Eco. Env. & Cons. 30 (October Suppl. Issue) : 2024; pp. (S274-S287)
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ISSN 0971–765X

DOI No. http://doi.org/10.53550/EEC.2024.v30i06s.041

Exploring pisciculture potentiality in Samdihi OCP: A comparative study on trace elements, potentially toxic metals and basic nutritive components of two edible cultured fish species of Samdihi OCP, Paschim Bardhaman, West Bengal, India

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(Received 23 March, 2024; Accepted 27 May, 2024)

ABSTRACT

Opencast coal mining results into formation of huge pit like void locally called *khadan* which eventually being filled with water serves as a reservoir of aquatic resources. Present study intends to explore the pisciculture potentiality in one abandoned Samdihi opencast coal pit using two economically important edible fish species, *viz*. *Cirrhinus mrigala* (mrigal) and *Oreochromis niloticus* (tilapia). Analysis of trace elements of fish samples were done by using energy-dispersive X-Ray fluorescence spectrometry, dominant potentially toxic metals of water and fish samples were done using atomic absorption spectroscopy, and basic nutritional evaluation through AOAC FAM (2012) and Lowry *et al.* (1951) protocols. The comparative analysis of trace elements, *viz.*, sodium and potassium revealed that the fish from culture pond had slightly elevated concentrations compared to opencast coal pit bred fish and they ranged between 1116.54±1.54 and 3791.01±1.35 mg/kg and 5321.96±1.11 and 6797.96±2.78 mg/kg for sodium and potassium respectively. On the other hand, the comparative values of calcium and chloride revealed similar trends, where the opencast coal pit bred fish had higher concentrations (6658.46±2.03 to 9767.91±1.10 mg/kg for calcium and 3266.55±1.08 to 4238.54±1.71 mg/kg for chloride respectively) than fish from culture pond. Analysis of potentially toxic metals *viz.,* cadmium, arsenic, lead and nickel of fish from opencast coal pit and culture pond revealed values within the standard FSSAI limit, where, cadmium concentration in mrigal and tilapia from opencast coal pit were much lower (0.25±0.02 and 0.24±0.02 mg/kg respectively) than fish from culture pond and similar trends were followed by arsenic, lead and nickel. The comparative study on nutritive components of fish from opencast coal pit and culture pond revealed that the total protein content, total carbohydrate and total fat content were within 77.20±0.25 and 85.82±0.40 mg/g, 1.75±0.02 to 4.14±0.15% and 14.42±0.34 and 18.51±0.42 mg/g respectively, where in most of the cases the opencast coal pit bred fish were found having a little higher values. Results revealed that there is no significant difference in comparing the macronutrients like sodium, calcium, potassium and chloride in fish from opencast coal pit and culture pond. Whereas, average values of potentially toxic metals (cadmium, arsenic, lead and nickel) concentration in opencast coal pit and culture pond were within the safe limits as per FSSAI, as well as lower values of target hazard quotient (THQ<1) predicting no potential risk of metal toxicity for human. Also, both the opencast coal pit and control pond bred fish maintained a good status in respect to protein, carbohydrate and fat content. In terms of estimated daily intake, estimated fish nutritional index, basic nutritional profiling and macronutrients study, the fish cultured in opencast coal pit showed relatively higher values than that of fish from culture pond. Thus, the current investigation features the intense potential of sustainable

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pisciculture in Samdihi abandoned opencast coal pit directing the sustainable development of socio-economy of local community along with environmental resource reclamation.

Key words : *Samdihi Opencast Coal Pit, Fish Nutrition, Potentially toxic metal, Target hazard quotient, Human health risk, Cirrhinus mrigala (Mrigal), Oreochromis niloticus (Tilapia)*

Introduction

Coal mining activity is a significant reason for changing the land-use patterns. In India, opencast coal mining is considered as one of the best and most cost-effective methods of extracting coal. Opencast mining results in a void with huge water resource [opencast coal pit (OCP) or large reservoirs locally called as *khadans*] filled in eventually by surface runoff and groundwater seepage *via* khari and/or jhors. This transformation of pit-lake into fish lakes and/or other methods of aquacultural practices is referred to as one of the most useful cycles of environmental reclamation and generation of a useful asset (Pal *et al*., 2013; Pal *et al*., 2014 and Dey and Ghosh, 2023), which would serve the goals of sustainable development through financial upliftment (Ghosh *et al*., 2005 and Hidayat, 2014). These water bodies can possibly be considered for pisciculture, especially the culture of trout, as well as for other recreational purposes (Viadero and Tierney, 2003; D'Souza *et al*., 2004; Viadero *et al*., 2004; Miller, 2008 and Sriwahyuni, 2022). Endlessly, fish are considered to be a significant part of human food regimen because of high market-based interest for quality and good food, as they have a great deal of protein, important unsaturated fats, nutrients, and fundamental minerals (Elavarasan, 2018 and Mohanty *et al*., 2019). According to the American Heart Affiliation's Nourishment Panel, cardiovascular and vascular infections can be avoided by consumption of fish around two times every week, also consuming fish and fish-based products can provide necessary nutrition for human development (Fernandes *et al*., 2012 and Lichtenstein *et al*., 2021). Present study evaluated the potential sustainable approach towards reclamation of OCP water comparing the nutritive status and metal accumulation in two cultured fish species (*Cirrhinus mrigala* and *Oreochromis niloticus*) from OCP and a culture pond along with human health risk assessment. Evidences of successful culture of Indian Major Carps (IMCs), *Channa punctata*, *Oncorhynchus mykiss* and other commercial fish species in coal pits and/or using mine water established the objective of this study of sustainable pisciculture in OCP (Viadero and Tierney, 2003; Viadero *et al*., 2004; Ghosh *et al*., 2005; Talukdar *et al*., 2017 and Mandal *et al*., 2021) along with great nutritional quality and without human health risk. Several authors (Rumble, 1989; Ochere *et al*., 2004; Ghosh *et al*., 2005) also investigated the potential possibilities of aquaculture in pit-lakes and concluded its significance as a great resource. As a result, mine pits and restored abandoned reservoirs can serve as an ecologically reclaimed productive zone and ultimately, as a source of income, generation of employment and protein food for the communities, fulfilling the number of Sustainable Development Goals, *viz*., SDGs 2, 3, 8, 9, 11, 12, 14, when population explosion is limiting the horizontal resources.

Materials and Methods

Description of study areas

Samdihi opencast coal pit (OCP) (or khadan/dihi/dighi) is situated at Samdihi Colliery (Samdihi Opencast Coal Mine) in Lohat locale of Salanpur mining area of Raniganj Coalfield (RCF) areas of Eastern Coalfields Ltd. restricted under Paschim Bardhaman region of West Bengal inbetween latitudinal and longitudinal expansion of around 23°47'06"N to 23°47'07"N and 86°55'37"E to 86°55'40"E respectively. Reportedly, the mining activity in this colliery was officially concluded in and around the year 2010 and by 2012; finally, it became a completely abandoned OCP with a huge water resource. Approximate total land front of this area is around 114.0 km^2 with an extraordinary populace of around 2.50 lakh individuals as indicated by 2011 census and the closest human habitat is in 0.5 km at Sangramgarh, Samdihi. This OCP is taken by Samdi Shiv Shankar Matshya Baboharkari Gosti from 2015 and fish seeds are usually supplied by the Department of Fisheries, West Bengal through Chandimata Fish Farm, Khano, Purba Bardhaman.

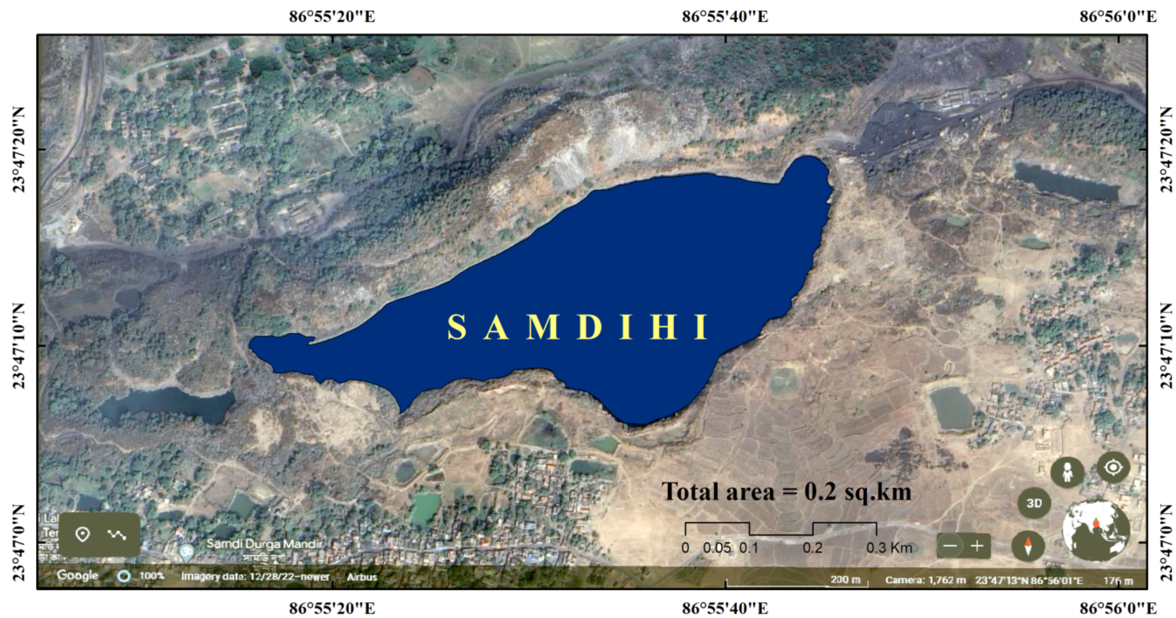

Fig. 1. Map output of Samdihi OCP

Collection of samples

Fingerlings of two edible cultured fish species of *Cirrhinous mrigala* (mrigal) and *Oreochromis niloticus* (tilapia) were collected from Chandimata Fish Farm, Khano and subsequently reared in the Samdihi OCP and simultaneously in one culture pond of Chandimata Fish Farm (control pond). For the study, fingerlings of mrigal of average length and weight 11±0.10 cm and 70±1.00 g respectively and tilapia of average length and weight 9.00±0.15 cm and 50±0.25 g respectively were reared for a period of 12 months maintaining same feed and rearing protocols. After experimentation of 12 months, multiple, matured individuals of both the species were collected from both Samdihi OCP and culture pond. The collected samples were immediately transported to the departmental laboratory in oxygenated water tanks for further investigations.

The average final length and weight of the mrigal of OCP were 34±0.40 cm and 1100±5.00 g respectively; and a culture pond were 28±0.20 cm and 850±4.00 g respectively. The average final length of tilapia collected from OCP and culture pond was 24±0.10 and 19±0.15 cm respectively; and average final weight was 800±2.00 and 550±1.50 g respectively.

Instruments and protocols used

For analysis of trace elements, muscle tissues were primarily lyophilised then the freeze-dried samples were grounded into fine powder by using mortar pestle and sieving them through 20-micron mesh. In order to eliminate any remaining moisture, the final samples were once more lyophilised and analysed by energy-dispersive X-Ray fluorescence spectrometry (EDXRF) for trace elements at the Kolkata Centre of UGC-DAE-CSR facility and potentially toxic metals were evaluated using atomic absorption spectroscopy (AAS).

AOAC FAM (2012) protocols were utilized for the evaluation of fish nutrition. Water content of fish was estimated by taking the initial weight of the fish and afterward oven drying the sample at around 101^{o}C in a hot air oven for 24 h or until complete drying, then, the final weight was noted once again. Ash content of fish were estimated by taking the initial dry weight of the sample and afterward, burning the sample in a muffle furnace at 550^{o}C for about 6 hours the final dry weight of the incinerated leftover was noted. Total protein content was estimated following Lowry *et al.* (1951).

All the evaluated parameters and their values were compared with standards to determine the fish nutritional quality by following Panda (2021).

Estimated Daily Intake (EDI)

Calculation of 'Estimated Daily Intake' (EDI) of metals (Maurya *et al*., 2019; Sekhar *et al*., 2021) was adopted using the formula:

$$\text{EDI } (\mu g/kg/day) = \frac{C \times FIR}{BW}$$

Where, C = Mean metal conc. in fish (µg/g) of dry weight (a transformation factor of 4.8 was utilized to get dry to fresh weight of fish) (Rahman *et al*., 2012; Mandal *et al*., 2021); FIR (food ingestion ratio) = Everyday utilization of freshwater fish (g/day) per capita (normal FIR is 21 g/individual/day)[Dang *et al*. (1996); Giri and Singh(2015)], also, BW = Normal body weight (70 kg for typical adult in Indian mainland) [Guerra *et al*. (2012)].

Target Hazard Quotient (THQ)

Target Hazard Quotient (THQ) is the most sensible and competent index to evaluate the potential expected risks to human well being from the intake of toxic metals, as suggested by the USA Environmental Protection Agency (Maurya *et al*., 2019). In light of this technique, if the THQ is under 1, the exposed populace would display no malicious impacts from eating the defiled fish. THQ can be determined as follows:

$$\text{THQ} = \frac{EDI / RfD}{1000}$$

Where, EDI = Estimated daily metal intake; RfD = Reference dose of that respective metal [the RfD for cadmium, arsenic, lead and nickel are 0.0005, 0.03, 0.0004 and 0.02 mg/kg/day respectively (Elumalai *et al*., 2017; Dayananda and Liyanage, 2021)]; and 1000 = Conditional factor.

Estimated Fish Nutritional Index (EFNI)

The estimated fish nutritional index (EFNI) can be used to estimate the daily nutritional intake of a person. For the present study, the EFNI was calculated using the following formula:

$$\text{EFNI } (mg/kg/day) = \frac{NCspecified \times DIF}{BW}$$

Where, $NC_{Specified}$ = Dry weight (mg/kg) of specified nutrient content (Rahman *et al*., 2012), DIF = Daily intake of fish expressed in g/individual/day and BW= Average Indian body weight. The average value of DIF and BW in India are 2 g/individual/day and 70 kg respectively (Dang *et al*., 1996; Guerra *et al*., 2012; Giri and Singh, 2015).

Statistical analysis

One-way analysis of variance or single factor ANOVA was performed for individual parameters with a sample size of 20 using Statistical Package for the Social Science (SPSS) version 22.0 to ascertain the significance of the data set.

Results and Observations

Trace elements analysis

Trace elements in the form of macro- and/or micronutrients like sodium, calcium, potassium and chloride are the necessary elements for human beings which are responsible for various metabolic functions keeping healthy biological system. Sodium, calcium, potassium and chloride concentrations (Table 1) in muscle tissue of mrigal and tilapia of OCP and culture pond were in good concentration. Concentrations of sodium in mrigal and tilapia of OCP and culture pond were 2158.78±1.61, 3791.01±1.35 and 1116.54±1.54, 2627.64±0.95 mg/kg respectively, where mrigal from culture pond revealed the higher concentration of sodium; the calcium values were 7774.57±0.98, 6658.46±2.03 and 9767.91±1.10, 8155.97±1.81 mg/kg respectively in mrigal and tilapia of OCP and culture pond, where, tilapia from OCP showed the higher concentration of calcium; similarly, potassium concentrations in mrigal and tilapia of OCP and culture pond were 5321.96±1.11, 5758.61±1.67 and 6026.28±1.38, 6797.96±2.78 mg/kg respectively, here, tilapia of culture pond recorded higher concentration of potassium. The chloride concentrations in mrigal and tilapia of OCP and culture pond were 3527.11±1.34, 3266.55±1.08 and 4238.54±1.71. 4161.86±1.50 mg/kg respectively, and tilapia from OCP exhibited the higher concentration of chloride. All the data are significant at 0.01% significance level.

Analysis of potentially toxic metals

Accumulation and subsequent effects of potentially toxic metals (PTMs) in organisms like invasion of many diseases and damage of organ systems and increased risk of fatality are well illustrated by different works. In the present study, the concentrations of different PTMs like cadmium, arsenic, lead and nickel in mrigal and tilapia of OCP and culture pond were well below the Food Safety And Standards (Contaminants, Toxins And Residues) Regulations, 2011 (FSSAI) limit (Table 1). Concentrations of cadmium, arsenic, lead and nickel in mrigal of OCP and culture pond were 0.25±0.02, 0.21±0.09, 0.02±0.02 and 1.34±0.08, and 0.29±0.04, 0.44±0.07, 0.0 3±0.02 and 1.04±0.11 mg/kg respectively; similarly,

Table 1. Analysis of nutritional trace elements, potential toxic metals (PTMs) and basic nutritional quality of fish from OCP and culture pond

Components	Parameters	*Cirrhinous mrigala* (Mrigal)		*Oreochromis niloticus* (Tilapia)		Reference (FSSAI, 2011)
		OCP	Culture	OCP	Culture	
Trace Elements						
	Sodium (mg/kg)	2158.78±1.61**	3791.01±1.35**	1116.54±1.54**	2627.64±0.95**	>900
	Calcium (mg/kg)	7774.57±0.98**	6658.46±2.03**	9767.91±1.10**	8155.97±1.81**	>2300
	Potassium (mg/kg)	5321.96±1.11**	5758.61±1.67**	6026.28±1.38**	6797.96±2.78**	>3700
	Chloride (mg/kg)	3527.11±1.34**	3266.55±1.08**	4238.54±1.71**	4161.86±1.50**	>2500
Potential Toxic Metals (PTMs)	Cadmium (mg/kg)	0.25±0.02**	0.29±0.04**	0.24±0.02**	0.29±0.02**	<0.3
	Arsenic (mg/kg)	0.21±0.09**	0.44±0.07**	0.91±0.02**	0.99±0.08**	<76
	Lead (mg/kg)	0.02±0.02**	0.03±0.02**	0.02±0.01**	0.03±0.02**	<0.3
	Nickel (mg/kg)	1.34±0.08**	1.04±0.11**	0.60±0.08**	0.77±0.28**	<1.5
Nutritional Quality	Moisture content (%)	70.64±0.17**	71.46±0.26**	72.26±0.14**	72.71±0.12**	NA
	Ash content (%)	2.18±0.35**	1.85±0.09**	3.82±0.06**	3.10±0.21**	NA
	Total protein (mg/g)	85.82±0.40**	85.32±0.93**	77.20±0.25**	80.26±0.33**	NA
	Total carbohydrate (%)	1.75±0.02**	2.14±0.01**	4.14±0.15**	3.69±0.05**	NA
	Total fat (mg/g)	18.51±0.42**	17.36±0.42**	14.42±0.34**	15.63±0.08**	NA

Note: Values are expressed as mean±standard deviation (n=20) **significant at p<0.01

in tilapia of OCP were 0.24±0.02, 0.91±0.02, 0.02±0.01, 0.60±0.08 mg/kg respectively and of culture pond were 0.29±0.02, 0.99±0.08, 0.03±0.02 and 0.77±0.28 mg/kg respectively. Results revealed that the residual metal accumulation in both the OCP fish fauna showed mere significance in comparison to that in culture pond fish.

Analysis of estimated daily intake (EDI)

Estimated daily intake (EDI) is an estimation of average intake rate of any food or food components for a human which helps in calculation of accumulation factors (Mandal *et al.,* 2021). In this study, estimated daily intake (EDI) of cadmium, arsenic, lead and nickel in mrigal of OCP and culture pond were 0.360 and 0.417, 0.302 and 0.633, 0.028 and 0.043 and 1.929 and 1.497 µg/kg/day/day respectively; on the other hand, in tilapia of OCP and culture pond were 0.345 and 0.417, 1.310 and 1.425, 0.028 and 0.043 and 0.864 and 1.108 µg/kg/day respectively. As measured, the average EDI values of fish from OCP were comparatively lower than that of culture pond (Figure 2).

Analysis of Target Hazard Quotient (THQ)

Target hazard quotient (THQ) is the human health risk assessment factor by which it can be predicted the fate of any toxicant in human system (Mandal *et al.,* 2021). In the present study, target hazard quotient (THQ) values of metals (cadmium, arsenic, lead and nickel) for mrigal and tilapia of OCP and culture pond were below 1, such as, 0.720 and 0.835, 0.010 and 0.021, 0.072 and 0.108 and 0.096 and 0.074 respectively (Figure 3); similarly, values of THQ of cadmium, arsenic, lead and nickel in tilapia of OCP and culture pond were 0.691 and 0.835, 0.043 and

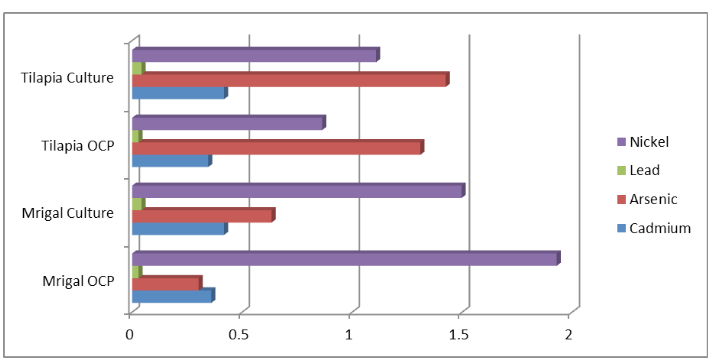

Fig. 2. Estimation of daily intake (EDI) (represented in µg/kg/day)

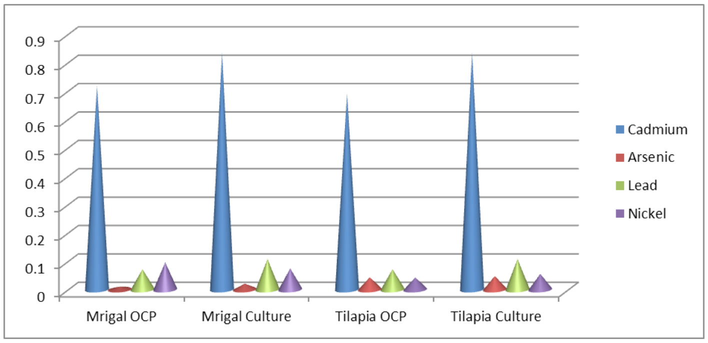

Fig. 3. THQ analysis of OCP and culture fish

0.047, 0.072 and 0.108 and 0.043 and 0.055 respectively, which are well below 1.

Analysis of basic nutritional quality

Moisture content: Basically, the water content in fish tissue is an important indication of fish health and quality. Percentage values of moisture content of mrigal and tilapia of OCP and culture pond were 70.64±0.17, 71.46±0.26 and 72.26±0.14, 72.71±0.12 respectively, showing the maximum value (72.71±0.12%) in tilapia of culture pond.

Ash content: The total inorganic mineral mass of any food which acts as a nutrient pool and determines the physicochemical property of food is known as ash content. The percentage values of ash content of mrigal and tilapia of OCP and culture pond were 2.18±0.35, 1.85±0.09 and 3.82±0.06, 3.10±0.21 respectively, where, tilapia of OCP showing the greater percentage (3.82±0.06%).

Protein, carbohydrate and fat: The fundamental and important macronutrients for biological organisms which help as building materials as well as energy generation are protein, carbohydrate and fat. The total protein contents of mrigal and tilapia of OCP and culture pond were 85.82±0.40, 85.32±0.93 and 77.20±0.25, 80.26±0.33 mg/g respectively, where mrigal of OCP showed the higher (85.82±0.40 mg/g) protein content; average values of carbohydrate percentage of mrigal and tilapia of OCP and culture pond were 1.75±0.02, 2.14±0.01 and 4.14±0.15, 3.69±0.05 respectively, here, tilapia of OCP recorded the higher concentration (4.14±0.15 %); and total fat content of mrigal and tilapia of OCP and culture pond was 18.51±0.42, 17.36±0.42 and 14.42±0.34, 15.63±0.08 mg/g respectively, where, mrigal of OCP showed the higher concentration (18.51±0.42 mg/g). All the data are significant at 0.01% significance level.

Estimated fish nutritional index analysis

The estimated fish nutritional index (EFNI) is used to estimate the daily nutritional intake of an individual. EFNI signifies the amount of individual nutritional elements a person can get from a food source (Mandal *et al.*, 2021). In this study, the EFNI for sodium in mrigal and tilapia of OCP and culture

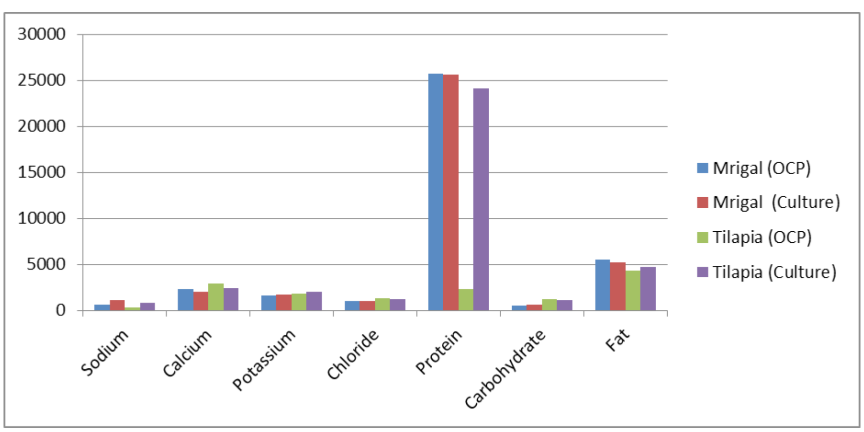

Fig. 4. EFNI analysis of fish from OCP and culture pond (mg/kg/day)

pond was 647.634, 1137.303 and 334.962, 788.292 mg/kg/day respectively, here, mrigal of culture pond showing the higher value; similarly, EFNI for calcium in mrigal and tilapia of OCP and culture pond was 2332.371, 1997.538 and 2930.373, 2446.791 mg/kg/day respectively, here tilapia from OCP revealed the higher value. For potassium, the EFNI in mrigal and tilapia of OCP and culture pond was 1596.588, 1727.583 and 1807.884, 2039.388 mg/kg/day respectively, and tilapia of culture pond revealed the higher value. EFNI for chloride in mrigal and tilapia of OCP and culture pond was 1058.133, 979.965 and 1271.562, 1248.558 mg/kg/day respectively, here, tilapia of OCP showed the higher value; similarly, for total protein, the EFNI in mrigal and tilapia of OCP and culture pond was 25746, 25596 and 2316, 24078 mg/kg/day respectively, and mrigal from OCP revealed the higher value; for total carbohydrate values in mrigal and tilapia of OCP and culture pond, the EFNI values were 525, 642 and 1242, 1107 mg/kg/day respectively; here, tilapia of OCP showed the higher quantity. The EFNI for total fat in mrigal and tilapia of OCP and culture pond was 5553, 5208 and 4326, 4689 mg/kg/day respectively showing the higher value in mrigal of OCP.

Discussion

Present study intends to explore the susceptive feasibility of long-term use of samdihi OCP for commercial pisiculture through a comparative analysis based on values of some trace elements, potentially toxic metals and nutritional parameters like sodium, calcium, potassium, chloride, cadmium, arsenic, lead, nickel, moisture content, ash content, total protein, carbohydrate and fat in two fish species *Cirrhinous mrigala* (mrigal) and *Oreochromis niloticus* (tilapia) under two conditions, *viz*., OCP and culture pond.

Sodium (Na) is one of the most important nutrient elements in human body which contributes to cellular ionic channel and development. Human body relies heavily on sodium as it regulates body's fluid balance, supports the work of nerves and muscles, and helps keeping blood pressure normal. In this study, the Na concentrations in both the fish species from the OCP and culture pond were impressive and were higher than the FSSAI (2011) prescribed the minimum requirement of 900 mg/kg, here, mrigal from culture pond had the higher value (ranged from 1116.54±1.54 to 3791.01±1.35 mg/kg). In order to maintain a healthy water balance within and around human cells, sodium plays the role of an essential electrolyte and fish sodium is easily digested by humans, facilitating muscle and nerve function directly (Mandal *et al*., 2021; Song *et al*., 2021). Additionally, it stimulates kidney function and aids in maintaining stable blood pressure levels. Stansby (1962) and Talat *et al*. (2005) evaluated the Na contents in commercial freshwater fish and industrial marine fish which were higher than our study and concluded that Na content of food within this range are best choice for nutrition, which thus, promotes the findings of this study to be nutritious and good for consumption.

Calcium is a mineral that is most often associated with healthy bones and teeth. However, it also helps muscles contraction, regulates normal heart rhythms and nerve functions, and helps blood clot. In this study, the Ca concentrations in OCP bred mrigal and tilapia were higher than culture pond (ranged from 6658.46±2.03 to 9767.91±1.10 mg/kg). Kim *et al*. (2007) observed that fish provides as good Ca source of at least 325 mg and stated the significance of Ca in body development. Similarly, Ca content recorded by Jung *et al*. (2005) in *Johnius belengerii* (hoki) (59.69 %), Hamada *et al*. (1995), Larsen *et al*. (2000), and Hossain and Yoshimatsu (2014) were having similar kind of results and explained that bony fish are of great Ca sources with a minimum dietary requirement of 24.4%. The Ca content in both the fish from Samdihi OCP were great and higher than FSSAI (2011) regulation (minimum requirement of 2300 mg/kg), hence, proving their worth as best nutritional alternatives.

Potassium (K), an essential electrolyte is required by tissues to trigger a variety of cell and nerve functions. Potassium can be obtained both naturally and through supplementation. Present study revealed that the K content in both the fish species from OCP and culture pond were much higher than the FSSAI (2011), where, the fish from culture pond were having a little higher value (ranged between 5321.96±1.11 and 6797.96±2.78 mg/kg) and tilapia of culture pond showing the higher concentration. Potassium assists in controlling the liquid equilibrium, muscle growth, heart constrictions and nerve signals and the amount of potassium found in fish species is entirely dependent on its habitat and variety but the majority of fish provide at least 10% of the recommended daily value for potassium in a single serving (Mandal *et al.*, 2021). Similar records were exhibited by Talat *et al*. (2005) in *Pamadasys* sp. and *G. microlepis* (3.77 and 13.59 mg/g); Udo and Arazu (2011) and the USDA (2010) in frozen *S. scombrus*, *T.tachurus* and *S. pilchardus* (ranging from 0.03 to 1.38 mg per 100 g of fish) and Thurston (1961) studied the potassium content of Pacific Ocean perch, Pacific cod, lingcod, and sablefish and indicated good nutritive values in fish (ranging from 62.0 to 131.0 mg/100 g), which are lesser than our findings, thus, the Samdihi OCP bred fish indicate healthy food for human.

Chloride (Cl) is an essential nutrient in almost all higher organisms (Naal *et al.*, 2018) and present in all bodily fluids. Chloride is an electrolyte which helps in maintaining the cellular osmotic functions, homeostasis, chloride channel, enzyme activity and metabolic development factors (Berend *et al.*, 2012; Jentsch *et al.*, 2002). In this present study, the Cl concentrations were satisfactory (between 3266.55±1.08 and 4238.54±1.71 mg/kg), where, the fish from OCP had higher Cl values than the fish from culture pond and OCP bred tilapia had the higher value. Similar observations were made by Atwood *et al.* (2001) in Nile tilapia and further explained the suppressing of nitrite toxicity and removal of metal toxicity in organisms. Mazik *et al*. (1991) recorded the Cl values (5 mg/g) in striped bass (*Morone saxatilis*) that helps in mitigating the metal toxicity a especially nitrite contamination. So, present study also promotes a good nutritional content of OCP bred fish with Cl values more than FSSAI (2011) regulation (minimum requirement of 2500 mg/g).

Cadmium (Cd) is referred as a toxic element to biological organisms even in trace amounts. Here, cadmium value in OCP bred fish (ranged from 0.24±0.02 to 0.29±0.04 mg/kg) was much lower than the FSSAI permissible limit of 0.3 mg/kg. Similarly, the EDI values for Cd ranged between 0.345 and 0.417 µg/kg/day which were extremely low than 1, portrays a very minimal THQ value. Similar results were disclosed by Mandal *et al*. (2021) in *Catla catla*, *Labeo rohita*, *Notopterus notopterus* and *Oreochromis niloticus*, indicating no potential human health risk. Accordingly, Shovon *et al*. (2017) proved that cadmium values (0.08 to 0.96 ppm) in *Labeo rohita* do not create any harmful condition for consumption. Thus, here also, present study explicitly evidenced the safe consumption of fish species of Samdihi OCP with no intent of human health risk based on standard THQ esteem (<1).

Arsenic (As) and its compounds are widely considered as potent poisons. Present study revealed the arsenic concentration in both the fish from OCP and culture pond (ranging from 0.21±0.09 to 0.99±0.08 mg/kg) were far lower than the standard limit by FSSAI regulation (2011) permissible limit, again, the OCP bred fish had relatively far lower concentration of As than fish from culture pond. Similarly, the EDI values were also extremely lower than 1. Storelli and Marcotrigiano (2000) studied the natural, inorganic and organic arsenic from the muscles of different fish like skate (*Raje* sp.), hake (*Merluccius merluccius*) and blue whiting (*Micromesistius poutassou*) of the South Adriatic Ocean (South Italy) and observed no major consequences to human health. Similar results were recorded by Juresa and Blanusa (2003), Julshamn *et al*. (2007, 2011, 2012, 2013) and Mania *et al*. (2015), where arsenic levels were below permissible limit as per FAO and/or WHO in food items (30 mg/kg). Thus, the lower values of THQ for As (<1) indicate no human health risk for the present study.

Lead (Pb) is one of the most proven toxic metals affecting almost every organ of human body especially cardiovascular, renal and nervous systems, and its extreme use in various fields like batteries, construction, fuel, electronics and laboratories has been a commonly encountered metal in biological systems (Baird and Cann, 2005). Present study revealed the lead concentration and EDI values (ranged from 0.02±0.01 to 0.03±0.02 mg/kg and 0.028 to 0.043 µg/kg/day respectively) in OCP bred fish had comparatively lower values than culture pond fish but all the values were well under the standard limits as per FSSAI regulation (2011). Similar observation was made by Storelli and Marcotrigiano (2000), which was much lower than the basic guideline limit (2 mg/kg) set by Italy government, WHO and FAO. The THQ of lead in the present study was less than 1, so, no potential threat to humans, which was also supported by Julshamn *et al*. (2007, 2011, 2012, 2013), Rashid (1995) and Rashed (2001) in a similar study in water system and tilapia of dam lake in Egypt predicted no human health risk. Thus, Samdihi OCP bred fish maintains a good quality and safe for consumption.

Nickel (Ni) acts as a nutrient, although known to be highly toxic for human beings if consumed in excess (Sigel *et al.*, 2008). In the current investigation, the Ni concentrations (ranged between 0.60±0.08 and 1.34±0.08 mg/kg) were much less than the maximum permissible limit set by WHO/FAO in fish items (2 mg/kg) and the FSSAI regulations (1.5 mg/kg). Though nickel is not readily stored in human body and gets eliminated by kidney, continuous and excessive intake of nickel especially oral consumption can lead to fatal diseases such as cancer, but in this case the EDI of nickel was in the range from 0.864 to 1.929 µg/kg)/day, portrays it in safer limits. Also, the THQ of nickel was much lower than 1, which shows no potential human health risk. In a similar study in Africa, Ekere *et al*. (2014) found the EDI and THQ values of nickel were well within the limits of WHO and FAO and with no health risk to human.

The moisture content in terms of water available in tissues either in free form or bound to proteins determines the proportion of water to solids in a given tissue mass, which plays an important role in maintaining the physiological activity. In the current study, the percentage of moisture content in *Cirrhinous mrigala* and *Oreochromis niloticus* both from OCP and culture pond exhibited sufficient quantity, though the percentage of moisture content in mrigal and tilapia from OCP (70.64±0.17 and 72.26±0.14 % respectively) were just a little less than that of mrigal and tilapia of culture pond (71.46±0.26 and 72.71±0.12 % respectively) which was supported by Mohanty *et al*. (2019) in four predatory species, *viz*., magur, murrels, koi and singhi (65 to 80%). Similar comparative examination was supportive to our observations was made by Matos *et al*. (2019) on five different fish species (74.7 to 81.7 %) and Joseph *et al*. (1990); Paul *et al*. (2016); and Shakir *et al*. (2013) on Indian major carps. But, in *Labeo ghonius* it is much lower (12.3 to 54.0 %) (Hussain *et al*., 1992). Azam *et al.* (2003) evaluated the much higher moisture content (26.13 to 97.7 %) in 13 distinct fish species.

Analysis of ash content indicates the amount of inorganic minerals which can assess the physicochemical properties of foods and/or food items and can reduce the growth of microorganisms. Flowra *et al*.(2013) reported that the ash content of five distinct fishes (chanda, churi, kachki, tangra and taki) varied between 9.63 and 22.73%. But in this study, the ash content of two different fish species (*Cirrhinous mrigala* (mrigal) and *Oreochromis niloticus* (tilapia)) from two different conditions (OCP and culture pond) ranged between 1.8 and 3.8%, where the samples from OCP showed relatively higher values than those from culture pond. Similar observation was made by Hussain *et al*. (1992) in 23 distinct dried fish species containing ash contents ranging from 1.4 to 21.6% and Azam *et al*. (2003) recorded an ash content of between 5.08 and 12.14 percent in 14 dried fishes. The present study revealed that ash content in mrigal from OCP (2.18%) was higher than the mrigal from culture pond (1.85%) and similarly, it was comparatively higher in tilapia from OCP (3.82%) than tilapia of culture pond (3.1%) which portrays a trend of OCP bred fish to have higher ash content which indicates the rich in minerals as also supported by Islam *et al*.(2003) and Chakraborty *et al*.(2015), where they reported the higher ash content of *Cirrhina reba* and *Channa punctatu s*proving nutritional significance.

Protein provides the structural frame in living life form, considered a fundamental supplement utilized as primary energy source. Fish contribute as potential sources of human-appropriate animal protein as well as nutrients (Fawole *et al*., 2007). Dietary fish proteins (Valine, Lysine, Tyrosine, Isoleucine, Cysteine) can assist with decreasing pulse, development of glucose digestion and enrichment of stomach microbial arrangement (Dale *et al*., 2019). Fish dry matter consists primarily of protein (Steffens *et al*., 2006), thus, they are an excellent source of animal protein for calorie-controlled diets and a low-calorie, high-protein option for human weight loss, hence, proved to be one of the best quality and balanced food items. Present study revealed the higher protein content in OCP bred fish than the fish of culture pond, in particular, the mrigal from OCP had the higher content (85.82±0.40 mg/g). Similar records were disclosed by Hoq (2004) and Flowra *et al*. (2013) in various dried fish species, ranged from 50 to 80 percent. Hussain (2012) exhibited the values ranging from 17.2 to 78 percent in 23 unique species: Azam *et al*. (2003) recorded 40.69 to 66.52 percentin 14 species and Islam (1982) reported protein content of rohu 73.26 percent. So, here, the fish protein content might be comparable to other animal-based proteins (Mohanty *et al*., 2019), therefore, fish faunas of Samdihi OCP might be utilized as a good food source with a decent protein amount consistently.

Carbohydrates are basically sugar molecules which are the cheapest source of energy for the diet and the fish species as a primary source of carbohydrate can provide maximum energy of about 1.6 kcal by consuming only 1.0 g of fish carbohydrate (Mandal *et al*., 2021). In the present study, total carbohydrate contents of both the fish from OCP and culture pond were satisfactorily ranged from 1.75±0.02 to 4.14±0.15 %, and OCP bred tilapia having the higher content. Similar results were recorded by Nurnadia *et al*. (2011) in 20 fish species ranged from 0.87 to 3.07%. Though, Mohanty *et al*. (2019) revealed lowest to negligible carbohydrate content in Indian edible fish. Adeniyi *et al*. (2012) exhibited carbohydrate values ranged from 3.85 to 8.86 % in 3 different fish species which were similar or slightly higher to our study. Sutharshiny and Sivashanthini (2011) evaluated carbohydrate content in *Scomberoides lysan*, *Scomberoides tol*, and *Scomberoides commersonianus* ranging from 0.07 to 0.3 %, which was much lower than our study; but, Maktoof *et al*. (2020) exhibited the carbohydrate content in common fish organs of 1.9 to 2.5 % and suggested the safe consumption of fish, which also signifies our studied results, thus, fish faunas from Samdihi OCP are of great carbohydrate content might be used as nutritious food.

Fats or lipids are non-polar biomolecules that play a significant role in human health development and energy store. Fish provide some primary natural lipid forms which can help in body nutrition management and wellbeing. Present study revealed relatively higher values of fat content in OCP bred fish than the fish from culture pond and the mrigal of OCP had the higher content (18.51±0.42 mg/g). Similar results were reported by Ackman *et al*. (2002) and Huynh and Kitts (2009) in different IMC's muscle, *viz*., *Labio rohita*, *Labeo bata*, *Catla catla* revealed 10 to 25 mg/g, also, Shirai *et al*. (2002) revealed that the fat content in Japanese sardine (*Sardinops melanostictus*) was ranged from 6.0 to 7.2%, which is little higher than our study, but, Iverson *et al*. (2002) evaluated the fat content of *Theragrachal cogramma*, *Clupea harengus* and *Oncorhynchus gorbuscha* widely ranged from 3.0 to 25% and suggested that fish with such fat content are safe to consume as a good energy source and have high energy content and thus validates the findings of this present study, therefore, fish cultured in Samdihi OCP can be consumed as a good source of lipid.

Conclusion

Present study has established the restored ecosystem condition of the Samdihi OCP endorsing a significant, suitable and normal standard for pisciculture, producing fish for safe human consumption. The OCP waterbody has been established to be a productive pisciculture system and a source of good natural food and nourishment for the fish production. The fish under investigation must not pose a threat of metals' concentration to human consumption because of their low concentrations within normal safety limits. The THQ values for all the investigated metals were extremely low, showing no significant toxic aggregation. The abundance of nutrient components was also highlighted by the estimated fish nutritional index (EFNI), which, demonstrated that the fish species cultured in opencast coal pit possess a good nutritional quality, even better in some aspects as compared to commercial culture fish farms and can be a useful source of food and protein for the local communities. So, after post-mining activities, the OCP reclamation in the RCF areas would pave a sustainable path for socio-economic development of the community. As a result, mine pits and restored reservoirs can serve as an ecologically rejuvenation area and ultimately as a source of income generation of employment and food for the communities, fulfilling the different Sustainable Development Goals, *viz*., 02 (Zero Hunger), 03 (Good Health and Well-Being), 08 (Decent Work and Economic Growth), 09 (Industry, Innovationand Infrastructure), 11 (Sustainable Cities and Communities), 12 (Responsible Consumption and Production) and 14 (Life Below Water).

Acknowledgements

The authors are greatly thankful to Samdi Shiv Shankar Matshya Baboharkari Gosti and Chandimata Fish Farm and their team members for permitting us for sampling and experimentation. The authors are indebted to UGC-DAE-CSR Kolkata Centre for helping in estimation of trace elements through EDXRF, especially, Dr. M. Sudarshan, Dr. A. Bhattacahrya and Mr. J. Biswas. The authors would like to express their earnest gratitude to DST, GoI and DST-FIST for giving infrastructural facilities to the Department of Environmental Science, the University of Burdwan for providing the opportunity to perform this study and help in its every step.

Conflict of interest

Authors declare that no conflict of interest exits.

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