Original Research Article

Analysis of seasonal fluctuations in nutritional composition and quality of key commercial fish species in the Ludhiana fish market, Punjab

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ABSTRACT

A study was carried out to investigate the nutritional composition and quality of four different fish species (*Wallago attu*, *Labeo rohita*, *Pangasianodon hypophthalmus*, and *Rastrelliger kanagurta*) sourced from the Ludhiana fish market spanning from September 2021 to August 2022, encompassing four distinct seasons: post-monsoon, winter, pre-monsoon, and monsoon. The proximate parameters were analysed through following the standard methods of AOAC (2019). Peroxide value (PV) was recorded by titration method and pH was recorded using pH meter. One way ANOVA ($p \leq 0.05$) was performed to evaluate the relationship among proximate composition and quality parameters in fish flesh. Statistical analysis was performed by using SPSS ver. 20 and Microsoft Excel software packages for the evaluation of proximate composition and quality parameters. The findings of the present study showed that all of the fish species recorded the lowest levels of moisture content in pre monsoon season, while the highest were recorded during the monsoon season. The selected fish species displayed seasonal fluctuations in their protein content. The lipid content of *P. hypophthalmus* was observed significantly greater (10.28%) in comparison to other species. Significant statistical differences in the average ash content were observed throughout various seasons in *L. rohita* and *R. kanagurta*. The peroxide value exhibited variations ranging from 2.15 to 4.17 milliequivalents of O2/kg throughout various seasons in different species. The fish species *R. kanagurta* had the lowest pH values, whereas *L. rohita* recorded the highest pH levels. In conclusion, the quality parameter served as a comprehensive framework for ensuring the safety of fish consumption. In India, fish markets have experienced significant growth, driven in part by a rise in per capita consumption of fish in recent years. Changing dietary preferences and increasing disposable incomes are expected to further boost fish consumption in the foreseeable future. A comprehensive scientific analysis of the nutritional composition and quality parameters of selected distinct fish species, sourced from the Ludhiana fish market, revealed intriguing seasonal variations. However, it's imperative to highlight that data related to various critical aspects of the fish industry in Punjab are documented.

Keywords: Fish market; Commercially important fish; Proximate composition; Quality parameters; Consumer safety

1. INTRODUCTION

Fish emerges as a remarkably valuable source of high-quality animal protein and stands as one of the most abundant reservoirs of essential minerals. The fishery and aquaculture sector exhibit immense potential in addressing concerns related to food security and nutrition [1]. As of the latest data for the year 2021-22, India's total fish production reached an impressive 162.48 lakh tonnes. Furthermore, it is worth noting that per capita fish consumption in India currently stands at 6.31 kg, a figure that highlights the significance of further interventions, particularly in regions like Punjab, where the per capita consumption stands at a mere 0.4 kg, significantly lower than the national average [2]. In the landscape of Asian countries, fish protein alone contributes a substantial 31% to the pool of animal protein sources [3].

The comprehensive analysis of the proximate composition of fish muscles offers valuable insights into the composition of different species. This allows for meaningful comparisons of nutritional differences both within and among species. Fish, as a dietary source, presents a rich array of essential nutrients, including noteworthy quantities of protein,

vitamins, minerals, and healthy fats. It is renowned as a globally accepted source of low-fat, high-quality protein and minerals, in addition to being a rich source of polyunsaturated fatty acids (PUFA) [4; 5].

Ensuring the nutritional integrity and safety of fish available in the market relies heavily on maintaining the highest standards of product quality. A multitude of factors come into play, including the duration between harvesting and consumption, as well as the meticulous control of temperatures during all stages of handling, processing, and storage. These factors exert profound influences on the biochemical composition, microbial load, and sensory attributes of the fish. Parameters such as pH, total volatile basic nitrogen (TVB-N), trimethylamine (TMA), and sensory evaluation serve as critical indicators of fish spoilage, reflecting alterations in protein degradation, lipid oxidation, and microbial proliferation over time. By monitoring these parameters, stakeholders can gauge the overall quality and safety of fish products, facilitating informed decisions regarding their consumption and commercial viability [6]. The objective of this research endeavor was to conduct a comprehensive examination into the nutritional composition and quality parameters of four diverse fish species, namely Wallago attu, Labeo rohita, Pangasianodon hypophthalmus, and Rastrelliger kanagurta, procured from the Ludhiana fish market to discern the variations in fish muscle composition across different seasons. This research endeavor sought to contribute to the assurance of consumer safety in the context of fish consumption.

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2. MATERIAL AND METHODS

The study focused on the Ludhiana fish market and spanned a period of one year, from September 2021 to August 2022. Data collection occurred at regular intervals throughout the post-monsoon, winter, pre-monsoon, and monsoon seasons. Analysis of the proximate composition encompassing parameters such as moisture, protein, lipid, carbohydrate, and ash content, along with quality parameters was performed on four commercially important fish species i.e. *W. attu*, *L. rohita*, *P. hypophthalmus*, and *R. kanagurta*.

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All the proximate parameters were analysed following the standard methods [7]. Moisture content was recorded by the standard hot air method using the hot air oven. The crude protein level of the fish meat was recorded by estimating total nitrogen by the Kjeldahl method using an electrically heating digestion and distillation unit. The crude lipid content of the fish meat was recorded by the Soxhlet extraction method using the Soxhlet fat extraction unit. The total carbohydrate content of the fish meat was recorded by the Anthrone method using the spectrophotometer. Ash content of the fish meat was recorded by the dry method at high temperature (550 ± 25ºC) using a muffle furnace.

Peroxide value (PV) was determined by titration method using 0.02 N sodium thiosulfate for titration [8]. The level of pH in fish flesh was estimated by the use of a pH meter. One way ANOVA (p=0.05) was performed using Tukey`s-b Post Hoc multiple comparisons method to evaluate the relationship among proximate composition and quality parameters. Statistical analysis was performed by using SPSS ver. 20 software package.

3. RESULTS AND DISCUSSION

3.1 Proximate composition of selected fish species

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3.1.1 Moisture content in fish flesh

In the Ludhiana fish market, the lowest moisture content in *W. attu* was observed in the pre-monsoon season (79.18%), while the highest was in the monsoon season (81.08%) (Table: 1). The lowest moisture content in *L. rohita* was recorded during the pre-monsoon season at 77.01%, while the highest was observed during the monsoon season at 79.92%. The lowest mean moisture content in *P. hypophthalmus* was recorded during the pre-monsoon season at 73.02%, while the highest was observed during the monsoon season at 74.96%. The lowest mean moisture content in *R. kanagurta* was recorded during the pre-monsoon season at 72.48%, while the highest was observed during the monsoon season at 74.94%.

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The moisture content in four different species (*W. attu*, *L. rohita*, *P. hypophthalmus* and *R. kanagurta*) varied from 72.48-81.08% in different season (Table 1). The acerage values of moisture content varied significantly across seasons ($p<0.05$) in selected species. The moisture content was observed minimum in R. kanagurta and maximum in *W. attu*.

An investigation was undertaken to ascertain the moisture content of *W. attu* specimens subjected to both fresh and frozen storage conditions within the Mymensingh district, Bangladesh. The recorded moisture content for *W. attu* under fresh and frozen conditions was found to be 79 ± 0.45% and 75 ± 1.01%, respectively [9].

The study reported an average moisture content of 79.18±0.43% in *L. rohita* collected from Loktak Lake, Manipur which closely aligns with the verdicts of the present study. The authors reported the highest moisture content in *P.*

hypophthalmus during the monsoon season compared to other seasons [10]. The study reported a moisture content of 72.24% in *R. kanagurta* and highlighted that moisture and fat content in fish are inversely proportional, indicating that fatty fishes tend to have relatively low moisture content [11].

Over all the moisture content was observed minimum in pre-monsoon and maximum in monsoon season which was similar to the findings [10]. The moisture and lipid content in fish fillets exhibit an inverse relationship, with their sum accounting for approximately 80% of the proximate composition, while other components make up the remaining 20% [12].

Table 1: Moisture content of selected fish during seasonal interval

Season	*W. attu*	*L. rohita*	*P. hypophthalmus*	*R. kanagurta*
Post-monsoon	80.44^{ab}±0.28	78.23^{b}±0.29	74.61^{ab}±0.28	73.41^{b}±0.29
Winter	79.53^{b}±0.25	77.32^{b}±0.29	73.66^{bc}±0.25	72.79^{b}±0.27
Pre-monsoon	79.18^{b}±0.29	77.01^{b}±0.32	73.02^{c}±0.28	72.48^{b}±0.27
Monsoon	81.08^{a}±0.32	79.92^{a}±0.29	74.96^{a}±0.30	74.94^{a}±0.33
Average	80.05±0.25	78.12±0.36	74.07±0.26	73.40±0.31

3.1.2 Protein content in fish flesh

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In *W. attu* lowest protein content was observed in monsoon season (14.62%), while the highest protein level was recorded in the pre-monsoon season (16.49%) (Table 2). The lowest protein level in *L. rohita* was recorded during the monsoon season at 14.35%, while the highest was observed during the pre-monsoon season at 16.05%. The lowest mean protein content in *P. hypophthalmus* was recorded during the monsoon season at 9.72%, while the highest was observed during the pre-monsoon season at 11.59%. The lowest mean protein content in *R. kanagurta* was recorded during the monsoon season at 16.48%, while the highest was observed during the pre-monsoon season at 18.36%.

The protein level in different species varied from 9.72-18.36% in different season (Table: 2). The average values of protein content varied significantly across various seasons ($p<0.05$) in selected four species. The protein content was observed minimum in *P. hypophthalmus* and maximum in *R. kanagurta*. The protein content was observed minimum in monsoon and maximum in pre-monsoon season. The increase in protein contents in post- monsoon season in the fish suggests a recovery of the fish from the strenuous act of breeding.

The author reported an average protein content of 15.95% during the monsoon season and 16.99% during the post-monsoon season in *L. rohita* collected from various fish markets in Sultanpur, Uttar Pradesh [13]. The increase in protein content during the post-monsoon season suggests a recovery of the fish from the strenuous act of breeding. The study reported protein content in *P. hypophthalmus* around 13.58% [14]. They also noted significant differences between live and dead fish samples, highlighting the impact of prolonged storage on fish quality, including chemical composition and nutritional profile. The author mentioned that protein content in fish generally varies seasonally, with the lowest values during the breeding season, such as the monsoon [13]. The study evaluated an average protein content of 19.14% in *R. kanagurta* harvested from the Ratnagiri coast. The study concluded that mackerel is a very good source of protein for all strata of people in society [11].

In the present study, protein level of fish was more during pre-spawning period (pre monsoon period) and its level decreased during spawning period (Monsoon) thus followed the similar trend of the findings [13]. The author also reported that in fish muscle water content increased to its highest levels, while muscle protein content decreased. Decrease in protein and increase in water content of the muscle were the results of gonadal development and maturation at the expense of muscle protein reserves during the monsoon [15].

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Table 2: Protein content of selected fish during seasonal interval

Season	*W. attu*	*L. rohita*	*P. hypophthalmus*	*R. kanagurta*
Post-monsoon	$15.74^{b}\pm0.11$	$15.21^{b}\pm0.10$	$10.65^{b}\pm0.11$	$17.54^{b}\pm0.11$
Winter	$15.76^{b}\pm0.14$	$15.70^{ab}\pm0.17$	$11.20^{ab}\pm0.15$	$18.13^{ab}\pm0.18$
Pre-monsoon	$16.49^{a}\pm0.23$	$16.05^{a}\pm0.17$	$11.59^{a}\pm0.16$	$18.36^{a}\pm0.18$
Monsoon	$14.62^{c}\pm0.19$	$14.35^{c}\pm0.19$	$9.72^{c}\pm0.18$	$16.48^{c}\pm0.20$
Average	15.65±0.22	15.33±0.20	10.79±0.22	17.63±0.23

3.1.2 Lipid content in fish flesh

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The lipid content in *W. attu* was observed lowest during the monsoon season (0.69%), while the highest was during the winter season (1.07%) (Table 3). The lipid content in *L. rohita* was recorded lowest during the monsoon season at 1.59%, while the highest was observed during the winter season at 2.05%. The lipid content in *P. hypophthalmus* was recorded lowest during the monsoon season at 9.33%, while the highest was observed during the winter season at 11.04%. The lipid content in *R. kanagurta* was recorded lowest during the monsoon season at 2.47%, while the highest was observed during the winter season at 4.05%.

The lipid content in different species varied from 0.69-11.04% in different season (Table 3). The lipid values were recorded minimum in *W. attu* and maximum in *P. hypophthalmus*. The lipid values were recorded minimum in monsoon and maximum in winter season.

Moisture and lipid content in fish fillets exhibit an inverse relationship, and their sum typically accounts for approximately 80% of the proximate composition, with other components making up the remaining 20% [12]. This inverse relationship was also observed in *W. attu*. The increased moisture content and the rapid decline in lipid content in this species could be attributed to the spawning season. The authors conducted a study on the seasonal biochemical variations in *W. attu* from the Krishna River near Audumber, Maharashtra. They reported a lipid content of 0.64% during the winter, which subsequently decreased until the monsoon period [16]. The study reported high lipid content in *L. rohita* during the post-monsoon season, attributed to active fish feeding. This lipid content subsequently decreased in the pre-spawning season, indicating its utilization during gonadal development and as an energy source during ovulation and spawning [13].

The author reported lipid content in *P. hypophthalmus* around 8.0% [14]. The study reported a lipid content of 3.83% in *R. kanagurta* collected from different fish outlets in Navi Mumbai, Maharashtra [17]. The authors reported that moisture and fat content is inversely proportional to each other indicating that fatty fishes have relatively low moisture content [11]. The similar type of inverse consecution was recorded between *W. attu* and *P. hypophthalmus* in present study.

Table 3: Lipid content of selected fish during seasonal interval

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Season	*W. attu*	*L. rohita*	*P. hypophthalmus*	*R. kanagurta*
Post-monsoon	$0.78^{a}\pm0.06$	$1.62^{a}\pm0.07$	$9.78^{b}\pm0.80$	$3.09^{b}\pm0.07$
Winter	$1.07^{a}\pm0.11$	$2.05^{a}\pm0.14$	$11.04^{a}\pm0.16$	$4.05^{a}\pm0.17$
Pre-monsoon	$1.02^{a}\pm0.14$	$1.94^{a}\pm0.05$	$11.00^{a}\pm0.13$	$3.98^{a}\pm0.14$
Monsoon	$0.69^{a}\pm0.12$	$1.59^{a}\pm0.13$	$9.33^{b}\pm0.13$	$2.47^{c}\pm0.15$
Average	0.89±0.06	1.80±0.07	10.28±0.23	3.40±0.21

3.1.3 Carbohydrate content

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The carbohydrate level in *W. attu* was observed lowest during the monsoon season at 0.54%, while the highest was observed during the pre-monsoon season at 0.78% (Table 4). The carbohydrate content in *L. rohita* was observed lowest during the monsoon season at 1.46%, while the highest was recorded during the pre-monsoon season at 2.04%. The

carbohydrate content in *P. hypophthalmus* was recorded lowest during the monsoon season at 0.62%, while the highest was observed during the pre-monsoon season at 1.13%. The carbohydrate content in *R. kanagurta* was recorded lowest during the monsoon season at 0.24%, while the highest was observed during the pre-monsoon season at 0.36%.

The carbohydrate content in different species varied from 0.23-2.04% in different season (Table 4). The carbohydrate values were recorded minimum in *R. kanagurta* and maximum in *L. rohita*. The carbohydrate values were recorded minimum in post-monsoon and maximum in pre-monsoon season.

The study reported carbohydrate content in *P. hypophthalmus* around 0.73%, which is nearly compriset with the values recorded in the present study [14]. The authors reported a low level of carbohydrates compared to other proximate compositions in fish, with a carbohydrate level of 0.51% in *R. kanagurta*. Glycogen in marine fishes does not play a significant role as a reserve energy source [18]. The study also reported lower level of carbohydrate content in total proximate composition of the fish muscle because most of the glycogen in freshwater fishes did not enlarge much to the reserves in the body in present study also collateral type of results were found [19].

During the study conducted by [19] on *W. attu* from the Indus River in Mianwali, Pakistan, an ash content of 4.46% was reported. Our present study aligns with this finding, as ash content varied between 2.54% and 3.78%. Additionally, the study reported higher ash content during the post-monsoon season and lower content during the monsoon season [13]. This correlation between higher ash content and increased mineral metabolism can be attributed to the significant rise in food availability during the post-monsoon season after the recession of water levels during the monsoon.

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Table 4: Carbohydrate content of selected fish during seasonal interval

Commented [L12]: There is some explanation why in these samples (W. attu and R. kanagurta), no significant difference was found in the different seasons of the year.

Season	*W. attu*	*L. rohita*	*P. hypophthalmus*	*R. kanagurta*
Post-monsoon	0.60^{a}±0.03	1.64^{b}±0.04	0.72^{b}±0.04	0.23^{a}±0.03
Winter	0.74^{a}±0.07	2.01^{a}±0.06	1.04^{a}±0.08	0.32^{a}±0.06
Pre-monsoon	0.78^{a}±0.08	2.04^{a}±0.07	1.13^{a}±0.07	0.36^{a}±0.05
Monsoon	0.54^{a}±0.06	1.46^{b}±0.08	0.62^{b}±0.07	0.24^{a}±0.06
Average	0.66±0.04	1.79±0.07	0.88±0.07	0.29±0.03

3.1.4 Ash content

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The ash content in *W. attu* was recorded lowest during the monsoon season at 2.54%, while the highest was observed during the pre-monsoon season at 3.78% (Table 5). The ash content in *L. rohita* was recorded lowest during the monsoon season at 1.65%, while the highest was observed during the pre-monsoon season at 2.28%. The ash content in *P. hypophthalmus* was recorded lowest during the monsoon season at 1.62%, while the highest was observed during the pre-monsoon season at 2.04%. The ash content in *R. kanagurta* was observed lowest during the monsoon season at 1.71%, while the highest was during the pre-monsoon season at 3.04%.

The ash content in different species varied from 1.62-4.34% in different season (Table 5). It was observed minimum in *P. hypophthalmus* and maximum in *W. attu*.

The study reported an ash content of 1.04% to 2.95% in *P. hypophthalmus*, with an average value of 1.75%, which is almost consistent with the findings of the existing study [20]. The authors reported an ash content of 1.42% in *R. kanagurta* harvested from off Ratnagiri Coast, Maharashtra [11]. The study reported higher ash content during the post-monsoon season and lower during monsoon season. Higher ash contents correlate with higher mineral metabolism. Availability of food increased considerably in the post-monsoon season after subsiding higher water level during monsoon [13]. The verdicts of the present study also indicated similar trend where ash content was highest in pre-monsoon and lowest in monsoon season.

Table 5: Ash content of selected fish during seasonal interval

Season	*W. attu*	*L. rohita*	*P. hypophthalmus*	*R. kanagurta*
Post-monsoon	3.61^{b}±0.07	1.79^{ab}±0.07	1.66^{a}±0.08	1.74^{b}±0.07
Winter	4.28^{a}±0.13	2.24^{a}±0.13	1.98^{a}±0.14	2.98^{a}±0.13
Pre-monsoon	4.34^{a}±0.13	2.28^{a}±0.12	2.04^{a}±0.12	3.04^{a}±0.13
Monsoon	3.14^{b}±0.14	1.65^{b}±0.13	1.62^{a}±0.14	1.71^{b}±0.14
Average	3.84±0.15	1.99±0.10	1.83±0.08	2.37±0.20

3.2 Quality assessment of selected fish during seasonal interval

3.2.1Peroxide value

The average peroxide values in different species varied from 2.15 to 4.17 milliequivalents of O_2/kg in different seasons (Table 6). Seasonal variation in peroxide value were statistically significant ($p<0.05$) in *L. rohita* however, peroxide content did not express significant seasonal fluctuations in *W. attu*, *P. hypophthalmus*, and *R. kanagurta.* The peroxide values were recorded minimum in *W. attu* and maximum in *R. kanagurta*. Peroxide values were observed minimum in the winter and maximum in pre-monsoon season.

The study recorded the peroxide value is used to evaluate the fat oxidation, and the product is considered rancid when the peroxide value is 20–40 milliequivalents of O_2/kg [21]. The existing study indicated much lower peroxide content in four different fish species collected from Ludhiana fish market in different seasons as compared with permissible limit of 20–40 milliequivalents of O_2/kg, which was similar to the findings [21].

Table 6: Peroxide value of selected fish during seasonal interval

Season	*W. attu*	*L. rohita*	*P. hypophthalmus*	*R. kanagurta*
Post-monsoon	2.55^{c}±0.10	2.62^{b}±0.11	3.49^{a}±0.22	3.99^{a}±0.13
Winter	2.15^{bc}±0.11	2.57^{b}±0.14	3.70^{a}±0.11	3.53^{a}±0.24
Pre-monsoon	3.88^{b}±0.13	4.03^{b}±0.10	4.07^{a}±0.12	4.17^{a}±0.13
Monsoon	2.88^{a}±0.13	2.92^{a}±0.12	4.01^{a}±0.11	4.06^{a}±0.14
Average	2.86±0.20	3.03±0.18	3.82±0.09	3.94±0.10

3.2.2 pH value of fish flesh

The pH content in four distinct fish species ranged from 6.46 to 6.87 across different seasons (Table 7). The mean values of pH in four selected fish showed significant variations across various seasons ($p<0.05$). Specifically, the lowest pH values were recorded in *R. kanagurta*, while the highest was recorded in *L. rohita* fish. It is noteworthy that, across all four species, the pH content exhibited a pattern of being lowest during the pre-monsoon season and highest during the monsoon season.

The pattern of pH during present study aligns with the findings [14], where variations in fish pH are influenced by factors such as seasonal changes, dietary habits, fish activity levels, and environmental conditions. The pH of fish experiences a decline during the initial stages of storage due to the anaerobic formation of lactic acid post-mortem. Conversely, in later post-mortem stages, the pH tends to rise as basic compounds are generated. Overall, changes in postmortem fish muscle pH are closely linked to alterations in fish quality [22]. Importantly, throughout the study period, the pH levels in all four species, namely *W. attu, L. rohita, P. hypophthalmus,* and *R. kanagurta*, consistently remained within the acceptable limit (<7) [23]. This reaffirms the safety of these fish species for consumption.

Table 7: pH of selected fish during seasonal interval

Season	*W. attu*	*L. rohita*	*P. hypophthalmus*	*R. kanagurta*
Post-monsoon	6.59^{c}±0.03	6.63^{c}±0.02	6.57^{c}±0.03	6.55^{c}±0.02
Winter	6.75^{b}±0.03	6.77^{b}±0.03	6.73^{b}±0.03	6.71^{b}±0.03
Pre-monsoon	6.48^{d}±0.03	6.49^{d}±0.02	6.47^{d}±0.02	6.46^{c}±0.03
Monsoon	6.85^{a}±0.02	6.87^{a}±0.02	6.86^{a}±0.02	6.85^{a}±0.02
Average	6.67±0.04	6.69±0.04	6.66±0.05	6.64±0.05

4. CONCLUSION

A comprehensive scientific analysis of the nutritional composition and quality parameters of four distinct fish species, namely W. attu, L. rohita, P. hypophthalmus, and R. kanagurta, sourced from the Ludhiana fish market, revealed intriguing seasonal variations. Specifically, the investigation unveiled that the pre-monsoon season exhibited the lowest moisture content, while the monsoon season showcased the highest moisture levels. Furthermore, an examination of the fish protein content disclosed that pre-spawning (pre-monsoon) individuals boasted higher protein levels, whereas during spawning (monsoon), there was a subsequent decline in fish protein levels. Conversely, lipid content was at its nadir during the monsoon season

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but peaked during the winter months. In terms of carbohydrates, the post-monsoon season exhibited the lowest carbohydrate content, while the pre-monsoon season displayed the highest carbohydrate levels. It is noteworthy that, among all the proximate composition criteria examined in this study, the percentage of carbohydrates was the lowest. Additionally, the pre-monsoon season featured the highest ash content, while the monsoon season had the lowest ash content. Importantly, none of the four different fish species sampled from the Ludhiana fish market during various seasons exceeded the permissible limit for peroxide levels, indicating their suitability for consumption. Moreover, the study recorded the lowest pH levels during the pre-monsoon season, whereas the monsoon season exhibited the highest pH levels. Remarkably, all four species-maintained pH values well below the permissible threshold ensure safety for human consumption.

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