Future Perspectives of Medical, Pharmaceutical and Environmental Biotechnology ISSN: 3009

RESEARCH ARTICLE

Vol. 1, No 2/2024

https://doi.org/10.21608/fpmpeb.2024.348227

Biological Study of Fish Quality in Damietta Port in Small-Scale Fisheries by Applying Value Chain Analysis

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Abstract

The Egyptian Mediterranean fisheries sector is a critical contributor to the country's economy, with fish exports amounting to approximately 40% of the country's total agricultural exports. The industry also plays a vital role in providing employment opportunities, particularly for those living along the Mediterranean coast. However, this sector has been facing various challenges, such as overfishing, illegal fishing practices, and environmental degradation, threatening its sustainability. A value chain analysis can help to identify the various stages of the fisheries sector and their interdependencies. Four value chain stages (onboard, wholesale, retail, and hypermarket) were examined in Damietta, Egypt, for particular fish species (*Mullus barbatus*, *Sardinella aurita*, and *Diplodus sargus*). The following parameters were assessed in all fish samples to perform the value chain study in the sampling areas of small-scale fisheries: thiobarbituric acid (TBA), total volatile nitrogen (TVN), and pH. The results of the TBA tests and TVN analysis revealed notable disparities between the groups. These tests are frequently used to assess the quality and freshness of fish, and their findings revealed that samples with higher concentrations of these substances had more failures. Conclusively, this study recommends stricter regulations on harvest size restrictions, monitoring programs, certification procedures, postharvest facilities, seasonal closures, social enterprises, finance facilities, and habitat protection, as suggested by applying value chain analysis in small-scale fisheries management.

Keywords: Value chain; Fisheries management; Protein sources; small-scale fisheries

1. Introduction

The relevance of the fisheries and aquaculture sectors in providing people with a necessary animal protein source while lowering unemployment rates in emerging countries is evident. This function is consistent with the Food and Agriculture Organization of the United Nations' strategic goals of "eliminating hunger, food insecurity, and malnutrition" [1]. Fisheries and aquaculture, which are among the world's most crucial productive food resources, should be carefully managed and sustained in order to secure food security since they constitute a safe and reasonable source of animal protein. Given Egypt's aquatic natural resources, both the fisheries and aquaculture sectors are well represented, generating 12% of the Egyptian economy's agricultural national income [2].

Regarding natural fisheries, Egypt has various resources such as northern lakes (Burullus, Mariut, Edku, and Manzala), coastal lagoons (Port Fouad and Bardawil), inland lakes (Al-Morrah, Temsah, Suez Canal, Qarun, Al-Raiyan, Nasser Lake, Toshka, and water bodies in the New Valley), and the Nile River. In 2019, the Egyptian Mediterranean accounted for 48.5% of the total marine production. Nevertheless, production hasplummeted over the past few decades, falling from77,388 tons in 2010 to 48,018 tons in 2019. Furthermore, the total percentage of fisheries production fell from 35% of total aquatic production in 2010 to 20% in 2019. Thus, there is acrucial need to study, analyze, and measure every stage in the natural fisheries sector, starting from the fishing process and ending with the final consumers. This analysis would define the reasons that might stand against developing the marine fisheries sector in Egypt, with a focus on the Egyptian Mediterranean.

The study of value chains in the fisheries sector is a systematic approach to analyzing the main components of the production process, particularly in small-scale fisheries, where ways of improving quality and product design are identified. Moreover, data and information needed for management options and measures are provided [3,4].

Moreover, red mullet, *Sardinella aurita*, and *Diplodus sargus* are the most commercially important fish species in Damietta Port. *Sardinella aurita* is a commercially important fish that needs special attention, and the study of its food and feeding is essential. Several studies were conducted on fisheries and biology [5]. Similarly, *Diplodus sargus* is one of the demersal perciform fishes with high commercial value; it is found in coastal waters worldwide and sustains important recreational and commercial fisheries [6].

Freshness is strongly tied to quality; it is one of the most significant parameters for the fish sector. The determination of postmortem pH provides indications of changes in the physical properties of fish muscles during the storage period [7]. TVN is responsible for the odor and flavor of fish that linger for several days after being caught, and it is used to assess the quality of fish [8]. An estimate of thiobarbituric acid (TBA) was used to evaluate the buildup of secondary oxidation products [9]. Fish is highly susceptible to biogenic amine formation [10]. The Egyptian Mediterranean waters extend for about 1,100 km from west to east, comprising different environmental features where the seabed is flat, primarily muddy to sandy along the middle and eastern coast, and it is rocky in the western area [11].

The proposed study seeks to understand and analyze the value chains of fish and fishery products in Damietta Port, with a focus on thesmall-scale sector, to determine the nutritional value of Mediterranean fish through value chain analysis, which can help identify the different stages of fisheries. Hence, this study aims to evaluate fish freshness levels by applying value chain analysis in small-scale fisheries management

2. Materials and Methods

2.1 Collection of Samples

In total, 30 random samples of fresh fish from different stages, represented by *Mullus barbatus*, *Sardinella aurita*, and *Diplodus sargus*, were collected in December 2023. The lengths of the samples ranged from 10 to 20 cm (*Mullus barbatus*, *Sardinella aurita*, and *Diplodus sargus*). Each sample was kept in a separate plastic bag, held in an ice box, and then transported to the laboratory for examination. Tissue samples were taken from each fish individually using stainless steel instruments on clean glass worktops as recommended by [12].

2.1 Sample Coding: Stages and Species of the *Chain Analysis*

The groups are categorized as follows: Onboard (coded as A), Wholesaler (coded as B), Retailer (coded as C), and Hypermarket (coded as D).

The species under study were identified by the following codes: *Sardinella aurita* (coded as 1), *Mullus barbatus* (coded as 2), and *Diplodus sargus* (coded as 3).

2.2 Determination of pH

Approximately 10 g of material was blended with 10 mL of neutralized distilled water in a blender. The homogenate was shaken continuously for 10 min at room temperature. The pH value was determined by Bye model 6020 (USA). The pH meter calibration utilizes two buffer solutions with known pH (alkaline pH, 7.01; acidic pH, 4.01). Therefore, the pH electrode was washed with neutralized water and then introduced into the homogenate after the temperature correction system was adjusted [13].

2.3 Determination of Total Volatile Nitrogen (TVN)

First, 10 g of the sample was added to 30 mL of distilled water in a clean, dry beaker and thoroughly mixed for 2 min with a blender. Two drops of 0.02M HCl were applied to achieve a pH of 5.2. The homogenate was heated to 70°C and then cooled to room temperature before being filtered. The outer ring was precisely filled with 2 mL sample extract and 1 mL saturated potassium carbonate (KCO_3). The Conway unit was rotated as gently as possible, and the dish was covered and incubated at 36°C for 2 h; HCl in the inner ring was titrated against 0.01M NaOH using methyl red indicator (T1ml): TVN/l00 g = 26.88 x (2-T1), where T1 is the volume of NaOH consumed in the titration [12].

2.4 Determination of Thiobarbituric Acid (TBA)

The method adopted for estimating TBA [9] was applied as follows: TBA test, which depends on the determination of malonaldehyde (MD) as an end product of lipid peroxidation. The extent of oxidative rancidity is typically reported as TBA number or values and expressed as milligrams of malonaldehyde equivalents per kilogram of the samples.

2.5 Statistical Analysis

An analysis of variance (ANOVA) test was applied for statistical evaluation of the results obtained for each parameter according to [14].

3. Results

3.1 pH, TVN, and TBA Values

3.1.1 pH Values for Sardinella aurita

Table 1 shows the pH values in Damietta Port from the four stages (onboard, wholesaler, retailer, hypermarket). Onboard values varied from 6.28 to 6.35 with an average of 6.31; wholesaler from 6.30 to 6.40 with an average of 6.4; retailer from 6.48 to 6.55 with an average of 6.51; hypermarket from 6.40 to 6.55 with an average of 6.46.

Table 1: TVN, TBA, and pH values for *Sardinella aurita* in Damietta*

Stages	TVN (mg/100 g)	TBA (mg malonaldehyde/kg)	pH
A1	24±0.52	2.3±0.86	6.3±1.69
B1	24.3±0.30	2.4±1.04	6.4±0.05
C1	25.2±0.52	2.5±0.96	6.5±0.036
D1	26±0.1	2.5±1.22	6.6±0.07

*Values are represented as mean values ± SD.

3.1.2 TVN Values for Sardinella aurita

TVN values in examined fish onboard samples, varied from 23 to 24 with an average of 23.6 mg%, from wholesaler 24 to 24.6 mg% with an average of 24.3 mg%, Retailer 24.8 to 25.8 mg% with an average 25.2 mg%, and hypermarket 25.8 to 26 mg% with an average of 25.6.

3.1.3 TBA Values for Sardinella aurita

TBA values in the four stages of Damietta Port, varied from 2.2 to 2.3 mg% with an average of 2.25 mg% from the vessel, wholesale 2.3 to 2.45 mg% with an average of 2.38 mg%, retailer from 2.40 to 2.5 mg% with an average of 2.45 mg%, and hypermarket from 2.5 to 26 with an average 2.5.

Table 2: TVN, TBA, pH values for *Mullus barbatus* in Damietta*

Stage	TVN (mg /100 g)	TBA (mg mda/kg)	pH
A2	1.9±0.1	0.2±0.2	6.35±0.1
B2	2.2±0.25	0.45±0.5	6.5±0.05
C2	2.8±0.20	0.5±0.04	6.6±0.07
D2	3.2±0.52	0.7±0.22	6.7±0.10

*Values are represented as mean values ± SD.

3.1.4 pH Values of Mullus barbatus

Table 2 shows the pH values in examined *Mullus barbatus* samples in Damietta Port from four stages (onboard, wholesaler, retailer, and hypermarket). Onboard values varied from 6.2 to 6.45 with an average of 6.2; wholesaler from 6.45 to 6.55 with an average of 6.5; retailer from 6.50 to 6.65 with an average of 6.6; hypermarket from 6.60 to 6.80 with an average of 6.7.

3.1.5 TVN Values of Mullus barbatus

Table 2 presents the TVN values in examined fish onboard samples, which varied from 1.8 to with an average of 1.9 mg%, wholesaler from 2 to 2.5 mg% with an average of 2.2 mg%, retailer from 1 to 2.5 mg% with an average of 2.99 mg%, and hypermarket 2.8 to 3.8 mg% with an average of 3.2.

3.1.6 TBA Values of Mullus barbatus

Table 2 lists the TBA values in four stages types of Damietta Port; for different stages, samples from the vessel varied from 0 to 0.4 mg % with anaverage of 0.2 mg%, wholesale from 0.40 to 0.50 mg% with an average of 0.45 mg%, retailer from 0.50 to 0.59 mg% with an average 0.5 mg%, and from hypermarket 0.59 to 1 with an average of 0.7.

3.1.7 pH Values of Diplodus sargus

Table 3 shows the pH values in examined *Diplodus sargus* samples in Damietta Port from four stages (onboard, wholesaler, retailer, and hypermarket). Onboard values varied from 6.45 to 6.5 with an average of 6.5; wholesaler from 6.46 to 6.55 with an average of 6.6; retailer from 6.50 to 6.60 with an average of 6.5; hypermarket from 6.55 to 6.65 with an average of 6.6.

Table 3: TVN, TBA, pH values for *Diplodus sargus* in Damietta*

Stages	TVN (mg/100 g)	TBA (mg mda/kg)	pH
A3	28±0.6	0.7±0.085	6.5±0.02
B3	28.2±0.77	0.8±0.01	6.6±0.04
C3	28.6±0.8	0.8±0.04	6.5±0.05
D3	28.7±0.9	0.9±0.05	6.6±0.05

*Values are represented as mean values ± SD.

3.1.8 TVN Values Diplodus sargus

Table 3 demonstrates the TVN values in examined fish onboard samples, which varied from 27.9 to 28.3 with an average of 28 mg%; wholesaler 28 to 28.45 mg% with an average of 28.2 mg%; retailer from 28.5 to 28.80 mg% with an average 28.6mg%; hypermarket from 28.5 to 29 mg% with an average of 28.7.

3.1.9 TBA Values in Diplodus sargus

Table 3 displays the TBA values in four stages types of Damietta Port for different stages. Values for samples vessel varied from 0.60 to 0.77 mg% with an average of 0.7 mg%, wholesale from 0.77 to 0.80 mg% with an average of 0.8 mg%, retailer from 0.80 to 0.88 mg% with an average of 0.8 mg%, and hypermarket from 0.88 to 0.99 with an average 0.9.

3.2 Statistical analysis

3.2.1 Correlation Matrix

The data from Damietta Port reveals that the correlation coefficient between TVN and TBA is 0.68, indicating a positive correlation. However, the pH value for TVN and TBA were -0.35 and -0.69, respectively, shows a nonsignificant correlation.
The correlation matrix for *Mullus barbatus* in Damietta Port, as shown in Table 7, reveals that the correlation coefficient between TVN and TBA is 0.75, indicating a positive correlation. However, the correlation between TVN and pH is -0.21, suggesting a nonsignificant correlation. Similarly, the correlation between TBA and pH is also nonsignificant, with a coefficient of -0.47.
The correlation matrix for *Diplodus sargus* in Damietta Port, reveals that the correlation coefficient between TVN and TBA is 0.5, indicating a positive correlation. However, the correlation between TVN and pH is -0.17, which shows a nonsignificant correlation. Similarly, the correlation between TBA and pH is also not statistically significant, with a coefficient of -0.46. Similar patterns can, therefore, be observed in the correlation matrices for *Sardinella aurita*, *Mullus barbatus*, and *Diplodus sargus*, with strong positive correlations between TVN and TBA, as well as moderate nonsignificant correlations between TVN, pH, and TBA, pH.

These findings provide insights into the biological characteristics of the three types of fish. *Sardinella aurita* shows higher TVN and TBA values, indicating potentially more increased levels of protein breakdown and oxidative rancidity. *Mullus barbatus* exhibits lower TVN and TBA values, suggesting better preservation of protein qualityand lower lipid oxidation. *Diplodus sargus* falls between the other two types in terms of TVN and TBA values.

3.2.2 ANOVA Analysis

The ANOVA analysis provides the p-values and significance levels for TVN, TBA, and pH for each type of fish in the four stages in each port. The p-value represents the probability of obtaining the observed results by chance, according to [15].
Table 4. ANOVA of TVN, TBA, and pH in the examined samples of *Sardinella aurita*, *Mullus barbatus*, and *Diplodus sargus* for all stages. A) Representing ANOVA: Single Factor summary; B) Other ANOVA results.

Table 4A: ANOVA Single Factor Summary

Table 4B: Other ANOVA tests

Group	Count	Sum	Average	Variance
TVN	16	299.73	18.73313	129.5562
TBA	16	24.27	1.516875	0.910356
pH	16	104.47	6.529375	0.032006

Source of variation	SS	Df	MS	F	p-value	f-value
Between groups	2509.0	2	1254.54	28.84	8.68E^{-09}	3.2
Within groups	1957.4	45	43.49			
Total	4466.5	47				

The sum of Squares between-group SS quantifies the variability among the sample means of different groups. Degrees of Freedom (DF) refer to the number of independent values or pieces of information used to estimate a statistical parameter, crucial for determining the significance of differences between group means. MS (Mean Squares) combines both inter- and intra-group freedom, reflecting the total freedom boundaries in unifying change by adding aesthetics of inter- and intra-group boundaries. F-statistic is a statistical measure utilized in Analysis of Variance (ANOVA), indicating the ratio of variance between groups to within groups.

In table 4A and B, source of variation in the port of Damietta for *Sardinella aurita*, *Mullus barbatus*, and *Diplodus sargus*, was significant between groups with p-value 8.68E^{-09}.

4. Discussion

Chemical indicators, such as pH, TVN, and TBA, are the most widely used criteria in assessing fish quality [16]. Three types of marine fish (*Sardinella aurita*, *Mullus barbatus*, and *Diplodus sargus*) were examined chemically in this study to determine the extent of their preservation and safety for human consumption.
Regarding the pH value, the present results were consistent with those reported by [17] but higher than those obtained by [18,19]. pH is considered a limited factor for survival of bacteria in fish [20]. It decreases uniformly during the frozen storage [21]. pH value is not a suitable index for freshness assessment and can be helpful as a guideline for the quality control of fish [22]. The differences

between species were nonsignificant. [15] reported the critical limits of pH for the fish portion, which should not be more than 6.5. Hence, 94.44% of the samples were deemed acceptable, whereas 5.56% were considered unacceptable, resulting in a 100% acceptance rate.

Regarding the TVN value, the result was balanced with those of former studies [8,16], TVN levels are affected by the method of catch, postmortem treatment, and storage temperature [23] and differ according to species [24]. TVN is a poor indicator of fish freshness, but it has been used to evaluate fish muscle spoilage [25], and TVN does not reflect the mode of spoilage [8]. TVN is one of the most widely used parameters to evaluate fish quality[16]. TVN levels less than 20 mg% indicate fish ofgood quality, whereas doubtfully accepted fish contain TVN around 30 mg%. However, fish containing 40 mg% are considered unfit for humanconsumption [26,27] recorded that initial sign of spoilage appear at 28–29 mg% TVN.

TBA is an important quality indicator for fatty fish. The higher the fat content in fish, the higher the TBA value in fish. TBA factor is responsible for decadent flavor, odor, and color as well as deterioration of texture [23]. Differences between the examined fish were highly significant (P <0.01). According to the Egyptian Organization for EOS standardization [15], the maximum permittedTBA value was 10. Finally, all tested samples were accepted.

5. Conclusion

This study concluded that specific chemical tests are efficient for the evaluation of fish quality. In this respect, TVN and TPA appeared to be reliable indicators for determining proteolytic activity. *Mullus barbatus* is the fish sampled with the lowest pH, TVN, and TMA, and this indicates a more extended period of availability. Caution should be exercised when handling *Sardinella aurita* and Deplodus sargus due to elevated levels of pH, TVN, and TMA, which are indicative of rapid spoilage.

Based on the results of this study, we suggest the following:

1. Chemical assessment of fish quality is recommended as it is a rapid, accurate method and provides a good indication of fish quality.
2. pH is a poor indicator of fish quality because it varies significantly between fish species.
3. TVN and TPA are suitable indices of freshness assessment for proteolytic activity.
4. When purchasing fresh whole fish, look for clear eyes with a slight bulge. The flesh on whole fish and fillets is firm and shiny. Fresh whole fish havebright red or pink gills that are free of bad slime. The skin is shiny and covered in scales that adheretightly.
5. There is no discoloration or darkening around the edges of the fish, including the gills. The fish smells fresh, devoid of any sour, fishy, or ammonia-like odors.

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Timeline of Publication
Received Date: 3 February 2024
Revised Date: 15 February 2024
Accepted Date: 28 February 2024
Published Date: 1 Mach 2024