World Journal of Advanced Research and Reviews

eISSN: 2581-9615 CODEN (USA): WJARAI

Cross Ref DOI: 10.30574/wjarr

Journal homepage: https://wjarr.com/

(Research Article)

Implementation of HACCP System in a tuna fish Industry

Ikbel Denden [1, *], Mondher Njehi [2] and Boubaker Krifi [2, 3]

[1] *Laboratory of Biologically Active Substances and Communicable Diseases (LR99ES27), Faculty of pharmacy, Monastir University, Monastir, Tunisia.*

[2] *Laboratory of Bio-ressources: Biologie Intégrative et Valorisation Biolival (LR14ES06) Monastir - Higher Institute of Biotechnology University of Monastir. Tunisia.*

[3] *Laboratory of Biochemistry"Nutrition-functional Foods and Vascular Health", Faculty of Medicine of Monastir, Tunisia.*

World Journal of Advanced Research and Reviews, 2024, 21(03), 1899–1909

Publication history: Received on 06 December 2023; revised on 27 February 2024; accepted on 29 February 2024

Article DOI: https://doi.org/10.30574/wjarr.2024.21.3.0158

Abstract

The challenge of this work was to guarantee the safety of canned tuna by HACCP implementation system. 4 critical control point (CCPs) were selected by an experienced team HACCP to evaluate the efficiency of the system in a tuna fish Industry. The CCP_1 is the control of the freshness of the flesh of tuna fish on receipt. The CCP_2 is a determination of the levels contents of the histamine and of the mercury of the tuna on receipt. The CCP_3 is the control of the seams. The CCP_4 is the sterilization. The levels of histamine and mercury contents in fish receipts were aranged between 10.5-29.5 and between 0.022-0.055 mg/kg respectively. No microbiological contamination was detected. pH values were ranged between 5.65-6.02 and the cold chain was respected. Thus, the results show that all CCPs are controlled and validated.

Keywords: Critical control point (CCP); HACCP; Quality; Safety; Tuna fish.

1. Introduction

In 2017, Tunisia produced 129.5 thousand tons of fish and aquaculture, with the majority intended for fresh consumption. Only around 15.6% of this production was exported, primarily in frozen form, while 30% was processed into canned and semi-preserved tuna and sardines (Tunisian Statistical Yearbook, 2017).

According to the Tunisian Ministry of Agriculture, Fisheries, and Water Resources, tuna exports experienced a notable surge in 2017, with a 79% increase in quantity, totaling 780.4 tons. The processing of tuna encompasses various species, including "*Thunnus thynnus*," renowned for its distinctive flavor, as well as other species like *yellow fin* tuna and *skipjack*, in response to high demand in the domestic market (Tunisian Statistical Yearbook, 2017).

The processing of tuna primarily focuses on the species *Thunnus thynnus*, prized for its exceptional taste characteristics. Canned Tunisian products, including sardines and tuna, have established a strong brand reputation and are highly regarded by consumers worldwide. These products are exported to various nations across the globe. Since 1998, the fish processing industry has adhered to stringent safety and hygiene standards to comply with regulations, ensuring the quality and safety of the final products (Official Journal of the Tunisian Republic, 1998).

The crucial aim of fish quality control, according to Domingo (2007), consists to find some methods by defining the suitability or excellence of the fish for processing. Among the control methods or systems for food safety, Hazard Analysis of Critical Control Points (HACCP) [Baş et al., 2006]. The HACCP system is recognized as an important tool in the reduction of food borne diseases (FBDs), and it is a global reference in terms of food safety control and it is recommended by the World Health Organization, the International Commission on Microbiological Specifications for

* Corresponding author: Ikbel Denden

Foods, the Codex Alimentarius, and food regulatory agencies in various countries (Cusato et al., 2011). The primary objective of fish quality control, as stated by Domingo (2007), is to establish methods for assessing the suitability or excellence of fish for processing. Among the various methods or systems for ensuring food safety, Hazard Analysis of Critical Control Points (HACCP) is highlighted (Baş et al., 2006). The HACCP system is widely recognized as a crucial tool in minimizing foodborne diseases (FBDs) and serves as a global standard for food safety control. It is recommended by prominent organizations such as the World Health Organization, the International Commission on Microbiological Specifications for Foods, the Codex Alimentarius, and regulatory agencies in numerous countries (Cusato et al., 2011). The recommended or mandatory use of HACCP is found in the regulations of several countries, and governments, industries, and consumers are showing a growing acceptance of the system. In the study conducted by Cicero et al. (2020) measuring histamine contents in fresh and processed fish samples from markets and from street vendors concluding the need to ensure the safety of fishery and fishery products. In the same context, Roudsari et al. (2020), measuring histamine concentrations in canned fish, note that the precise control programs, such as HACCP and good hygienic practices (GHP) should be implemented to ensure consumer safety. Thus, the implementation of HACCP has many benefits such as better use of resources, additional effective hazard analyses and better satisfaction of customers and high protection of public health (Food and Drug Administration, 2004). It has been reported by Lupin et al. (2010) that after the proper implementation of the HACCP system and compliance with HACCP-based regulations, most fish processing plants have experienced a decrease in total quality costs and an increase in quality. The reduction in safety/quality costs definitely pushes managers and owners in the industry to comply with HACCP regulations and to assume that HACCP system and HACCP audit are essential management functions in the modern context of the peach industry (Lupin et al., 2010). In addition, the use of HACCP increases exporting possibilities, because the system enables harmonization with international trade requirements (Cusato et al., 2011) and contributes to a positive image of the company, improving consumer confidence and reducing the possibilities of product recall (Ehiri et al., 1995). In this context, many companies have been motivated to adopt HACCP system (Henson et al., 1999). Thus, the aim of this work was to guarantee the safety and quality characteristics of the production of canned tuna, in a Tunisian by the implementation of the HACCP system. To the best of our knowledge, this study evaluate the efficiency of the HACCP system in tuna fish industry for the first time in Tunisia.

2. Materials and methods

2.1. Tuna fish

Tuna fish was obtained from the fisheries regional Counter. A safety certificate sheet signed by the veterinarian accompanies each receipt of raw materials. The control of fishery products was made according to the Official Journal of the Tunisian Republic (1998). The tuna products are prepared from fresh fish (Commission) and Tunisian standard (NT54.02. 1986).

2.2. Microbiological analysis

The thermophilic *Bacillus* strains were determined according to NF-V08-404 (1986). The thermophilic *Clostridium* were determined according to NF-V08-405 (1986).

2.3. Physico-chemical analysis

2.3.1. pH

The pH was determined following the laboratory manual of analytical methods and procedures for fish products (Lim, 1992). Measurements were conducted using a pH meter (Mettler type) with a control accuracy of ±0.1 pH units. For each sample, 5 g was homogenized in 20 mL distilled water for 1 minute at room temperature.

2.3.2. Histamine levels

Histamine levels were determined using High Performance Liquid Chromatography (HPLC) following the guidelines outlined in European Commission Regulation 2073 (2005).

2.3.3. Mercury levels

Mercury levels were analyzed using cold vapor Atomic Absorption Spectrometry (AAS) in accordance with NF EN 13806 (2003).

3. Results and discussion

3.1. The steps of production of canned tuna: HACCP plan

Growing consumer awareness and evolving legislative requirements within food production systems have catalyzed significant efforts in implementing control measures and assurance systems across various food sectors worldwide (Jedrzejczak et al., 2004; Michalis et al., 2000). The HACCP system is based on risk assessment and process control rather than solely relying on end product testing. It also encompasses standards and procedures for food services (Kök, 2009). In Table 1, primary risks and established Critical Control Points (CCPs) are presented, determined by an experienced HACCP team. CCPs were identified during the risk assessment of canned tuna processing and incorporated into the HACCP plan. The significance of each risk was assessed using the criticality citation method (Criticality = Severity x Frequency) (Mouffok et al., 2013), resulting in the establishment of four CCPs (Codex Alimentarius, 2007). CCP1, specifically focusing on the control of tuna freshness upon reception, was identified. The freshness of fish significantly contributes to the overall quality of fish and fishery products, influencing both the quality of raw materials and the subsequent food processing. Therefore, during each reception, the health surveillance committee, in accordance with regulations, evaluates the freshness of tuna fish, particularly assessing the firmness (torn skin) of the flesh. This parameter is deemed crucial as it represents the primary hazard, with a maximum allowable limit set at 2%. Under these circumstances, the CCP was deemed validated and under control. However, the presence of hydrocarbons poses another risk, albeit accounting for a very small percentage (%). In such scenarios (where the torn skin percentage exceeds 2% and/or traces of hydrocarbons are detected), control measures outlined in the internal specifications involve the rejection of raw materials and the selection of suppliers based on the ratings assigned to each supplier. The CCP2 involves monitoring histamine and mercury levels upon reception. Adherence to strict regulations governs the control of histamine and mercury, with systematic analyses conducted at each reception by an accredited laboratory. Raw materials are accepted only if histamine and mercury concentrations do not exceed 1 mg/kg and 100 mg/kg respectively; otherwise, they are rejected. The CCP1 and CCP2 were centered on controlling the raw materials; particularly emphasizing good hygienic practices (GHP), as the quality of raw materials significantly affects the final product. The initial quality of raw materials, including factors such as freshness, microbiological load, and physical damage, plays a crucial role in determining the quality of the end product (Quang et al., 2005). The CCP3 is the control of the welding boxes and the CCP4 is the monitoring of the sterilization. CCP3 is performed regularly to prevent possible contamination from the environment (boxes leaking). CCP3 was considered as validated meaning that the hazard was under control where the % of the leaky box. The CCP3 and CCP4 were dedicated to controlling the good manufacturing process (GMP). Under these circumstances (where the torn skin percentage exceeds 2% and/or traces of hydrocarbons are detected) control measures outlined in the internal specifications include the rejection of raw materials and the selection of suppliers based on the ratings assigned to each supplier according to internal specifications. The control measure for the CCP3 was the rejection of the boxes. Immediately, where the % exceeded 2%, frequent verifications were made. The auditors look for the probable origins of the case and apply the necessary corrections to reduce the hazard to an acceptable level in order to have a process under control. The CCP4 (sterilization) is monitored and checked regularly. Criteria were established using the parameters recommended for time-temperature in the sterilization process. The control measure implemented was the supervision of the scheduled process (time and duration). The hazard is the survival of *Clostridium botulinum* and thermophilic *Bacillus* spores. The CCP4 was considered validated when no spores were detected in the final products (Agwa et al., 2018). Under these conditions, the CCP4 was deemed validated. However, only control of the CCPs is not sufficient to ensure high quality for food products. Typically, for effectiveness, the HACCP system needs to be applied from the origin to the consumption of the foods (Jedrzejczak et al., 2004).

Table 1 Summary of the of HACCP plan with the significant hazards and CCPs selected

CCPs	Designation	Dangers	Control measures	Monitoring Parameters	Critical limits
CCP_1	Checking on receipt	Soft flesh and shredded	Rejection of the goods	*The freshness of the flesh (flesh farm)	< 2% of tuna fish (Torn skin).
CCP_2	Tuna on receipt	Histamine	For tuna during cold storage	*Determination of histamine level	n = 9 units 1)The average content shall not exceed 100 ng/g 2) 2 samples may have a content exceeding 100 ng/g but do not reach 200 ng/g. (European Union, 1989) no sample shall have a content exceeding 200 ng/g.
		Mercury	Tuna during cold storage	*Determination of mercury level	> 1 ng/g Rejection of the goods.
CCP_3	Control of the seams	Biological (due to microbial contamination boxes: leakage)	Rejection of the boxes	*External diameter *Height of the empty box *The box thickness (body box) *The height and the thickness of the seams *The end and the body hook *The overlap	Control of the seams (leaky box <2%).
CCP_4	Sterilization	Biological (high level of microbial load after sterilization)	Monitoring of the scale of the sterilization and stability test (oven)	*Temperature *Duration *Pressure	According to the scale of the sterilization

Practical experience and food safety research indicate that success in developing and verifying an effective HACCP system depends on a complex mix of managerial and organizational factors (Baş et al., 2006). This is why the Tunisian government mandates a training program on HACCP methodology for agro-food industries and has established legislation and enforcement programs to ensure food quality and safety, guaranteeing high-quality products. All necessary conditions and measures to ensure the safety and quality of tuna and tuna products at all stages of the food chain, from sea to end processing, are undertaken (internal specifications) and harmonized to ensure tuna safety. Based on Codex Alimentarius standards guidelines recommendations and risk assessments, this program includes HACCP system implementation, food hygiene practices, premises and equipment cleaning and disinfection, staff hygiene, germ awareness, and raw material reception, assured by specialists such as expert veterinarians (Codex Alimentarius, 2007). Additionally, we monitor certain parameters during production to ensure their control during the storage period of tuna fish at ≤ 4°C before canned tuna production. Currently, the government has mandated the ISO 22000 system as a quality assurance system for food products. The new ISO 22000 standard incorporates management systems and food safety practices (HACCP and prerequisite programs) in developing protocols to guarantee food product safety (ISO 22000, 2005; 2018).

3.1.1. Determination of histamine levels

Canned tuna products are highly significant processed foods worldwide. Different species of canned tuna also contain various toxic substances, such as histamine and mercury (Burger et Gochfeld, 2004). Freshly caught yellowfin tuna generally contain between 10 and 30 mg/kg of histamine (Widiastuti et al., 2013). Histamine is the biogenic amine responsible for scombroid poisoning, which results from the histidine decarboxylation by bacterial decarboxylases in various types of fish and fish products (Roudsari et al., 2020). Histamine fish poisoning (or scombroid poisoning) is a significant public health and safety concern (Silva et al., 2011). Elevated histamine levels are most commonly found in fish and fishery products, especially in the family *Scombridae*, and their accumulation is related to bacterial spoilage (Mergler et al., 2007). Histamine poisoning is the leading cause of fish-related foodborne infections in France (Duflos, 2009).

In our study, histamine contents (mean values) of the tested samples were found to be in the range of 10-30 mg/kg (Table 2). Histamine levels in tuna fish were lower than 100 mg/kg and were in agreement with the Official Journal of the Tunisian Republic (1998) and below the allowable limit fixed by the US FDA (50 mg/kg) (Food and Drug Administration, 2004). European Regulation establishes maximum limits for histamine in fishery products from fish species associated with high histamine amounts, with values ranging from 100 to 200 mg/kg. Histamine was investigated in fresh and canned tuna in Brazil; the mean levels were 0.19 mg/kg in fresh tuna from wholesale, 1.30 mg/kg in fresh tuna, and 4.41 in canned tuna from the retail market (Silva et al., 2011).

According to Roudsari et al. (2020), 60 canned fish samples collected from markets in Tehran, Iran, including canned tuna (n = 42) and other canned samples (n = 18), showed histamine concentrations in 46.6% of the samples, and 18.3% of the samples exceeded the histamine limit stipulated by the U.S. Food and Drug Administration (2004) (50 mg/kg). Mean values were found to be in the range of 0-80 mg/kg. Tsai et al. (2005) found that 4.2% of canned fish samples in Taiwan contained more than 50 mg/kg of histamine. In the study conducted by Maktabi et al. (2016), histamine content of the samples ranged from 4 to 236 mg/kg, and 18.9% of the canned tuna samples contained more than 50 mg/kg, the limit suggested by the US FDA. The main reasons for this high percentage of unacceptable canned tuna samples are likely the result of poor-quality fish used as raw material for canning and/or defective handling techniques during processing.

In Morocco, histamine levels were determined in 248 samples of commercially processed fish, with concentrations ranging from < 0.01 to 694 mg/100g and a mean of 12.33 mg % (Ababouch et al., 1986). These high levels indicate fish storage under conditions conducive to microbial growth and histamine production. According to Bilgin and Gençcelep, (2015), the elevated histamine values (up to 110.33 ± 9.87 mg/kg) in canned tuna were attributed to the poor quality of the raw fish material. However, Auerswald et al. (2006) note that histamine is seldom found in fresh fish, but its levels increase as fish decomposition progresses. Rossi et al. (2011) suggest that histamine production is associated to the growth of bacteria possessing the enzyme histidine decarboxylase. After the death of the fish and under specific storage conditions, particularly between +2°C and +5°C, histamine-producing bacteria can proliferate, leading to histamine formation; this production can occur rapidly at temperatures above +10°C (Duflos, 2009).

In conclusion, elevated histamine levels have been observed in fish, potentially resulting from non-compliance with good manufacturing practices, such as additional handling and processing or prolonged exposure to higher temperatures (Soares et Glória, 1994). Time and temperature conditions must allow for the production and accumulation of histamine and other biogenic amines in fish (Chang et al., 2008). Biogenic amines can also be generated throughout the manufacturing process and during storage of the end product if improper temperatures are maintained (Jinadasa et al., 2015). According to Jinadas et al. (2015), storing fresh yellow fin tuna below 4°C is sufficient to achieve a shelf life of two weeks, with the fish needing to be kept at < 4°C to prevent histamine formation during the 14-day shelf life. Additionally, the most recent HACCP guidelines for controlling histamine production recommend maintaining temperatures of 4.4°C or lower throughout handling, processing, and distribution of potentially hazardous fish (Kim et al., 2004).

3.1.2. Determination of mercury levels

Mercury is a known human toxicant, with the primary source of mercury contamination in humans being the consumption of fish (Khansari et al., 2005). It is classified as a hazardous and priority substance by the European Directive 2000/60/EC (2000). The European Commission has established maximum levels contaminants in foodstuffs (European Union, 2008), with the maximum total mercury content in edible parts of fishery products set at 0.5 mg/kg fresh weight, except for certain species where the limit is set at 1 mg/kg fresh weight (European Union, 1993).

In our study, mercury concentrations ranged from 0.025 to 0.55 mg/kg (Table 2), aligning with the regulations set by the European Union (1993). If the mercury content exceeds one ng/g, it signifies the rejection of the lot (CCP2). However, our results were lower than those reported in light tuna (0.205 - 0.594 mg/kg) and skipjack (0.299 - 0.322 mg/kg) (González-Estecha et al., 2013), as well as in canned tuna (maximum 351.30 µg/kg) (Pawlaczyk et al., 2020) and canned tuna fish (0.082-0.160 ng/g) (Khansari et al., 2005). The mean mercury level in tuna in our study is significantly lower than levels found in fresh tuna from the Mediterranean Sea, with a mean of 3030 µg kg−1 (Licata et al., 2005), as well as in Italy-Mediterranean Sea with means of 446 and 660 (µg kg−1) (Bella et al., 2015). Seafood from the Mediterranean Sea is suggested to have a higher mercury content due to the geochemical characteristics of the basin (Kotnik et al., 2013). Thus, CCP1 is validated as the control of raw material by the experienced team and the analysis of mercury levels meet internal specifications, ensuring the raw material used was healthy.

Table 2 Histamine and mercury levels in tuna fish on receipt (mg/kg)

	mean value	**mean value**	**mean value**
Histamine levels	10.5 ± 0.5	16.8 ± 0.6	29.5 ± 1
Mercury levels	0.015 ± 0.002	0.025 ± 0.005	0.055 ± 0.006

Data are the mean of three samples of three replicates (N=9) for histamine. n = 3 for mercury

3.1.3. Microbiological analysis

Fresh fish is more perishable products than other foodstuffs (Lu et al., 2016). Quality deterioration of fresh fish occurs rapidly during handling and storage and limits the shelf life of the product (Adebayo-Tayo et al., 2012). The microbiological indicators are most often used to assess food safety and good manufacturing practices rather than the freshness of products. According to El-Dengawy et al. (2012), Egyptian Organization for Standardization for Microbiological Aspects of Fishery Products stated that the canned tuna, the salted tuna should not contain *Clostridium*. The general recommended value for the total viable bacteria in fish is 510^5 CFU/g (Altekruse et al., 1998). The goal of the HACCP system should be to reduce the risk of food borne illness to the consumer. In this study, the microbiological quality of canned tuna fish by the analysis of *Bacillus* and *Clostridium* thermophilic spore forms was evaluated and we focused especially on spore's forms, which are known for their heat resistance. *Clostridium botulinum* produces spores that are the most heat resistant of all pathogenic microorganisms. Consequently, the fish canning industry must rely on thermal processes sufficient to ensure the lowest probability of survival of *C. botulinum* spores to present no significant health risk to consumers. Therefore, reliable safety and quality assurance program should systematically integrate the quality of raw material; the hygiene and sanitation, the proper thermal processing (including design, application, and monitoring); the proper can seaming (welding). The obtained results showed the absence of the spores which may indicate that the CCP_4 (sterilization) is controlled. Under these conditions, CCP_4 was considered as validated. Thus, we can conclude that the good hygienic practices (GHP) (no contamination) are applied and we proved, according to the results, that the good manufacturing practices (GMP) and the safety of product are provided (Casalinuovo et al., 2015).

3.1.4. pH measurements

pH could serve as a useful parameter to assess the qualitative changes in fish during storage, wherein the degradation of fish quality involves a complex process encompassing physical, chemical, and microbiological deterioration (González-Fandos et al., 2005). Abbas et al. (2008) established a correlation between fish freshness and pH during cold storage, suggesting that this physical characteristic could be a suitable tool for analyzing fish freshness, surpassing the inherent uncertainties associated with sensory evaluation methods. To evaluate the effectiveness of the cold chain for fresh salmon (*Salmo salar*) and tuna fish (*Sardina pilchardus*) in a food processing plant, the final pH value in the finished tuna product depends more on the quality of the raw material than on the processing (Calanche et al., 2013). Abbas et al. (2008) have shown that pH affects fish freshness.

As shown in Table 3, the pH values ranged from 5.65 ± 0.5 to 6.02 ± 0.1. These results are consistent with those reported by Susanto et al. (2011) and Jinadasa et al. (2015). According to the results obtained, we did not observe an increase in pH after 24 hours of storage at temperatures ≤ 4°C, since pH is one of the essential conditions allowing the growth and activation of enzymes by bacteria capable of releasing histamine (ANSES, 2012). Furthermore, as indicated in Table 2, the recorded temperatures are below 5°C, consistent with internal specifications. This demonstrates compliance with the cold chain and indicates the effectiveness of the implemented HACCP system. Based on the results obtained, it appears that the tuna used as a raw material is safe for human consumption (Abbas et al., 2008).

Table 3 pH and temperature of raw material during storage

	Temperatures (°C)	**pH**
number of cases	**An average of 24 hours**	**An average of 24 hours**
1	4.6	5.75 ± 0. 2
2	3.8	5.74 ± 0.4
3	4.0	6.02 ± 0.1
4	2.9	5.80 ± 0.1
5	4.6	5.76 ± 0.2
6	3.4	5.65 ± 0.5
7	4.0	5.90 ± 0.3
8	3.7	6.00 ± 0.1
9	4.4	6.02 ± 0.1
10	4.7	5.82 ± 0.2

4. Conclusion

The implementation of HACCP systems in the fishery industry has led to improvements in product safety and quality. As a preventive approach, HACCP emphasizes control over raw materials, processes, environments, personnel, storage, and distribution, starting as early as possible in the production system. In this study, the implementation of HACCP in the tuna industry yielded satisfactory results. Consequently, we can infer that the raw materials are of high quality, the process of canned tuna fabrication is well controlled, and the final product is safe for consumption. The implementation of the HACCP system in canned tuna production has proven to be an effective tool for enhancing the safety and quality attributes of the product.

Compliance with ethical standards

Acknowledgments

We extend our gratitude to the receiving fishery industry for their assistance in facilitating student internships, as well as for their collaboration and dedication to implementing the HACCP system.

Disclosure of Conflict of interest

The authors declare that there is no conflict of interest

Authors' Contributions

Conceptualization B.K., I.D., and M.G; Methodology, I.D, M.N., M.G., and K.B.; Data curation, I.D, M.G., and K.B; *Investigation*, B.K., I.D, M.N, Supervision, B.K and M.G.; Resources, I.D., M.N., and B.K.; Writing—original draft preparation, I.D., B.K., and M.N.; Writing—review and editing, I.D., B.K., and M. N. All authors have read and agreed to the published version of the manuscript.

References

[1] Ababouch, L., Alaoui, M., & Busta, F. (1986). Histamine levels in commercially processed fish in Morocco. *Journal of food protection, 49*(11), 904-908. https://doi.org/10.4315/0362-028X-49.11.904

[2] Abbas, K., Mohamed, A., Jamilah, B., & Ebrahimian, M. (2008). A Review on Correlations between Fish Freshness and pH during Cold Storage. *American Journal of Biochemistry and Biotechnology, 4*(4), 416-421.

[3] Adebayo-Tayo, B. C., Odu, N. N., & Okonko, I. O. (2012). Microbiological and physiochemical changes and its correlation with quality indices of tilapia fish (*Oreochromis niloticus*) sold in Itu and Uyo markets in Akwa Ibom State, Nigeria. *New York Science Journal 5*, 38-45.

[4] Agwa, O.K., Solomon, L., & Harrison, I.S. (2018). Microbial quality of canned fish stored under cold and ambient temperatures and their public health significance. *International Journal of Veterinary, Poultry and Fisheries Sciences, 7* (9).

[5] Altekruse, S. F., Timbo, B. B., Mowbray, J. C., Bean, N. H., & Potter, M. E. (1998). Cheese-associated outbreaks of human illness in the United States, 1973 to 1992: sanitary manufacturing practices protect consumers. *Journal of food protection, 61*(10), 1405-1407.

[6] ANSES. (2012). Opinion of the French Agency for Food, Environmental and Occupational Health & Safety (ANSES) regarding the request for scientific and technical support on the definition of fish products undergoing enzymatic maturation subject to a criterion for histamine. Referral No. 2010-SA-0261. Retrieved from: https://www.anses.fr/fr/system/files/MIC2010sa0261.pdf

[7] Auerswald, L., Morren, C., & Lopata, A. L. (2006). Histamine levels in seventeen species of fresh and processed South African seafood. *Food Chemistry, 98*(2), 231-239. https://doi.org/10.1016/j.foodchem.2005.05.071

[8] Baş, M., Ersun, A. Ş., & Kıvanç, G. (2006). Implementation of HACCP and prerequisite programs in food businesses in Turkey. *Food Control, 17*(2), 118-126. https://doi.org/10.1016/j.foodcont.2004.09.010

[9] Bella, G. D., Potortì, A. G., Turco, V. L., Bua, D., Licata, P., Cicero, N., & Dugo, G. (2015). Trace elements in *Thunnus thynnus* from Mediterranean Sea and benefit–risk assessment for consumers. *Food Additives & Contaminants: Part B, 8*(3), 175-181. https://doi.org/10.1080/19393210.2015.1030347

[10] Bilgin, B., & Gençcelep, H. (2015). Determination of Biogenic Amines in Fish Products. *Food Science. Biotechnology. 24*(5), 1907-1913. https://doi.org/10.1007/s10068-015-0251-4

[11] Burger J., & Gochfeld M. (2004). Mercury in canned tuna: White versus light and temporal variation*.* *Environmental Research 96*(3): 239-49. https://doi.org/10.1016/j.envres.2003.12.001

[12] Calanche, J., Samayoa, S., Alonso, V., Provincial, L., Roncalés, P., & Beltrán, J. A. (2013). Assessing the effectiveness of a cold chain for fresh fish salmon (*Salmo salar*) and sardine (*Sardina pilchardus*) in a food processing plant. *Food control, 33*(1), 126-135. https://doi.org/10.1016/j.foodcont.2013.02.005

[13] Casalinuovo F, Gazzotti T, Rippa P, Ciambrone L, Musarella R, Pratticò E. (2015). Microbiological Stability of Canned Tuna Produced in Italy and in Non-European Countries. *Ital J Food Saf. 19*; 4(1),4780. https://doi: 10.4081/ijfs.2015.4780

[14] Chang, S. C., Kung, H. F., Chen, H. C., Lin, C. S., & Tsai, Y. H. (2008). Determination of histamine and bacterial isolation in swordfish fillets (*Xiphias gladius*) implicated in a food borne poisoning. *Food Control, 19*(1), 16-21. https://doi.org/10.1016/j.foodcont.2007.01.005

[15] Cicero, A., Cammilleri G., Galluzzo, F. G., Calabrese, I., Pulvirenti, A., Giangrosso, G., Cicero, N., Cumbo, V., Vella, A., Macaluso, A. & Ferrantelli, V. (2020). Histamine formation and the freshness of yellowfin tuna (*Thunnus albacares*) stored at different temperatures Histamine in Fish Products Randomly Collected in Southern Italy: A 6-Year Study. *Journal of Food Protection, 83*(2), 241–248. https://doi.org/10.4315/0362-028X.JFP-19-305

[16] Codex Alimentarius Commission, Procedural manual. (2007). World Health Organization (WHO), FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS (FAO) (17th edition). Rome. Retrieved from http://www.fao.org/3/a1472e/a1472e.pdf

[17] Cusato, S., Tavolaro, P., & Oliveira, C. A. (2011). Implementation of Hazard Analysis and Critical Control Points System in the Food Industry: Impact on Safety and the Environment. *Novel Technologies in Food Science,* 21-37. https://doi.org/10.1007/978-1-4419-7880-6_2

[18] Domingo, J. L. (2007). Omega-3 fatty acids and the benefits of fish consumption: Is all that glitters gold? *Environment International, 33*(7), 993-998. https://doi.org/10.1016/j.envint.2007.05.001

[19] Duflos, G. (2009). Le Risque Histamine Dans Les Produits De La Pêche. *Bulletin De L' Académie Vétérinaire De France,* (1), 241. https://doi.org/10.4267/2042/47999

[20] Ehiri, J. E., Morris, G. P., & Mcewen, J. (1995). Implementation of HACCP in food businesses: The way ahead. *Food Control, 6*(6), 341-345. https://doi.org/10.1016/0956-7135(95)00045-3

[21] El-Dengawy, R. A., El-Shehawy, S. M., Kassem, A. E., El-Kadi, S. M., & Farag, Z. S. (2012). Chemical and microbiological evaluation of some fish products samples. *Journal of Agricultural Chemistry and Biotechnology, 3*(8), 247-259. https://dx.doi.org/10.21608/jacb.2012.54981

[22] European Union. (1989). Council Regulation (EEC) No 2136/89 of 21 June 1989 laying down common marketing standards for preserved sardines, L 212/79. *Official Journal of the European Union,* Luxembourg.

[23] European Union. (1993). Commission Decision No 93/351/EEC of 19 May 1993 determining analysis methods, sampling plans and maximum limits for mercury in fishery products, L 144. *Official Journal of the European Union,* Bruxelas.

[24] European Union (2000). Directive 2000/60/EC of the European Parliament and of the Council establishing a framework for Community action in the field of water policy. *Official Journal* L 327, 22 December 2000, p. 1-72. For consolidated version 2000L0060, 20 November 2014, pp. 1-93. http://https//eur-lex.europa.eu/homepage.html

[25] European Union. (2005). Commission Regulation (EC) No 2073/2005 of 15 November 2005 on microbiological criteria for foodstuffs, L338/1. Official Journal of the European Union, Bruxelas.

[26] European Union. (2008). Commission Regulation (EC) No 629/2008 of 2 July 2008 amending Regulation (EC) No. 1881/2006 setting maximum levels for certain contaminants in foodstuffs, L 173/6. *Official Journal of the European Union,* Bruxelas.

[27] Food and Drug Administration. (2004). What you need to know about mercury in fish and shellfish: EPA and FDA advice for women who might become pregnant, women who are pregnant, nursing mothers, young children. *US Food and Drug Administration.* Retrieved from: http://www.foodprotect.org/issues/packets/2010Packet/attachments/I_006__all.pdf

[28] González-Estecha, M., Martínez-García, M. J., Fuentes-Ferrer, M., Bodas-Pinedo A., Calle-Pascual, A., Ordóñez-Iriarte, J. M., Fernández-Pérez, C., Martell-Claros, N. , Rubio-Herrera, M. Á., Gómez-Hoyos, E., Guillén-Pérez, J. J. (2013). Mercury in Canned *Tuna* in Spain, Is Light *Tuna* Really Light? *Food and Nutrition Sciences, 4*(7), 48-54. http://dx.doi.org/10.4236/fns.2013.47A007

[29] González-Fandos, E., Villarino-Rodríguez, A., García-Linares, M., García-Arias, M., & García-Fernández, M. (2005). Microbiological safety and sensory characteristics of salmon slices processed by the sous vide method. *Food Control, 16*(1), 77-85. https://doi.org/10.1016/j.foodcont.2003.11.011

[30] Henson, S., Holt, G., & Northen, J. (1999). Costs and benefits of implementing HACCP in the UK dairy processing sector. *Food Control, 10*(2), 99-106. https://doi.org/10.1016/S0956-7135(98)00162-5

[31] ISO 22000. (2005). Food Safety Management Systems—Requirements for Any Organization in the Food Chain. International Organization for Standardization with Technical Committee: Geneva, Switzerland, 2005; p. 32. https://www.iso.org/standard/35466.html

[32] ISO 22000. (2018). Food Safety Management Systems—Requirements for Any Organization in the Food Chain. International Organization for Standardization with Technical Committee: Geneva, Switzerland, 2018; p. 37. https://www.iso.org/standard/65464.html

[33] Jedrzejczak, R., Brulinska-Ostrowska, E., Traczyk, I. (2004). The activity of Codex Alimentarius Commission FAO/WHO Committee on Methods of Analysis and Sampling. *Roczniki Państwowego Zakładu Higieny, 55* (1), 99-105.

[34] Jinadasa, B., Galhena, C., & Liyanage, N. (2015). Histamine formation and the freshness of yellowfin tuna (*Thunnus albacares*) stored at different temperatures. *Cogent Food & Agriculture, 1* (1). https://doi.org/10.1080/23311932.2015.1028735

[35] Khansari F. E., Ghazi-Khansari M & Abdollahi M. (2005). Heavy metals content of canned *tuna* fish. *Food Chemistry, 93*(2), 293-296. https://doi.org/10.1016/j.foodchem.2004.09.025

[36] Kim, S., Eun, J., Chen, T., Wei, C., Clemens, R., & An, H. (2004). Evaluation of Histamine and Other Biogenic Amines and Bacterial Isolation in Canned Anchovies Recalled by the USFDA. *Journal of Food Science, 69*(6), M157-M162. https://doi.org/10.1111/j.1365-2621.2004.tb11003.x

[37] Kök, M. S. (2009). Application of food safety management systems (ISO 22000/HACCP) in the Turkish poultry industry: A comparison based on enterprise size. *Journal of food protection, 72*(10), 2221-2225. https://doi.org/10.4315/0362-028X-72.10.2221

[38] Kotnik, J., Sprovieri, F., Ogrinc, N., Horvat, M., & Pirrone, N. (2013). Mercury in the Mediterranean, part I: Spatial and temporal trends. *Environmental Science and Pollution Research, 21*(6), 4063-4080. https://doi.org/10.1007/s11356-013-2378-2

[39] Licata, P., Trombetta, D., Cristani, M., Naccari, C., Martino, D., Caló, M., & Naccari, F. (2005). Heavy metals in liver and muscle of bluefin tuna (*Thunnus thynnus*) caught in the straits of Messina (Sicily, Italy). *Environmental monitoring and assessment, 107*(1-3), 239-248. https://doi.org/10.1007/s10661-005-2382-1

[40] Lim, P. Y. (1992) Measurement of pH. Laboratory manual on analytical methods and procedures for fish and fish products 2nd edition, Retrieved from: http://repository.seafdec.org/handle/20.500.12066/6025

[41] Lu, J., Huntley, B., & Ludwig, L. (2016). Development of an Effective ASME IX Welding Procedure Qualification Program for Pipeline Facility and Fabrication Welding. *Volume 3: Operations, Monitoring and Maintenance; Materials and Joining. https://doi.org/10.1115/IPC2016-64169*

[42] Lupin, H., Parin, M., & Zugarramurdi, A. (2010). HACCP economics in fish processing plants. *Food Control, 21*(8), 1143-1149. https://doi.org/10.1016/j.foodcont.2010.01.009

[43] Maktabi, S., Zarei, M., & Chadorbaf, M. (2016). Effect of a traditional marinating on properties of rainbow trout fillet during chilled storage. Veterinary Research Forum: An International Quarterly Journal, 7(4), 295-300. PMid:28144420.

[44] Mergler, D., Anderson, H. A., Chan, L. H., Mahaffey, K. R., Murray, M., Sakamoto, M., & Stern, A. H. (2007). Methylmercury Exposure and Health Effects in Humans: A Worldwide Concern. *AMBIO: A Journal of the Human Environment, 36*(1), 3-11. https://doi.org/10.1579/0044-7447(2007)36[3:MEAHEI]2.0.CO;2

[45] Michalis M. Efstratiadis, Argiro C. Karirti. (2000). Implementation of ISO 9000 to the food industry: An overview. *International Journal of Food Sciences and Nutrition, 51*(6), 459-473. https://doi.org/10.1080/09637480050208071

[46] Mouffok, N., Benhadja, L., Ferhat, Z., & Bousbia, N. (2013). Identification et analyse des dangers d'un procèss de fromage fondu selon l'ISO 22 000. *QUALITA2013*, Mar 2013, Compiègne, France. ⟨hal-00823126⟩

[47] NF EN 13806. (2003). Foodstuffs - Determination of trace elements - Determination of mercury by cold-vapour atomic absorption spectrometry (CVAAS) after pressure digestion

[48] NF V08-404. (1986). Microbiology of food products. Preserves. Detection of *Bacillus thermophilus*.

[49] NF V08-405. (1986). Microbiology of food products. Preserves. Detection of *Clostridium thermophilus*.

[50] NT 54.02. (1986). Decree of the Minister of Industry and Trade of 30 September 1986, for the certification of the Tunisian standard for canned sardines and sardine-type products. *Official Journal of the Tunisian Republic*, 1143.

[51] Official Journal of the Tunisian Republic. (1998). Order of the Minister of Agriculture of 19 September 1998 laying down health control and monitoring of production conditions of fishery products and their marketing. *Official Journal of the Tunisian Republic, p.1995-1999*.

[52] Pawlaczyk, A., Przerywacz, A., Gajek, M., & Szynkowska-Jozwik, M. I. (2020). Risk of Mercury Ingestion from Canned Fish in Poland. *Molecules, 25*(24), 5884. https://doi.org/10.3390/molecules25245884

[53] Quang, N. H., Einarsson, H., & Eyþórsdóttir, M. A. (2005). Guidelines for handling and preservation of fresh fish for further processing in Vietnam. *The United Nation University Fisheries Training Programme. Iceland. 57p*.

[54] Rossi, F., Gardini, F., Rizzotti, L., La Gioia, F., Tabanelli, G., & Torriani, S. (2011). Quantitative analysis of the histidine decarboxylase (hdcA) gene transcription and histamine production by Streptococcus thermophilus PRI60 in conditions relevant for cheese making. *Applied and Environmental Microbiology, 77*(8) 2817-2822. http://doi.org/10.1128/AEM.02531-10

[55] Roudsari, P. L., Rahmani, A., Shariatifar, N., Tajdar-Oranj, B., Mazaheri, M., Sadighara, P., & Khaneghah, A. M. (2020). Occurrence of Histamine in Canned Fish Samples (Tuna, Sardine, Kilka, and Mackerel) from Markets in Tehran. *Journal of Food Protection, 83*(1), 136-141https://doi.org/10.4315/0362-028X.JFP-19-288

[56] Silva, T. M., Sabaini, P. S., Evangelista, W. P., & Gloria, M. B. (2011). Occurrence of histamine in Brazilian fresh and canned tuna. *Food Control, 22*(2), 323-327. https://doi.org/10.1016/j.foodcont.2010.07.031

[57] Soares, V. F., & Glória, M. A. (1994). Histamine Levels in Canned Fish Available in Belo Horizonte, Minas Gerais, Brazil. *Journal of Food Composition and Analysis, 7*(1-2), 102-109. https://doi.org/10.1006/jfca.1994.1009

[58] Susanto, E., Agustini, T., W., Ritanto, E., P., Eko, D., N., & Swastawati, F. (2011). Changes in oxidation and reduction potential (Eh) and pH of tropical fish during storage. *Journal of Coastal Development 14*(3), 223-234.

[59] Tsai, Y., Kung, H., Lee, T., Chen, H., Chou, S., Wei, C., & Hwang, D. (2005). Determination of histamine in canned mackerel implicated in a food borne poisoning. *Food Control, 16*(7), 579-585. https://doi.org/10.1016/j.foodcont.2004.06.019

[60] Tunisian Statistical Yearbook. (2017). Ministry of Agriculture, Water Resources and Fisheries, Institution of Agricultural Research and Higher Education, Higher Institute of Fisheries and Aquaculture of Bizerte, 2017. Retrieved from: http://www.ispab.agrinet.tn/docs/annuaire/stat2017.pdf

[61] Widiastuti, I., Putro, S., Fardiaz, D., Trilaksani, W., & Inaoka, T. (2013). Changes in Freshness of Steak and Loin Tuna (*Thunnus albacares*) during 15 Day-chilled Storage. *Journal of Fisheries and Aquatic Science, 8*(2), 367-377. http://doi.org/10.3923/jfas.2013.367.377