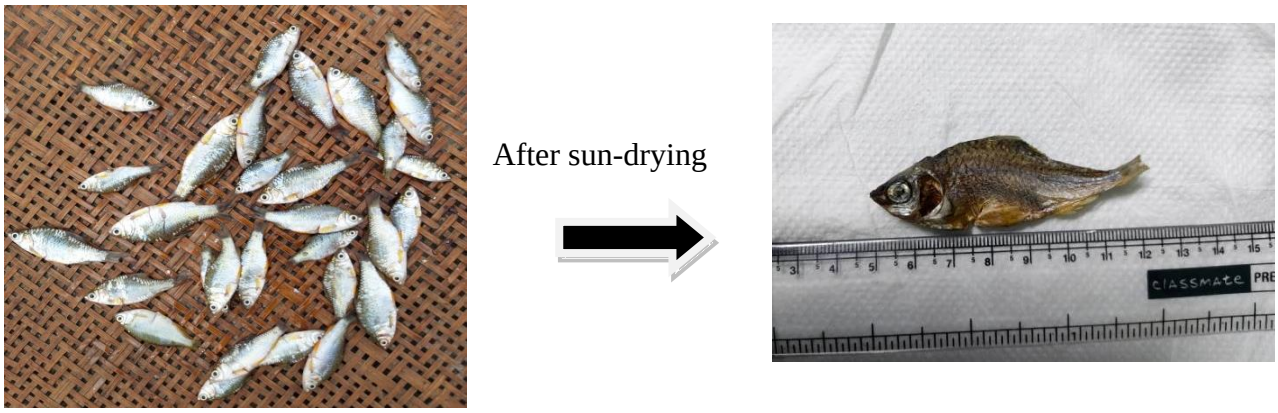
Fig. 1. *Puntius sophore*

Sample preparation

The fresh fish samples collected were washed with clean tap water, and eviscerated; scales and fins were removed and again washed thoroughly under running tap water. The prepared samples were divided into two equal batches. In one batch, all the analysis were carried out under fresh condition. In the corresponding batch, all the tests were carried out in sun-dried condition.

Preparation of sun-dried samples

The sun-dried samples were prepared as per the procedures of **Kalita *et al.* (2020)**. The eviscerated and cleaned samples were laid upon bamboo trays (locally called 'Saloni') and kept under the sun for 10-15 days from morning 9am to evening 4pm until the samples were dried. The average temperature noted was between 25- 30°C.



(a) (b)

Fig. 2. (a) Preparation of sun-dried samples of fish species *Puntius sophore* in bamboo trays (Saloni); **(b)** Sun-dried *P. sophore*

Proximate analysis

Proximate analysis was conducted by using standard methods given in Association of Official Analytical Chemists **(AOAC, 2015)**. All types of analysis were carried out in triplicate. Electronic balance was used for weighing purpose.

Moisture content

The moisture content of the samples was determined by taking a known weight of the sample in a glass petridish of 125cm and drying it in a hot air oven at 100- 105°C till a constant weight was achieved.

The difference in weight of the sample indicated the moisture content, which was calculated by using the following formula:

$$\text{Moisture content (\%)} = \frac{\text{Initial weight} - \text{Final weight}}{\text{Initial weight of sample taken}} \times 100$$

Crude protein content

The protein content of the fish samples were determined by the micro-kjeldahl method. 2g of the sample were digested in a digestion unit for 45 minutes by concentrated H_2SO_4 and a digestion mixture comprising of finely powdered copper sulphate and potassium sulphate (mixed in the ratio 1:8). The digested sample was then distilled in distillation unit. Finally, it was titrated with 0.1 N HCl, and the titration reading value was noted. Crude protein was obtained by multiplying the total nitrogen by a conversion factor of 6.25 (Jone's factor).

$$\text{N (\%)} = \frac{(\text{Titration reading} - \text{blank reading}) \times \text{strength of acid} \times 14 \times 100}{\text{Weight of the sample}} \times 100$$

Crude protein content (%) = N (%) ×6.25.

Crude fat

Fat content was estimated using Soxhlet method. For the estimation of fat content, the dried samples left after moisture determination were finely grinded. About a 2g fish sample was kept in a thimble and placed in extraction apparatus. Extraction thimble was placed in extraction jars, and fat was extracted using non-polar solvent, diethyl ether. The fat % was calculated using standard formula:

$$\text{\% Crude fat} = \frac{\text{Weight of the residue}}{\text{Sample weight}} \times 100$$

Ash

A 4g fish sample was weighed into an empty pre-weighed crucible and kept in a muffle furnace which was then ignited at 550°C till the residue became white. The furnace was turned off to cool, and then the sample was weighed again. The ash content was calculated as follows:

$$\text{\% Ash} = \frac{\text{Weight of crucible plus sample after ashing} - \text{Empty weight of crucible}}{\text{weight of the sample before adding}} \times 100$$

Carbohydrate

The percentage of carbohydrate was determined by subtracting the total percentage of moisture, protein, fat and ash from 100. The following equation was used to estimate the amount of carbohydrate **(De *et al.*, 2019)**, as follows:

Carbohydrate (%) = 100 – (% moisture + % protein + % fat + % ash)

Amino acid analysis

High performance liquid chromatography (HPLC) (method QA.16.5.10/AOAC 19th edition) was employed for the determination of amino acid contents of the fish samples.

Preparation of hydrolyzed amino acid sample

About 100mg of homogenized fish mince was weighed in to a test tube filled with nitrogen and digested at 120ºC for 24hrs in an oven. The contents of the test tube were cooled and filtered using Whatman No 1 filter paper. The filtrate was then evaporated in a vacuum flash evaporator. The contents were made acid free by repeatedly washing with distilled water and subsequent evaporation.

HPLC analysis

20µL of the hydrolyzed sample was injected in HPLC (1260 Infinity) equipped with a C18 reverse phase (RP) column and a fluorescence detector. The amino acids were identified, and their concentrations were calculated using the formula

$$\frac{\text{Area of Spl x Std. Conc. x Vol. x Dil x P}}{\text{Wt of Sample x Area of Std x 1000000}}$$

Mineral analysis

Mineral contents of the fish muscle were assayed using atomic an absorption spectrometry (AAS). About a 4g fish muscle tissue was taken in a conical flask. To the flask, a digestion mixture comprising of 3ml $HClO_4$ + 21ml HNO_3 + 1.5ml H_2SO_4 was added and incubated overnight at room temperature. It was then heated for 2–3 hour until it became colorless, and then filtered with Whatman paper no. 42 making the volume up to 100ml with 2% HNO_3 **(Gokoglu*et al.*, 2004)**. Minerals (Na, K, Ca, Mg, Fe, Zn) were estimated using the atomic absorption spectrophotometer (Varian Spectra-220 AA, Australia). The mineral contents were expressed in mg/100 g of dry weight basis.

Vitamin analysis

The high performance liquid chromatography (HPLC) (Method QA:16.5.3/AOAC 19th edition) was employed for the determination of fat soluble vitamins in the fish samples. Oil extracted from fish meat **(Folch *et al.*, 1957)** was used for the analysis of fat soluble vitamins. About 0.15g of fish oil was refluxed with 25ml methanol and 150% potassium hydroxide (KOH) in water bath for 30min, and then it was extracted with 50ml petroleum ether. The petroleum ether layer was collected, concentrated, and dissolved in 5ml acetonitrile (ACN). About 100µl of the sample was then injected in a HPLC (HPLC 1260 Infinity), equipped with C18 RP column and UV detector. The fat soluble vitamins

were then identified and quantified by comparing retention times and peak area with those of vitamins standards (Sigma-Aldrich).

The concentration of each type of vitamin was calculated using the formula:

$$\frac{\text{Area of Spl x Vol x Dil x Std. Conc. x 100}}{\text{Wt of Sample x Area of Standard}}$$

RESULTS

1. Proximate composition

The moisture, crude protein, crude fat, ash and carbohydrate content of *P. sophore* in fresh condition were 72.01± 0.25, 16.45± 0.19, 3.95± 0.33, 3.79± 0.20, and 3.8± 0.24%, respectively. While in case of sun-dried *P. sophore*, the moisture, crude protein, crude fat, ash and carbohydrate content were 7.09± 0.32, 54.11± 0.22, 9.95± 0.34, 11.34± 0.26, and 17.51± 0.29%, respectively.

2. *Amino acid profile*

The pre-dominant essential amino acids (g/100g) in *P. sophore* in fresh condition were: lysine (3.95± 0.03g/ 100g), followed by histidine (3.19± 0.01g/ 100g), leucine (2.17± 0.02g/ 100g), valine (1.43± 0.03g/ 100g), phenylalanine (1.32± 0.01g/ 100g), methionine (0.91± 0.01g/ 100g), isoleucine (0.41± 0.02g/ 100g), threonine (0.19± 0.02g/ 100g), and tryptophan (0.16± 0.01g/ 100g). While in the sun-dried samples of *P. sophore*, the pre-dominant essential amino acids were: histidine (3.65± 0.02g/ 100g), followed by lysine (2.72± 0.02g/ 100g), valine (1.49± 0.02g/ 100g), leucine (1.45± 0.01g/ 100g), threonine (0.95± 0.02g/ 100g), methionine (0.78± 0.01g/ 100g), tryptophan (0.48± 0.02g/ 100g), phenylalanine (0.41± 0.01g/ 100g), and isoleucine (0.23± 0.01g/ 100g).

Table 1. Proximate composition of fresh and sun-dried *P. sophore*. Values (in % or g/100g) are expressed as Mean ±SD, n=3. T-test was performed and there was a significant difference ($P< 0.05$) between the means of individual proximate parameters in fresh and sun-dried conditions.

Proximate composition	*P. sophore* (Fresh) (g/100g)	*P. sophore* (Sun-dried) (g/100g)
Moisture	72.01±0.25	7.09±0.32
Crude protein	16.45±0.19	54.11±0.22
Crude fat	3.95±0.33	9.95±0.34
Ash	3.79±0.20	11.34±0.26
Carbohydrate	3.8±0.24	17.51±0.29

The pre-dominant non-essential amino acids in *P. sophore* in fresh condition were: glutamic acid (7.31± 0.02g/ 100g), followed by glycine (5.89± 0.01g/ 100g), proline (5.73± 0.01g/ 100g), alanine (4.40± 0.01g/ 100g), glutamine (1.71± 0.02g/ 100g), serine (1.36± 0.02g/ 100g), aspartic acid (1.23± 0.02g/ 100g), arginine (0.69± 0.01g/ 100g), tyrosine (0.61± 0.02g/ 100g), and cysteine (0.39± 0.01g/ 100g). While in the sun-dried samples of *P. sophore*, the pre-dominant non-essential amino acids were: glutamic acid (9.63± 0.03g/ 100g), followed by glycine (4.47± 0.01g/ 100g), proline (4.09± 0.01g/ 100g), alanine (2.67± 0.02g/ 100g), glutamine (2.43± 0.02g/ 100g), arginine (1.33± 0.01g/ 100g), serine (1.16± 0.06g/ 100g), aspartic acid (1.09± 0.02g/ 100g), tyrosine (0.58± 0.01g/ 100g), cysteine (0.21± 0.01g/ 100g).

3. **Fat soluble vitamin content**

The fat soluble vitamins, namely vitamins A, D, E and K, were studied for *P. sophore* in both fresh and sun-dried condition.

Vitamin E was the dominant fat-soluble vitamin followed by vitamin D, vitamin K and vitamin A in *P. sophore* in fresh condition. The values recorded were 1743.45± 0.66µg/ 100g, 393.92± 0.33µg/ 100g, 315.16± 0.58µg/ 100g, and 59.16± 0.70µg/ 100g, respectively, for vitamins E, D, K and A (Table 3).

In the sun-dried condition of *P. sophore*, the predominant fat soluble vitamins were: vitamin E (989.05± 0.75µg/ 100g), followed by vitamin D (513.32± 0.49µg/ 100g), vitamin K (121.53± 0.52µg/ 100g) and vitamin A (26.63± 0.83µg/ 100g) (Table 3).

Table 2. Amino acid content of fresh and sun-dried, *P. sophore*. Values (in g/100g, dry weight) are expressed as Mean ±SD, n=3. T-test was performed and there was a significant difference ($P<0.05$) between the means of individual AAs in fresh and sun-dried conditions

Essential amino acids	Fresh *P. sophore* (g/100g)	Sun-dried *P. sophore* (g/100g)
Histidine	3.19±0.01	3.65±0.02
Isoleucine	0.41±0.02	0.23±0.01
Leucine	2.17±0.02	1.45±0.01
Lysine	3.95±0.03	2.72±0.02
Methionine	0.91±0.01	0.78±0.01
Phenylalanine	1.32±0.01	0.41±0.01
Threonine	0.19±0.02	0.95±0.02
Tryptophan	0.16±0.01	0.48±0.02
Valine	1.43±0.03	1.49±0.02
Non-essential amino acids		

Alanine	4.40±0.01	2.67±0.02
Arginine	0.69±0.01	1.33±0.01
Aspartic acid	1.23±0.02	1.09±0.02
Asparigine	ND	ND
Cysteine	0.39±0.01	0.21±0.01
Glutamic acid	7.31±0.02	9.63±0.03
Glutamine	1.71±0.02	2.43±0.02
Glycine	5.89±0.01	4.47±0.01
Proline	5.73±0.01	4.09±0.01
Serine	1.36±0.02	1.16±0.06
Tyrosine	0.61±0.02	0.58±0.01

Table 3. Vitamin content of fresh and sun-dried *P. sophore.* Values are expressed as µg/100g, n=3. T-test was performed and there was a significant difference ($P< 0.05$) between the means of individual vitamins in fresh and sun-dried conditions of *P. sophore*

Fat soluble Vitamins	*P. sophore* (Fresh) (µg/100g)	*P. sophore* (Sun-dried) (µg/100g)
Vitamin A	59.16±0.70	26.63±0.83
Vitamin D	393.92±0.33	513.32±0.49
Vitamin E	1743.45±0.66	989.05±0.75
Vitamin K	315.16±0.58	121.53±0.52

4. Mineral content

Macrominerals such as calcium (Ca), sodium (Na), potassium (K), magnesium (Mg) and microminerals such as zinc (Zn), iron (Fe) were estimated for *P. sophore*in both fresh and sun-dried condition.

- Calcium: Among the macrominerals, Ca content was found to be the pre-dominant mineral both in fresh and sun-dried condition. Calcium content values were 3101.25± 0.13mg/ 100g and 1896.05± 0.16mg/ 100g, respectively, for fresh and sun-dried *P. sophore* (Table 4).

- Potassium: Potassium content was found to be 191.47± 0.14mg/ 100g in *P. sophore* (Tables 3, 4). In the sun-dried samples, there was an increase in potassium content, and the value recorded was 207.09± 0.09mg/ 100g in *P. sophore* (Table 4).

- Magnesium: Mg content was 93.78± 0.12mg/ 100g for *P. sophore* in fresh condition (Tables 3, 4). Mg content was decreasing in the sun-dried samples in comparison with the fresh fish samples, and values were recorded at 87.91± 0.08mg/ 100g in *P. sophore* (Table 4).

- Sodium: Na content was 72.61± 0.13mg/ 100g for *P. sophore* in fresh condition. However, there is an increase in Na content in the sun-dried samples, and the values were registered at 89.13± 0.17mg/ 100g in *P. sophore* (Table 4).

- Zinc: Zn content in the fresh fish samples was 3.26± 0.13mg/ 100g in *P. sophore*. However, there was an increase in Zn content in sun-dried condition, and values were recorded at 5.18± 0.15mg/ 100g in *P. sophore* (Table 4).

- Iron: In the fresh fish samples, Fe content was 2.93± 0.09mg/ 100g in *P. sophore*. In the sun-dried condition, increasing values in Fe content were observed. Fe content was recorded at 4.63± 0.10mg/ 100g in sun-dried *P. sophore* (Table 4).

Table 4. Mineral composition of fresh and sun-dried *Puntius sophore*. Values (in mg/100g, dry weight) are expressed as Mean ±SD, n=3. T-test was performed, and there was significant difference ($P<0.05$) between the means of minerals in fresh and sun-dried condition of *P. sophore*

Mineral	*P. sophore* (Fresh) (mg/100g)	*P. sophore* (Sun-dried) (mg/100g)
Calcium (Ca)	3101.25±0.13	1896.05±0.16
Potassium (K)	191.47±0.14	207.09±0.09
Magnesium (Mg)	93.78±0.12	87.91±0.08
Sodium (Na)	72.61±0.13	89.13±0.17
Zinc (Zn)	3.26±0.13	5.18±0.15
Iron (Fe)	2.93±0.09	4.63±0.10

Ethno-medicinal aspects of sun-dried *P. sophore*

The present study examined secondary information gathered from local communities concerning the utilization of sun-dried *P. sophore*, as an ethno-therapeutic remedy for specific diseases (Table 5).

Table 5. Ethnomedicinal applications of different cuisines prepared from sun-dried *P. sophore*

Scientific name	Part used	Mode of preparation	Therapeutic application
Puntius sophore	Whole body in sun-dried condition	Cooked with fern/ lettuce leaves, chilly, black pepper	Physical weakness and malaria
		Cooked with black pepper or chilly	Eye problem
		Cooked with bamboo shoot	Blood purifier
		Sun-dried fish is fermented and then made into a paste and then cooked with rice or vegetables	Gastric ulcer
	Head part in sun-dried condition	Cooked/boiled with vegetables and spices	Night blindness, memory loss

DISCUSSION

Proximate composition

Moisture content: In the present study, the moisture content of *P. sophore* in fresh condition was 72.01± 0.25% which is almost similar to the findings of **Mohanty *et al.* (2014)** and **Jana *et al.* (2018)**, where the moisture content was recorded to be 72.02± 0.25 and 72.65± 0.33%, respectively, for *P. sophore*. However, **Majumdar (2017)** assessed a value of 75.89% for the same species (in fresh condition) which is slightly higher than the value recorded for the present study. The moisture content of sun-dried *P. sophore* in the present study was 7.09± 0.32%, which is within the range mentioned by **Haque (2004)**, who stated that the normally sun-dried fish have an average moisture content of 10-20%. **Nurullah *et al.* (2006)** studied the proximate composition of the sun-dried fish collected from the market and found the moisture content in the range of 23.26 to 26.42%, which is higher than the value recorded in the present study. Noticeably, fish processors and retailers occasionally let dried fish items retain more moisture in order to make them heavier so as to boost their sales profit. Additionally, the dried fish are sold out loose in the markets, and hence there is an uptake of moisture from the environment resulting in an increased moisture content. The present study recorded a similar observation which is in accordance to the findings of **Ullah *et al.* (2016)**, who determined

that the moisture content of the sun-dried fish collected from different markets ranged from 2.772 to 7.818%. The reduction of moisture content in sun-dried *P. sophore* is basically due to the evaporation of moisture from the flesh while drying under the sun.

Crude protein content: In the present study, the crude protein content of *P. sophore* in fresh condition was 16.45± 0.19%. A study by **Mahanty *et al.* (2014)** revealed that the crude protein content of *P. sophore* (in fresh condition) was 16.2± 0.14%, which is almost similar to the findings of the present study. In another study carried out by **Jena *et al.* (2018)**, the crude protein content was found to be 14.44± 0.29%, which is less than the value recorded in the present study. The value of crude protein in the sun-dried *P. sophore* was 54.11± 0.22% in the present study, which is almost similar to the value recorded by **Jahan *et al.* (2017)** (54.31± 3.54%), however higher than the value recorded by **Mansur *et al.* (2021)** (33.07± 1.13%). The process of sun-drying results in a significant increase in crude protein content as compared to that of the fresh fish. Different researches have suggested that this might be due to the retainment of protein nitrogen during drying **(Farid *et al.*, 2016)** or may be caused by the dehydration, which causes the removal of water molecules that are present between protein molecules, which subsequently results in the aggregation of protein **(Kumar *et al.*, 2017)**.

Crude fat content: The crude fat content of fresh *P. sophore* was found to be 3.95±0.33% in the present study. **Mahanty *et al.* (2014)** studied the crude fat content of *P. sophore* in fresh condition (3.55± 0.15%) and the recorded value was almost similar to the present finding. However, in another study done by **Jana *et al.* (2018)**, they found the crude fat content of *P. sophore*as to be 4.19±0.12%, which is higher than the findings of the present study. In the sun-dried condition, the value of crude fat content was 9.95± 0.34% in the present study. **Jahan *et al.* (2017)** recorded the crude fat content as 13.33± 0.23%, which is higher than the present study. However, the crude fat content recorded by **De *et al.* (2019)** in dried *P. sophore* was 8.92 ± 1.98% which is more or less in correspondence with the present study. The increase in the crude fat content in the sun-dried samples could be ascribed to the dehydration resulting in an increase in crude fat amounts per unit weight than in their fresh counterparts. The increase of crude fat content during sun-drying concurs with the findings of **Tenyang *et al.* (2020)**.

Ash content: In the present study, the ash content was recorded at 3.79± 0.20% in fresh *P. sophore,* which is almost similar to the outcomes of **Kashid and Sonawane (2018)**, where the ash content recorded was 3.99± 0.07% in the fresh samples of *P. sophore*. On the other hand, **Bhalerao (2020)** recorded values for the ash content of *P. sophore* with 1.91 and 2.2%, respectively, at Dewas and Ujjain sites of Madhya Pradesh in India, which are lower than the value recorded in the present study. However, the ash content of the sun-dried *P. sophore* was 11.34± 0.26% in the present study. **Majumdar (2017)** and **Mansur *et al.* (2021)** recorded higher values of ash content, with 16.17% and 30.17±

1.22%, respectively, for the sun-dried *P. sophore*. Differences in ash content values among studies might have resulted from the different sun-drying conditions, leading to the deposition of varied organic matter in the sun-dried samples increasing the ash content.

Carbohydrate content: The carbohydrate content of fresh *P. sophore* in the present study was 3.8± 0.24%. **Jana *et al.* (2018)** and **Jena *et al.* (2018)** recorded similar values of carbohydrate content as 4.48± 0.15 and 4.44± 0.61%, respectively. In the present study, carbohydrate content of sun-dried *P. sophore* was 17.51± 0.29%, which is more or less in agreement with the results of **Jahan *et al.* (2017)** and **De *et al.* (2019)**, who recorded values of 19.23± 1.19 and 18.86± 2.08%, respectively.

Amino acid content: In terms of amino acid composition, the present study revealed the presence of both essential and non-essential amino acids in both fresh and sun-dried conditions. In the present study for *P. sophore* in fresh condition, the predominant essential and non-essential amino acids (g/100g) were lysine (3.95± 0.03g/ 100g) and glutamic acid (7.31± 0.02g/ 100g), respectively (Table 2). **Mohanty *et al.* (2014)** recorded the amino acid content of 27 fish species including *P. sophore*, where the predominant essential and non-essential amino acids were histidine (1.4± 0.3g/ 100g) and aspartic acid (1.2± 0.2g/ 100g), respectively. Another study by **Kakati *et al.* (2018)** postulated that the essential and non-essential amino acids of *P. sophore* in fresh condition were lysine (11.5± 1.5g/ 100g) and glutamic acid (21.0± 2.3g/ 100g), respectively, which coincide with the present study's values.

In the present study, the pre-dominant essential and non-essential amino acids in sun-dried samples of *P. sophore* were histidine (3.65± 0.02g/ 100g) and glutamic acid (9.63± 0.03g/ 100g), respectively (Table 2). A study by **Goswami and Manna (2019)** found that the pre-dominant essential and non-essential amino acids in the sun-dried *P. sophore* were leucine (6.1± 0.1g/ 100g) and aspartic acid (9.6± 1.2g/ 100g), respectively. Another study by **De *et al.* (2019)** revealed similar results to the present study where the pre-dominant essential and non-essential amino acids were lysine (3.36± 0.15g/ 100g) and glutamic acid (5.76± 0.13g/ 100g), respectively, in dried *P. sophore.*

In comparison with *P. sophore* in fresh condition, the amino acids namely histidine, threonine, tryptophan, valine, arginine, glutamic acid, glutamine were significantly increased ($P<0.05$) in the sun-dried samples (Table 2). However, some amino acids decreased in the sun-dried samples compared to the fresh samples. Amino acids such as isoleucine, lysine, leucine, methionine, phenylalanine, alanine, aspartic acid, cysteine, glycine, proline, serine, and tyrosine were significantly decreased ($P<0.05$) in the sun-dried fish samples (Table 2). In sun-drying process, heat is responsible for the reduction in the amino acid score for lysine as stated by **Akintola *et al.* (2013)**.

Additionally, based on the data in the study of **Cockerell *et al.* (1971)**, sun-drying resulted in Maillard reaction, in which the free epsilon amino group of lysine is susceptible to heat damage, forming additional compounds with non-protein compounds, resulting in the reduction of lysine content. The decrease in amino acid content in the sun-dried samples might be due to the heating process that causes an excessive denaturation of protein and a destruction of amino acid. However, apart from the increase or decrease in amino acid content in sun-dried fishes, the presence of all essential amino acids, including the sulphur containing amino acids like methionine and cysteine, were recorded, which are lacking in plant proteins **(Atowa *et al.*, 2014)**. Furthemore, methionine and lysine are found in sun-dried fishes **(Tacon & Metian, 2013)**. Different fish processing techniques, such as sun-drying, lead to the formation of different inter- and intra-molecular bonds, which results in the unfolding of protein chains and the exposure of free carboxylic and amino groups, thus altering the content of amino acids **(Boziaris, 2014)**.

Vitamins In the present study, vitamins A, D, E and K contents in fresh *P. sophore* were found to be 59.16± 0.70µg/ 100g, 393.92± 0.33µg/ 100g, 1743.45± 0.66µg/ 100g and 315.16± 0.58µg/ 100g, respectively. Vitamin E was the pre-dominant followed by vitamins D & K. Moreover, **Roos *et al.* (2003)** recorded that the vitamin A content in *P. sophore* is 60RE/ 100g, which agrees with the value found in the present study. **Mahanty *et al.* (2014)** recorded vitamin A (861.38µg/ 100g), vitamin D (406.66µg/ 100g), vitamin E (3068.58µg/ 100g) and vitamin K (884.2µg/ 100g) of fresh *P. sophore*, where the values recorded are significantly different and higher from the findings of the present study. The values of vitamin A (54µg RAE/ 100g), vitamin D (1.29µg/ 100g) and vitamin E (0.15µg/ 100g), as mentioned by **Bogard *et al.* (2015)**, are however lower than the values recorded in the present study.

In the sun-dried condition of *P. sophore*, the predominant fat soluble vitamins were vitamin E (989.05± 0.75µg/ 100g), followed by vitamin D (513.32± 0.49µg/ 100g), vitamin K (121.53± 0.52µg/ 100g), and vitamin A (26.63± 0.83µg/ 100g). Vitamins A, D, K were decreasing in the sun-dried samples, as compared to the fresh samples which are supported by findings of **Roos *et al.* (2002)** and **Abraha *et al.* (2018)**. They stated that vitamins can easily be degraded at high temperatures and in sunlight, especially in the case of vitamin A in the sun-drying small fish. However, an increase was detected in vitamin D in the sun-dried samples, as compared to the fresh condition.

Minerals In the present study for *P. sophore* in fresh condition, Ca (3101.25± 0.13mg/ 100g) was found to be the pre-dominant macro-mineral, followed by K (191.47± 0.14mg/ 100g), Mg (93.78± 0.12mg/ 100g) and Na (72.61± 0.13mg/ 100g). Amongst the micro-mineral, Zn (3.26± 0.13mg/ 100g) and Fe (2.93± 0.09mg/ 100g) were recorded. A study by **Roos *et al.* (2003)** recorded the Ca content as 1042mg/ 100g (dry weight basis) which is significantly lower than the present study. Another study by **Zaman *et al.***

(2014) recorded the Ca, K, Na, Mg, Zn and Fe of fresh *P. sophore* on raw weight basis as 1984.32± 1.1mg/ 100g, 224.79± 3.4mg/ 100g, 328.20± 2.01mg/ 100g, 148.16± 0.62mg/ 100g, 27.06± 0.04mg/ 100g, 10.31± 0.2mg/ 100g, respectively. Ca content (2792± 0.27mg/ 100g on dry weight basis) estimated in a study by **Hossain *et al.* (2024**) was almost similar to the present study.

As recorded in the present study, similar to the fresh fish samples, in the sun-dried samples of *P. sophore,* Ca (1896.05± 0.16mg/ 100g) was the pre-dominant macro-mineral, followed by K (207.09± 0.09mg/ 100g), Na (89.13± 0.17mg/ 100g), Mg (87.91± 0.08mg/ 100g), Zn (5.18± 0.15mg/ 100g) and Fe (4.63± 0.10mg/ 100g). **Ullah *et al.* (2016)** reported the presence of minerals such as Fe, Ca, K, C, S, P, Si, Al, Mg, Na, and O in ten dried fish samples collected from Northeast India. **De *et al.* (2019)** recorded the macromineral content of dried *P. sophore* in Tripura, India, where the values of K, Mg, Ca, Zn, and Fe were reported to be 652.60± 7.40, 119.25± 2.63, 121.08± 2.52, 11.34± 0.72 and, 32.62± 1.45mg/ 100g, respectively. The present study indicates that in the sun-dried samples, Ca and Mg contents were decreased, while K, Na, Zn, and Fe contents were increased in comparison to the fresh conditions. In general, the high dehydration in which moisture level decreases to the level of 10% or lower is the leading cause for the substantial increase in dry matter or mineral content **(Abrol *et al.*, 2014)**. A reduction in moisture content and an increase in mineral content in the sun-dried fishes is due to the concentration-effect after the drying process.

Ethnomedicinal use of sun-dried *P. sophore*

According to the World Health Organization (WHO), traditional medicine is defined as "the sum total of knowledge, skill and practices based on theories, beliefs and experiences indigenous to different cultures that are used to maintain health as well as to prevent, diagnose, improve or treat physical and mental illnesses." Previous researches document the use of sun-dried fishes as a traditional medicine among the different ethnic tribes of North-eastern region. A maiden report regarding the existence, preparation procedure and use of Hukoti, by different tribal communities of Upper Assam revealed the consumption of Hukoti as a painkiller and also as a local remedy to cure diseases like malaria, among others. **(Sharma *et al.*, 2013)**. **Sarma *et al.* (2014)** studied indigenous technique by Deori community of Upper Assam for the preparation of dry fish and products namely nadubasiyan (dry fish) from fish species such as, *Puntius sophore, Mystus tengra, Trichogaster fasciata, Trichogaster labiosa, Amblypharyngodon mola, Heteropneustes fossilis, Clarius batrachus, Lepidocephalous guntea, Channa punctatus, Channa gachua, Gudusia* sp., *Labeo bata, Macrognathus aral, Macrognathus pancalus,* among others. Use of fern leaves (*Pteridium acquilinum*) during drying and packaging were also used as local painkiller. Sun-dried fingerlings of *Channa punctatus* and *Botia lohachata* were grounded, and the powder obtained was used to dry sore. A paste was

made and put around the sore. The sun-dried filamentous tail of *Sisor rhabdophorus* was grounded to powder, and a part of that powder was applied for the treatment of pneumonia **(Kumar *et al.*, 2015)**. The existence and use of a dry fish product namely Hukoti, with its prevalence and perhaps preference being strong among the Sonowal, Missing, and Deori communities was studied by **Ghosh *et al.* (2022)**. The use of Posa Hukoti (fermented dry fish) by the Moran and Motok communities was also recorded during the survey. Hukoti is made by sun-drying the fish **(Sharma *et al.*, 2013)**, whereas in Posa Hukoti, the fish are allowed to be fermented. During the fermentation process, maggots that develop in the fish are crushed together to make a paste and then dried on heat to increase the nutritional value. A traditional sun-dried and fermented fish product prepared from *P. sophore* along with herbs was also recorded to be used in the treatment of gastric ulcer, plague, improving eyesight **(Chanu *et al.*, 2016; Duarah & Das, 2019)**.

However, these ethnomedicinal practices are only confined to certain communities of the region. Hence, proper documentation and scientific validation are urgently required to behold an insight into varying areas and communities, so as to conserve the traditional knowledge for the benefit of stakeholders and the scientific community in order to structure future community development initiatives.

CONCLUSION

Food security is radical for a healthy human life. However, with the expectations of the global population to reach astounding numbers in the future, food security challenges will intensify, particularly in underdeveloped and developing countries. These regions often suffer from malnutrition, leading to stunted growth and increased susceptibility to various ailments. According to a 2023 report by five UN agencies, approximately 74.1% of Indians—about 1.043 billion people—were unable to access a nutritious diet in 2021, a situation worse than in Nepal, Sri Lanka, and Bangladesh. In this context, small indigenous fish species (SIFs), which are highly nutritious and affordable, offer a promising solution to malnutrition. SIFs are rich in animal protein and provide an easy way to bridge the nutritional gap. Additionally, sun-dried fish, which retain much of the nutritional value of fresh fish, can also play a significant role in combating nutritional deficiencies. However, the potential of dry fish is often overlooked due to misconceptions about its nutritional value, consumption habits, and cooking methods. Research on fish-based ethnomedicine has gained attention, especially in specific tribes, where traditional knowledge is rapidly being lost. Preserving this ethno-zoological knowledge is crucial to avoid losing valuable information on traditional remedies. Therefore, more efforts should be directed toward gathering baseline data on the nutritional advantages of SIFs and sun-dried fish for future studies.

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