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Original Research

Quality Assessment and Impact of Gamma Irradiation on Histamine Content in Some Fish Consumed in Sharkia Province, Egypt

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Abstract

The current study was conducted to investigate the quality assessment of some fish (Tilapia, Mullet, Mackerel, and Sardine) consumed in Sharkia province, Egypt using chemical parameters (pH, TMA, TBA, and TVN), bacteriological analyses (*S. aureus*, *E. coli*, and *Salmonella*), and sensory attributes. The histamine content of analyzed fish was also investigated, along with the effect of gamma irradiation (Dose 0, 1, 3, 5 KGy) on its level. The results indicate that the overall grades of organoleptic evaluations were acceptable and all examined fish samples were within the histamine permissible limit. All the fish samples tested were found to be below the allowable Egyptian Standards for pH, TMA, TBA, and TVN. Furthermore, the obtained results revealed that the maximum viable count of *S. aureus* isolates was detected in sardines. Tilapia and mullet were the most contaminated fish with *E. coli* (73%). Mullet was the most abundant fish contaminated with *Salmonella* spp (53%), while sardine was the least frequent (20%). On the other hand, the histamine level was reduced significantly ($p < 0.05$) and progressively in a dose-dependent manner as the gamma irradiation dosage increased in fish fillet artificially inoculated with histamine. The treated fish fillet with a dose of 5 KGy gamma radiation had the lowest mean value (5.27±0.78).Iin conclusion, application of gamma irradiation can considerably minimize the danger of histamine poisoning related with fish and fish products deterioration.

KEYWORDS
Bacteriological evaluation, Fish, Gamma Irradiation, Histamine, Quality assessment, Sensory evaluation.

INTRODUCTION

Fish is currently getting expanding consideration in human food in both advanced and developing countries due to its palatability, nutritious and healthy animal protein, in addition to its role in solving the problem of animal meat shortages, especially in the last decade (Morshdy *et al*., 2022). Fish is extensively consumed by humans in several parts of the world due to its high digestible protein content, essential amino acids, minerals, and a fair proportion of B-vitamins to maintain good health. Fish also contains a low amount of saturated fat and two types of omega-3 polyunsaturated fatty acids, which are essential for normal growth as they diminish cholesterol levels and the incidence of heart disease (Al bader, 2008).

Fish is a perishable food product, so the quality deterioration occurs rapidly by enzymatic and chemical reactions that cause an initial loss of freshness and microbial activity that is responsible for the obvious spoilage (Pal *et al*., 2016). After death of fish, the activity of spoilage bacteria increases, resulting in a subsequent increase in the reduction of trimethyle-amine oxide (TMAO) to trimethyle-amine (TMA) (Yusuf *et al*., 2010). Total volatile basic nitrogen (TVB-N) is formed by microbial activity after the breakdown of protein and non-protein nitrogenous compounds (Fan *et al*., 2008). Thiobarbituric acid (TBA) is an indication of oxidative rancidity in fish and fish products (Tsaknis *et al*., 1999). Besides, *Salmonella*, *Escherichia coli* and *S. aureus* are the leading food-borne pathogens that have been detected repeatedly in a lot of fish and fish products (Kuhnert *et al*., 2000; Karmali, 2004; Amagliani *et al*., 2012). Therefore, it is necessary to ensure hygiene and food safety for the consumer´s health.

Between 2005 and 2010, histamine intoxication outbreaks using the Rapid Alert System for Food and Feed (RASFF) exceeded 100 cases (EFSA, 2011). Histamine is an endogenous substance that occurs naturally in the human body and is derived from the decarboxylation of the amino acid histidine. Histamine can also be found in foods containing free histidine, and it is produced by certain bacteria during the spoilage and fermentation of meat and meat products (Mahmoud *et al*., 2021). Its biological effects are usually seen only when large amounts of it are released in the course of allergic and other reactions (Parisi *et al*., 2015). Scombroid poisoning is commonly associated with the consumption of spoiled fish. Scombrotoxin is a poisonous substance that is formed during spoilage and is usually associated with the formation of heat-stable biogenic amines like histamine (Huss *et*

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al., 2004).

Irradiation is a 'cool' technique known as (cool pasteurization) that does not cause a temperature increase. Irradiated fish maintain their flavors and aromas. It also avoids the employment of chemical treatments to control bacteria and other pests, such as fumigation or insecticides (Ashraf *et al*., 2019). Irradiation is recognized as an effective, widely used food processing technique. This process involves exposing food to a carefully controlled amount of energy in the form of high-speed particles or rays which reduces the risk of food poisoning, controls food spoilage and extends the shelf life of food while posing no health risks and having minimal effect on nutritional or sensory quality (ICGFI, 2002). Therefore, the current study was carried out to investigate the quality assessment of certain fish consumed in Sharkia province, Egypt as well as to investigate the effect of gamma irradiation (Dose 0, 1, 3, 5 KGy) on fish fillet artificially inoculated with histamine.

MATERIALS AND METHODS

Samples collection

The collected samples included tilapia, mullet, mackerel, and sardine (25 of each). Samples were randomly collected from different fish markets in Sharkia Province, Egypt. Each sample was kept in a separate sterile plastic Ziplock bag and immediately transported to the Meat Hygiene, Safety, and Technology Laboratory within 1 h.

Sensory evaluation of the investigated fish

The sensory assessment was performed using the scoring test developed by Kilinc and Cakli (2004). The score for sensory evaluation of fish fillets: Overall acceptability = 20 (5 for each of appearance, odor, texture, and flavor); 20 = Excellent (Acceptable); 18.2–19.9= Very good (Acceptable); 15.2–18.1 = Good (Acceptable); 11.2–15.1= Middle; 7.2–11.2= Poor (Border line); Spoiled (Unacceptable) = 4–7.1.

Chemical analyses of examined fish

The proximate composition of the studied fish was applied for determination of moisture, protein, fat, carbohydrates, and ash according to the standard method recommended by the Association of Official Analytical Chemists (AOAC, 2005). The pH was determined according to the method described by Pearson (2006). Total volatile basic nitrogen (TVB-N) content was estimated according to ES: 63-9 (2006). The thiobarbituric acid (TBA) content was calculated by the method of ES: 63-10 (2006). Measurement of the Trimethylamine (TMA) value was performed according to FAO (1980).

Bacteriological analyses of the investigated fish

The aerobic Plate Count (APC) was performed according to ISO 4833-1 (2013) using plate count agar and incubated for 48 h at 37°C. *Staphylococcus aureus* CFU/g was calculated as a presumptive count (APHA, 1992). Phenotypic identification of the *Staphylococcus aureus* isolates was based on standard bacteriological methods (Becker *et al*., 2015) and the API 20S identification kit (BioMerieux, Marcy l'Etoile, France). Also, detection and typing of enterotoxins were detected according to Shingaki *et al*. (1981). The suspected *E. coli* and *Salmonella* spp. colonies were subjected to isolation according to Barrow and Feltham (1993) and Vassiliadis (1983), respectively. The colonies were also morphologically identified according to MacFaddin (2000), in addition to being serologically identified according to Kok *et al*. (1996) and Kauffman (1974), respectively.

Determination of histamine levels

The determination of histamine levels in the fish samples was performed by using ELISA (Leszczynska *et al*., 2004), in combination with a supplementary kit (available for purchase separately, cat. no. BA E-1100). For sample preparation, the protocols, which are based on the Association of Official Analytical Chemists (AOAC) Official Method 937.07, were applied. The concentrations of histamine can be read directly from the standard curve.

Artificial inoculation of fish fillets by histamine

The samples were aseptically excised with sterile knives and cut into 2 × 2 cm pieces (4 cm2) to a thickness of about 0.5 cm. The samples (12 per experiment: 3 control untreated samples, 3 gamma-treated at 1 KGy, 3 gamma-treated at 3 KGy, and 3 gamma-treated at 5 KGy) were placed flattened out on the bottom of sterile small petri dishes. Then the samples were inoculated by spreading a 25 micron/gm of standard solution of the inoculum that was equal to 25 mg of histamine per 100 gm of sample as the inoculum was prepared by adding 10 mg of histamine to every 1 ml of distilled water. The inoculum was spread evenly over the entire surface of each sample, and the samples were allowed to dry for 15 min before exposure to gamma irradiation.

Gamma irradiation treatment

The irradiation process was carried out at the National Center for Radiation Research and Technology (NCRRT) in Nasr City, Cairo, Egypt. The Indian Gamma Cell was employed for irradiation and the dose rate was 0.7881 KGy/h. The radiation source was Cobalt60, which assured uniform gamma irradiation of the experimental samples. The fish fillet samples were prepared and grouped before being submitted to the previously stated gamma irradiation procedure. The tests were replicated three times. Upon completing the desired passes, each package was returned to the cooler along with ice and transported to the laboratory for analysis.

Statistical analysis

The values were presented as means±standard error (SE). The data were subjected to the statistical package for social sciences (SPSS-16.; Chicago, IL, USA) software and one-way Analysis of Variance (ANOVA) at 95 % level of confidence. Significant differences among the means were determined by Tukey's Kramer HD test considering $P < 0.05$ as significant.

RESULTS

Sensory evaluation of the investigated fish samples

In this study, the organoleptic properties of the analyzed fish revealed that all fish were approved, as poor and spoilage records were not observed among these fish. The overall score was 18.0±0.03, 19.4±0.01, 18.8±0.04 and 17.2±0.02; hence, the overall grade for Tilapia, Mullet, Mackerel and Sardine was Good, Very good, Very good and good, respectively (Table 1).

Table 1. Sensory evaluation of the examined fish samples.

Fish samples	Color (5)	Odor (5)	Texture (5)	Flavor (5)	Overall score (20)	Grade
Tilapia	4.8±0.01	4.2±0.05	4.4±0.01	4.6±0.04	18.0±0.03	Good
Mullet	5.0±0.00	4.6±0.01	5.0±0.00	4.8±0.00	19.4±0.01	Very good
Mackerel	4.8±0.05	4.6±0.04	4.6±0.03	4.8±0.03	18.8±0.04	Very good
Sardine	4.6±0.03	4.0±0.01	4.2±0.00	4.4±0.02	17.2±0.02	Good

Bacteriological analyses of the investigated fish samples

Aerobic plate count (APC)

As shown in Table 2, mullet and sardine had the lowest and highest aerobic plate count (APC) among the investigated fish samples, with mean values of 6.25 and 7.85 log_{10} CFU/g, respectively.

Table 2. Statistical analytical results of APC (log_{10} CFU/g) of the examined fish samples.

Fish samples	Minimum	Maximum	Mean±SE
Tilapia	5.00	7.80	6.28±0.27^{b}
Mullet	5.00	9.22	6.25±0.33^{b}
Mackerel	5.38	8.13	7.40±0.18^{a}
Sardine	5.00	9.72	7.85±0.38^{a}

Means within the same column carrying different superscripts are significantly different at ($p < 0.05$) based on Tukey's Kramer HD test. S.E. = Standard error of mean.

Staphylococcus aureus and *Staphylococcus aureus* enterotoxins (SEs)

According to the data in Table 3, the *Staphylococcus aureus* count (log_{10} CFU/g) had the highest mean value in the examined sardine samples (4.71±0.24) that ranged from 0.00 to 5.83. These results are not significantly different ($p > 0.05$). The acceptability of *Staphylococcus aureus* must not exceed 10^3 CFU/g for chilled and frozen fish according to the permissible limit (PL) recommended by Egyptian standards (ES, 2005).

In the present study, *S. aureus* enterotoxins A, C and D were detected (Fig. 1). The enterotoxin A was detected in 33.3% of the isolates from Tilapia, whereas enterotoxin C was found in 50% of Mullet isolates. On the other hand, both enterotoxin A and D were recorded in Sardine isolates. Fortunately, all Mackerel isolates were non-toxigenic strains.

Table 3. Statistical analytical results of *S. aureus* count (log_{10} CFU/g) of the examined fish samples.

Fish samples	Minimum	Maximum	Mean±SE
Tilapia	3.40	4.68	3.77±0.17^{b}
Mullet	3.36	5.53	3.75±0.20^{b}
Mackerel	3.23	4.88	4.44±0.11^{a}
Sardine	3.28	5.83	4.71±0.24^{a}

Means within the same column carrying same superscripts are not significantly different at ($p > 0.05$) based on Tukey's Kramer HD test.

Identification Escherichia coli

From the results illustrated in Fig. 2, Tilapia and Mullet were the common fish food infected with *E. coli* with a prevalence rate of 73% followed by Mackerel and sardine. Regarding to the *E. coli* serotypes among the tested fish samples, EHEC and EPEC strains were detected among all tested fish samples; meanwhile, one EAEC strain was found only among Mullet samples. Two EIEC strains were distributed among both Mackerel and Sardine, however, three ETEC strains were detected among Tilapia (2) and Mackerel (1).

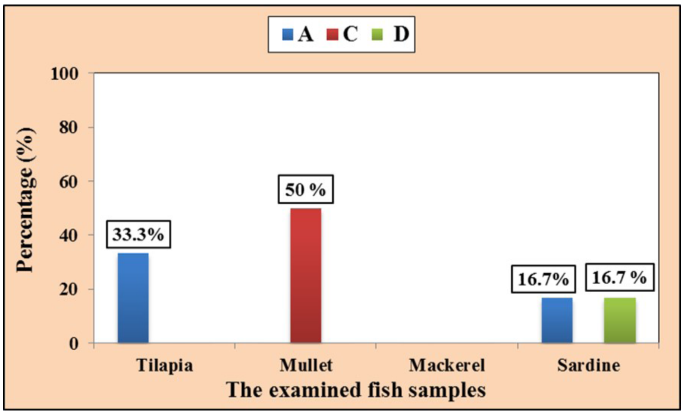

Fig. 1. Prevalence of enterotoxins in the coagulase Positive *S.. aureus* fish samples.

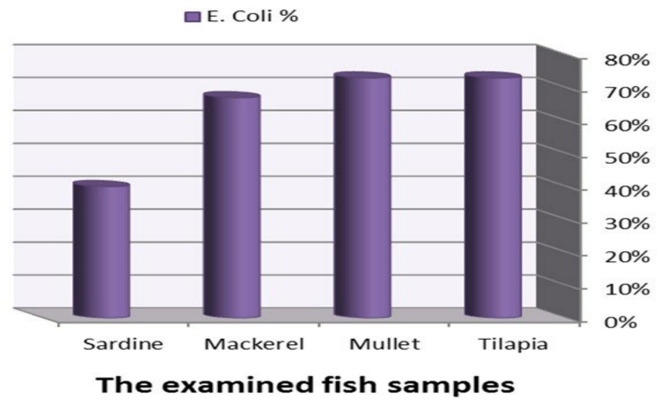

Fig. 2. Prevalence of *E. coli* in the investigated fish samples.

Identification of *Salmonella*

The summarized results obtained in Fig. 3, revealed that mullet was the common fish contaminated with *Salmonella* spp with a prevalence rate of 53% while, sardine prevalence was the lowest (20%). According to the results of serotyping, *Salmonella enteritidis* was detected in all analyzed fish samples. One isolate of each *Salmonella* Typhimurium, *Salmonella chester*, *Salmonella derby*, and *Salmonella* anatum was identified among Mackerel, Sardine, Mullet, and Tilapia fish samples, respectively. Two *Salmonella saintpaul* and the other two *Salmonella rissen* strains were distributed among Mackerel, Sardine and Mullet, Tilapia, respectively.

Chemical analyses of the investigated fish samples

Proximate composition of examined fish

The proximate composition of the examined fish was shown in Table 4. The moisture content has the lowest and the highest mean values in Tilapia and Sardine 72.70±0.23 and 74.07±0.24, respectively. The lowest and highest Protein % was recorded among Mackerel and Tilapia with mean values of 18.53±0.20 and 22.2±0.38, respectively. The highest Fat content was recorded in Mackerel with a mean value of 3.93±0.24. The highest Ash % was recorded in Tilapia with a mean value of 2.20±0.17. Meanwhile, carbohydrates % had no significant difference among the examined fish.

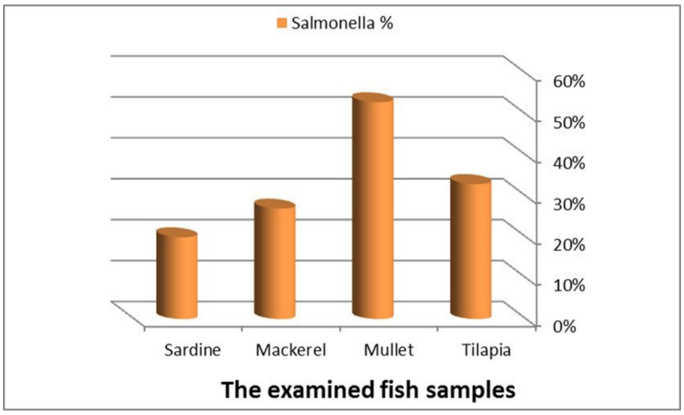

Fig. 3. Prevalence of *Salmonella* species in examined fish samples.

Chemical quality of the investigated fish samples

As shown in Fig. 4, All examined samples were within the permissible limits of pH, TMA, TBA and TVN recommended by the Egyptian standards (ES, 2005), which are 6.50, 10 mg N /100 g, 4.5 mg monoaldehyde /100 g and 25-35 mg N /100 g, respectively.

Determination of histamine content in examined fish samples

The results illustrated in Table 5, declared that the level of histamine (mg/100g) in the examined fish samples ranged from 1.89 to 5.86 with a mean value of 4.24±5.18; from 0.25 to 0.75 with a mean value of 0.35±1.00; from 0.25 to 2.87 with a mean value of 1.31±4.31 and from 0.25 to 8.18 with a mean value of 1.84±0.00 for Tilapia, Mullet, Mackerel and Sardine, respectively. The permissible limit of histamine suggested by the Egyptian standards (ES, 2005) is 10-20 Mg/100 g, so all samples were within this range.

Effect of gamma irradiation on histamine levels in artificially contaminated fish fillet

The data shown in Fig. 5, reveal that irradiation has a significant effect ($p < 0.05$) on histamine levels. The differences between the examined fillet (control, 1, 3 and 5 KGy irradiation doses) was 25.00±0.00, which afterwards reduced to 11.90±1.46, 8.13±0.50 and 5.27±0.78 mg/100 g, respectively.

DISCUSSION

In addition to being a healthy food with high nutritional value, fish can act as a source of food-borne intoxications. Fish quality has great importance for consumers, food processors, and public health authorities. So, providing safe and acceptable fish can be

Table 4. The proximate composition of the examined fish samples.

Fish samples	Minimum	Maximum	Mean±SE
		Moisture %	
Tilapia	72.3	73.1	72.70±0.23[b]
Mullet	72.9	74.0	73.47±0.32[ab]
Mackerel	72.8	73.7	73.23±0.26[ab]
Sardine	73.6	74.4	74.07±0.24[a]
		Protein %	
Tilapia	21.5	22.8	22.20±0.38[a]
Mullet	19.4	20.6	19.90±0.36[b]
Mackerel	18.2	18.9	18.53±0.20[c]
Sardine	18.9	19.6	19.20±0.21[bc]
		Fat %	
Tilapia	1.6	2.1	1.83±0.15[c]
Mullet	2.3	2.9	2.57±0.18[bc]
Mackerel	3.6	4.4	3.93±0.24[a]
Sardine	2.4	3.2	2.77±0.23[b]
		Carbohydrates %	
Tilapia	0.6	0.9	0.73±0.09[a]
Mullet	0.7	0.9	0.83±0.07[a]
Mackerel	0.6	0.8	0.67±0.07[a]
Sardine	0.8	1.0	0.87±0.07[a]
		Ash %	
Tilapia	1.9	2.5	2.20±0.17[a]
Mullet	1.7	2.1	1.87±0.12[ab]
Mackerel	1.9	2.2	2.03±0.09[ab]
Sardine	1.5	1.8	1.63±0.09[b]

In each individual criterion: Means within the same column carrying different superscripts are significantly different at ($p < 0.05$) based on Tukey's Kramer HD test.

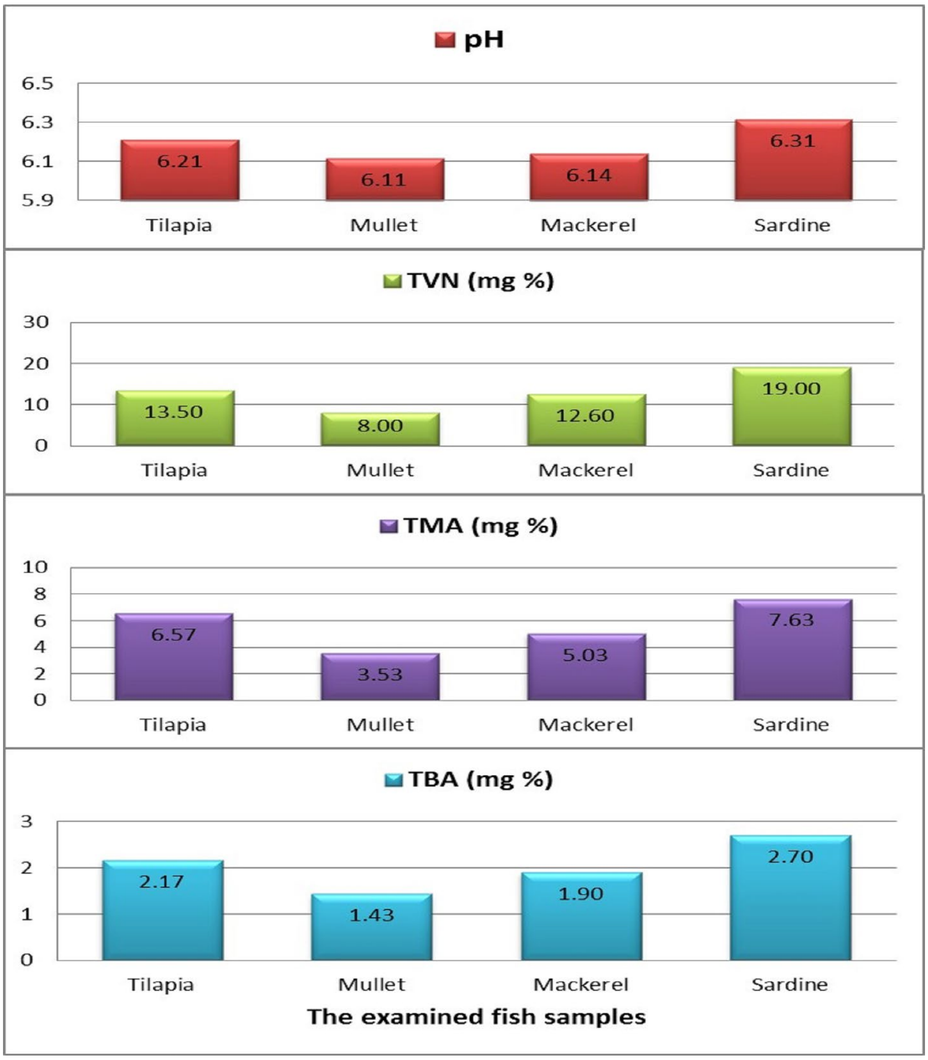

Fig. 4. Chemical quality of the examined fish samples.

acquired by control of contamination from the time of harvesting till marketing.

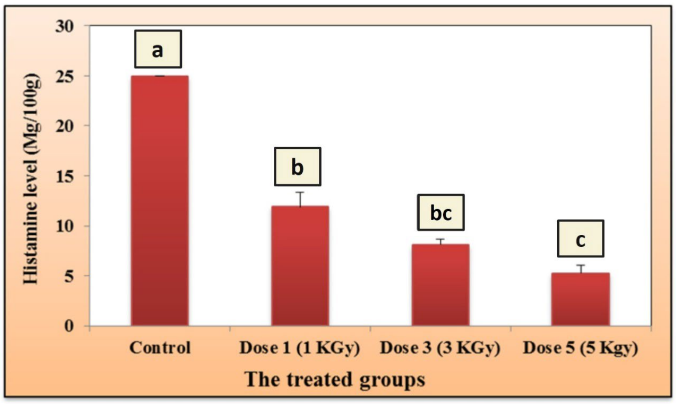

Fig. 5. Effect of different doses of gamma irradiation on the histamine content (mg/100g) in artificially contaminated fish fillet.

The organoleptic evaluations are rapid, cheap, and non-destructive methods for evaluating the freshness changes in the fish and may be used in determining the fair price of the fish products. In this study and in accordance with Morshdy *et al.* (2002), the overall grades of organoleptic evaluations were good, very good, very good, and good for Tilapia, Mullet, Mackerel and Sardine, respectively.

Although fish flesh itself is normally sterile because pathogen invasion is prevented by the natural defense system of the body while the fish is alive. After death, the defense system breaks down, so the bacteria multiply and invade the flesh. Due to the aforementioned crises, there is a public challenge to provide the community with safe and acceptable fish, so microbiological evaluations are essential to prevent the wide spread of food-borne pathogens.

Table 5. Histamine content (mg/100g) in the examined fish samples.

Fish samples	Minimum	Maximum	Mean±SE
Tilapia	1.89	5.86	4.24±5.18^{a}
Mullet	0.25	0.75	0.35±1.00^{c}
Mackerel	0.25	2.87	1.31±4.31^{b}
Sardine	0.25	8.18	1.84±0.00^{b}

Means within the same column carrying different superscripts are significantly different at ($p < 0.05$) based on Tukey's Kramer HD test.

Aerobic plate count (APC) is considered as an indicator of the overall degree of microbial contamination of fish. The APC acceptability according to the permissible limit recommended by the Egyptian standards (ES, 2005) is not more than 6 $\log_{10}$ CFU/g for chilled and frozen fish. The results illustrated in this study were above the permissible limit and at nearly the same range as the previous reports by El-Habib (2011) and Mustafa *et al.* (2013), and higher than other studies by Popovic *et al.* (2010) and Prabakaran *et al.* (2011).

The high counts of *S. aureus* and high percentages of isolation among investigated fish samples in this study and other studies (Ezzeldeen *et al.*, 2011; Fatin Hassanien *et al.* 2014; Brandas *et al.* 2015; Macori *et al.*, 2016) were due to fish contamination during harvesting and subsequent unhygienic practices during handling and processing, as *S. aureus* does not normally appear as a part of the natural microflora of newly caught marine and cultivated fish. In contrast to the recorded result about *S. aureus* enterotoxins serotyping, Brandas *et al*. (2015) discovered no enterotoxin C in Mugil cephalus (bottarga). Additionally, Ali *et al*. (2020) found that one of *S. aureus* tested isolates from mackerel fish was positive for SEB and SEC.

On the other hand, a higher prevalence rate of *E. coli* and *Salmonella* spp. was recorded in contrast to other previous studies (Elham, 2017; Saad *et al*., 2018). The variance in fish microbiological contamination levels may be attributable to differences in handling procedures and the possibility of contamination by water sources. *E. coli* isolates were serologically identified in the current study, which agreed with Costa (2013), who reported that six types of diarrheagenic *E. coli* isolates have been identified as: enterotoxigenic *E. coli* (ETEC), enteropathogenic *E. coli* (EPEC), enteroinvasive *E. coli* (EIEC), enterohemorrhagic *E. coli* (EHEC), Shiga toxin-producing *E. coli* (STEC), or enteroaggregative *E. coli* (EAEC). Similarly, Vieira *et al*. (2001) isolated 18 enterotoxigenic *E. coli* (ETEC) bacteria from three of the 24 fresh fish samples collected from Brazilian markets. In accordance with the findings of the current study on isolated *Salmonella* serotypes, Allam *et al*. (2019) conducted a study which revealed that the most common serotypes were *S. typhimurium* (33.3%), followed by *S. enteriditis* (23%). According to Fernandes *et al*. (2018) *S. typhimurium* and *S. enteriditis* cause the majority of human salmonellosis illnesses linked to fish eating.

In comparison to the proximate composition of the investigated fish samples in this study, Kamal *et al*. (2007) and Makanjuola (2012) obtained higher results for moisture% and ash%, and lower protein percentage. Meanwhile, Ahmed *et al*. (2010) recorded comparable results for the recorded fat content in Tilapia samples. Furthermore, the recorded results for carbohydrate percent were slightly higher than Gram and Melchiorsen (1996), who discovered that most fish contain very little carbohydrate (0.5%) in their flesh.

Similar findings for pH value were recorded by Simeonidou *et al*. (1998); Mazrouh (2015); Ozogul *et al*. (2006) and Fan *et al*. (2009). However, the obtained TMA results were higher than those reported by Makharita *et al*. (2015) and Seibel and Walsh (2002), and lower than the results obtained by Talab *et al*. (2016); Ježek and Buchtov (2014) and Bilgin *et al*. (2016). According to Ruiz-Capillas and Moral (2005), TVB-N is considered as a fish quality index. Its concentration increases in response to the activity of spoilage, endogenous enzymes, and spoilage bacteria, which produce the characteristic off-flavors and off-odors of fish.

The recorded TVN results in the current study agreed with Muhammet and Sevim (2007). Furthermore, the obtained findings were greater than those published by Mary *et al*. (2013) and Nassar (2015), but lower than those reported by Ali (2011); Makharita *et al*. (2015); Talab *et al*. (2016) and Elattar *et al*. (2017). Tokur *et al*. (2006) determined that thiobarbituric acid (TBA) is an excellent indication of fatty fish quality, while Yarnpakdee *et al*. (2012) mentioned that TBARS readings may be used to determine Tilapia freshness. Also, Makharita *et al*. (2015) recorded nearly similar TBA results in mackerel. Meanwhile, higher findings were found by Elattar *et al*. (2017), whereas Ali (2011); Olgunoglu *et al*. (2002); Hussein *et al*. (2019); Nassar (2015) and Talab *et al*. (2016) discovered lower findings.

Fortunately, in this present investigation, the histamine content in all investigated fish samples was within the histamine permissible limit established by Egyptian standards (ES, 2005). Compared to results obtained, El-Ghareeb *et al*. (2021) found that mackerel had the highest mean concentrations of histamine (110.800±1.630 mg/kg), followed by sardine (78.550±1.536 mg/kg), mullet (22.550±0.738 mg/kg), and tilapia (17.700±0.506 mg/kg), respectively. On the other hand, histamine fish poisoning was recorded as a major foodborne disease in Japan from 1998 to 2008, where 13 % and 7 % of the involved histamine fish poisoning incidents in fish species were reported in mackerel and sardine (Taylor and Sumner, 1987).

In an attempt to apply a new and safe method of food preservation that can lower the risk of biogenic amine poisoning, food irradiation is an attractive technology for improving the quality of food (Naila *et al*., 2010). In general, irradiation maintained the overall good impression of the preserved food (Mantilla-Samira *et al*. 2012). Interestingly, the histamine concentration was reduced in a dose-dependent manner in this study, which is consistent with other published studies by Mendes *et al*. (2000); Mendes *et al*. (2005) and Ramakrishna Reddy *et al*. (2020), who concluded that histamine concentration was significantly reduced as the radiation dose increased in the examined fish samples. However, lower results obtained by Maltar-Strmečki *et al*. (2013) also show that gamma irradiation lowered histamine levels. In a brief context, we observed that the histamine concentration was reduced significantly as the radiation dose increased in the examined fish samples, and so the gamma irradiation reduces the risk of histamine poisoning and can control it.

CONCLUSION

Gamma irradiation is regarded as a valuable tool for controlling and reducing the danger of histamine poisoning associated with fish deterioration. A combination of chemical, bacteriological, and organoleptic tests would be the most effective method for determining fish freshness. The organoleptic and chemical evaluation results contradicted the microbiological evaluations of the examined fish samples. Improved sanitary standards in stores, retail, and markets, as well as developing control measures for keeping quality and delaying the formation of histamine, lower the health risk of histamine poisoning.

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CONFLICT OF INTEREST

The authors declare that they don't have conflict of interest.

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