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Study of the Hazard of Sulfites in Coastal Fishery Crustaceans in Morocco

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Abstract | Crustaceans are a major marine resource at the national level and are known for their exceptional quality and high commercial value. However, their highly perishable nature and their sensitivity to melanosis, a process of oxidation causing the blackening of their shells, leads professionals to use additives to prevent this phenomenon. This study investigates the use of sulfites in crustaceans in northern Morocco (Mehdia and Larache fish markets) through surveys conducted with 56 shrimp trawler owners. Residual sulfur dioxide levels were measured in 21 samples of pink shrimp. The survey results revealed that dusting with sulfites is a common practice in this sector, with 55.33% of the surveyed owners using it to prevent shrimp spoilage and 35.71% using it to prevent melanosis. The analyses revealed sulfite levels ranging from 155 to 375 ppm for samples from the Mehdia fish market, and from 124 to 239 ppm for those from the Larache fish market which is in compliance. The average SO_2 levels observed at both ports are compliant with regulatory limits, measuring 181 and 256 ppm, respectively. These results highlight the compliance of the majority of samples 82 % with national regulatory standards, underscoring the importance of strengthening professional awareness regarding good practices in the use of sulfites and implementing effective preventive measures through the application of good manufacturing guidelines and a robust self- monitoring to ensure the food safety of crustaceans.

Keywords | Crustaceans, Shrimp, Sulfites, Melanosis

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INTRODUCTION

The fishing industry and its related industries represent a significant socio-economic lever. They contribute to generating added value and maintaining the balance of the trade balance. The crustacean segment holds a prominent place in this industry, being one of the most important economic activities in this sector, with more than 50% of production being destined for export (Kandil, 2016). The volume of crustacean captures in Morocco is about 12,000 tons, which represents a value of approximately one billion DHS, or 7% of the total value of the national fish produc-

tion. The coastal fishing segment accounts for 42% of this value, while offshore fishing represents 58% (DPM, 2023). However, crustacean melanosis is a phenomenon that severely impacts the shelf life and overall commercial value of the final product. This enzymatic browning process has raised concerns among consumers, who associate this blackening with product deterioration. To remedy this situation, the use of chemical preservatives such as sulfites has proven indispensable. These food additives help preserve the attractive pink color that consumers appreciate. However, their use can be associated with health risks in cases of excessive and irrational usage, leading to exceeding the concentrations required by regulations. Sulfites are among the authorized food additives, and their permissible limit depends on the crustacean species. Products intended for the domestic market are regulated by the joint decree of the Minister of Agriculture and Maritime Fisheries and the Minister of Health n°1795-14 of May 14, 2014, which sets the list and limits of authorized food additives to be used in primary products and food products, as well as the indications that must appear on their packaging. For export, they are governed by the regulation (EC) No 1333/2008 of the European Parliament and of the Council of 16 December 2008 on food additives. Moreover, the penetration of international markets and the competitiveness of Moroccan crustaceans depend on compliance with increasingly strict sanitary and phytosanitary regulations. Crustaceans can cause harmful effects due to the excessive use of sulfites in consumers, potentially leading to rejection at borders (Dahani et al., 2017a). The primary objective of this research is to assess the use of sulfites in coastal fishery crustaceans in Morocco and to verify their compliance with current regulations. This is done through surveys conducted with 56 coastal fishery owners operating at the ports of Larache and Mehdia using a pre established questionnaire, along with determining the residual SO_2 levels in 21 samples of pink shrimp from the aforementioned fish markets using a rapid dosage kit.

MATERIALS AND METHODS

Ethical Approval

This study was conducted according to the guidelines of the Agronomic and Veterinary Institute Hassan II, Rabat, Morocco.

Methodology

The survey was conducted in the form of a direct questionnaire composed of various questions targeting the owners of Moroccan coastal shrimp fishing boats in two distinct fishing ports: Mehdia and Larache. The survey was anonymous, preliminary explanations were provided to the respondents to reassure them and to ensure that the survey responses were honest and reflective of actual practices.

Development of the Questionnaire

The questionnaire is organized into four distinct sections: the first focuses on general information related to the boats, species captured, and their destination. The second explores current practices and the reasons for using sulfites. The third evaluates the respondents' knowledge of sulfites and their potential impacts, and the final section invites the boat owners to share their suggestions and evaluates their willingness to collaborate with the competent health authority for future improvements. The questionnaire includes multiple-choice, binary responses, and score assignments for questions assessing aspects on a predefined scale. For questions requiring more detailed responses or explanations, open-ended answers are provided, allowing the respondents to offer personalized comments.

Conducting the Surveys

The survey concerned all active boats fishing for crustaceans in Mehdia and Larache. Three boat owners representing the seven existing boats at the Mehdia port participated in the survey during landings in the presence of the ONSSA inspector. At the Larache port, the survey was conducted as a group interview with 12 boat owners representing 49 shrimp trawlers, in the presence of the ONSSA veterinary service of Larache.

During the surveys, during the auction, samples were taken from all boats that landed their shrimp during the study period (April 3-16, 2024). 21 whole pink shrimp (*Parapenaeus longirostris*) samples were collected after sanitary and qualitative inspection. Six samples were taken at the Mehdia fish market, and 15 at the Larache fish market. All samples were immediately put under melting ice and transported to the laboratory for sulfite dosage. The time between sampling and arrival at the laboratory was half an hour for those from Mehdia and one hour for those from Larache. The shrimp were immediately processed.

Residual SO_2 Content

The measurement of residual SO_2 levels was performed using a rapid kit, a numerical measurement method recognized by the AOAC (Alonso *et al.*, 2019). All measurements were performed in triplicate and an average was calculated. The quantify total of sulfite was measured in headless raw shrimp, the dosage is carried out on peeled and decapitated shrimp, the flesh sample is crushed and homogenized.

The rapid kit uses a compact biosensor to quantify the total sulfite content, measured in SO_2, in raw shrimp with heads, headless raw shrimp, or boiled shrimp. This biosensor integrates a biochemical detection element (the Biotest, based on a specific redox enzyme) in close contact with a transduction system that correlates the SO_2 concentration with a measurable electric current signal.

Data Processing

The results from the surveys of coastal fishing boat owners and the measurement of residual SO_2 levels were processed using Excel software.

RESULTS AND DISCUSSION

The objective of this study is to understand the role of sulfites in coastal fishery crustaceans through a survey conducted with boat owners at the Mehdia and Larache ports, as well as by analyzing the residual SO_2 levels in pink shrimp from national production.

Survey Results

General information: The survey was conducted with 56 coastal shrimp trawlers at the Mehdia and Larache ports, 49 at the Larache port (87.5%) and 7 at the Mehdia port (12.5%). The capacity of the surveyed boats ranged from 2 to 100 TJB. The average duration of fishing trips ranged from 1 to 5 days for boats from Larache, while it did not exceed 3 days for boats from Mehdia. This justifies the use of sulfites to prevent blackening (melanosis). According to Gómez-Guillén *et al.* (2005), melanosis is the primary limiting factor for the shelf life of crustaceans due to the activation of tyrosinase by oxygen immediately after capture.

Nature of captured species and their destination: Four main species are captured: Pink shrimp (*Parapenaeus longirostris*), Norway lobster (*Nephrops norvegicus*), Red shrimp (*Aristeus* spp), and Scyllarus (*Scyllarus arctus*). Table 1 shows the distribution of species caught by port.

Table 1: Crustacean species captured by port.

Port	Species of crustaceans
Mehdia (7 boats)	Pink shrimp (*Parapenaeus longirostris*)
	Norway lobster (*Nephrops norvegicus*)
Larache (49 boats)	Pink shrimp (*Parapenaeus longirostris*)
	Norway lobster (*Nephrops norvegicus*)
	Red shrimp (*Aristeus* spp)
	Scyllarus (*Scyllarus arctus*)

Table 2: Pink shrimp production per trip (kg) by port.

		Production of Pink Shrimp (kg)		
Boat Origin	Number of Boats	Average (kg)	Minimum (kg)	Maximum (kg)
Larache	49	765	170	1360
Mehdia	7	303.5	85	391

Pink shrimp is the most abundantly caught species, as shown in Table 2, with catch tonnage representing 85% and 55% of the captures by boats surveyed at Larache and Mehdia, respectively, followed by Norway lobster. Red shrimp and Scyllarus are rarely caught. All captured crustaceans are sent fresh to wholesale markets and sales points.

Management and use of sulfites: Sulfites are commonly used for processing all species of crustaceans captured by the surveyed boat owners. However, a lot of boat owners do not keep a register to track the use of sulfites in their catches and they adopt the dosages mentioned in the product technical sheets or good practice guides. After capture, shrimp are separated from other species, washed with clean seawater, and then air-dried for 15 minutes to one hour before being treated once on board the boat. The timing between capture and the application of the anti-melanosis treatment is critical. Monique (1994), found that the speed of treatment is essential. In fact, in the presence of oxygen, light, and ambient temperature, the enzymatic browning process accelerates. Thus, late application of sulfites does not yield satisfactory results and may lead to double treatments to address the black spots formed due to oxidation before sulfite application.

Products used: Three types of sulfite-based products are commonly used for treating crustaceans after capture, without some of the respondents having previously read their labels. At the Larache port, professionals use three different sulfite-based products (Products A, B, and C). At the Mehdia port, professionals only use Product B. Table 3 presents the characteristics of these products.

Table 3: Characteristics of sulfite-based products used in shrimp processing.

Products	Characteristics		
	Format	Unit Weight Kg	Composition
A	Bag (Powder)	25	Sodium sulfite (E221)
B	Bag (Powder)	25	Sodium sulfite (E221)
C	Bag (Powder)	25	Sodium metabisulfite (E223), Sodium ascorbate (E301), Citric acid (E330)

Product C stands out as a good choice for shrimp treatment, particularly due to its lower sulfite content compared to the other two commercial formulas. Its composition includes a mixture of antioxidant agents providing a synergistic effect. The recommended dose is 15 g per kilogram, which helps maintain the residual SO_2 level below 60 ppm. Gómez-Guillén *et al.* (2005) studied the effectiveness of sulfite dusting treatments for preventing melanosis in pink shrimp (Parapenaeus longirostris), a treatment with Mel-acid Fresh at 60 g/kg, followed by storage at 2°C for 4 days, resulted in a residual SO_2 level of approximately 225 ppm. Another product, Freskor, achieved a residual level below 100 ppm, but was less effective in preventing melanosis. In contrast, the treatment with Melaplus inhibited black spot formation more effectively, but resulted in a residual level

exceeding the upper limit of 300 ppm in the shrimp flesh. These two latter products were used at a dose of 40 g/kg, as recommended by the manufacturer (Gómez-Guillén et al., 2005).

Method used: The only method used for treating the crustaceans in both ports is dusting. This operation is carried out in 95% of the cases by the cable operator, and in 5% of cases, it is done by several people under the supervision of the boat's supervisor. The professionals consider this method to be highly effective, easy to use, and safe. However, nearly 90% of them believe it is less effective in terms of uniformity.

According to Gómez-Guillén *et al.* (2005), the dusting technique generally leads to uneven distribution of the product among the shrimp, which results in irregular melanosis formation in different individuals. Furthermore, it is difficult to control the duration of the treatment, as the dry powder cannot be removed. On the other hand, when a single dose seems ineffective, another is applied, which increases the total sulfite content in the edible part, often exceeding the regulatory limits. Additionally, they observed that the residual sulfite levels tend to increase with storage time. In this case, the melting ice covering the shrimp may promote the penetration of sulfites present in the shell into the flesh. However, the dispersion of results remains significant due to the uneven spread of the product. In the same study, an immersion treatment for one hour with 50 g/kg of sulfite, combined with citric acid and chelators, proved effective in preventing melanosis for at least one week. With this treatment, the legal limit of 300 ppm of SO_2 in the flesh was not exceeded in most of the samples analyzed.

This immersion treatment remains the most effective and safe method in terms of efficacy and safety. However, it presents significant logistical constraints, particularly due to the large volume of treatment tanks, which are often unsuitable for coastal fishing boats. Additionally, it can cause discomfort for professionals, who are exposed to the risks of toxic fumes and burns.

The spraying technique, which is an intermediate approach between dusting and immersion, combines the ease of application of dusting with the efficacy and safety of immersion. It provides a promising solution to the challenges faced. Chantreau and Vallet (1991) recommend using a solution with a 3% sodium sulfite solution mixed with seawater. This simple technique allows for uniform treatment of shrimp with a solution whose concentration remains constant, thanks to a dosing pump.

Quantities used: The application of sulfites to crustaceans is done by dusting. The method of application and the quantity of sulfite added by professionals are fixed, regardless of the number of units of crustaceans per kilogram. At the Mehdia port, professionals take a quantity equivalent to a handful of sulfites, which corresponds to approximately 250g of product per box. This estimate is based on the fact that a 25kg bag allows them to treat 100 boxes of 17kg of shrimp. In contrast, at the Larache port, professionals use measuring cups to ensure that the quantity of sulfites does not exceed 150g per box. However, they admit that they tend to use a more generous amount of sulfites when the fishing trip lasts more than two days. They justify this practice by stating that the 150g per box does not adequately preserve the shrimp's color. This practice highlights a delicate compromise between maintaining shrimp quality, the duration of the fishing trip, and the rational use of sulfites. Laghmari and El Marrakchi (2005) studied the preservation of pink shrimp (Parapenaeus longirostris) under ice and at room temperature using a combined approach of organoleptic and chemical assessment. The results revealed a significant spoilage of shrimp, dependent on storage conditions and the nature of the spoilage flora, which itself depends on the capture site, determining the mesophilic or psychrophilic nature of the shrimp's natural flora. The shelf life of shrimp was estimated at 6 hours at room temperature and between 3 and 5 days under ice. Additionally, they observed a decrease in sulfite content during storage under ice.

Reasons for using sulfites: 55.35% of professionals use sulfites to prevent shrimp spoilage, 35.71% to avoid the blackening of shrimp, 7.14% to maintain the pink color of shrimp, and 1.87% to extend their shelf life. 68% of respondents observed that excessive use of sulfites in treating shrimp makes them soft and alters their natural color to a yellowish tint, accompanied by white spots on the shell. In contrast, 32% reported no negative effects of sulfites on the quality of the treated crustaceans.

Knowledge and concerns regarding sulfites: Almost all professionals surveyed recognize the dangers that sulfites may present to consumers, except for two boat owners from the Mehdia port, who seem unaware of these risks. They identified allergic reactions as the primary concern, representing about 53.57% of mentions. Others also mentioned potential links between sulfites and cancer (17.85%), heart disease (14.28%), and digestive disorders (10.71%). This perception highlights a divergence in understanding the effects of sulfites on health. The professionals stated that they have never received training on the use of sulfites and their dangers by the supervisory ministry, but they are continuously made aware of this issue by ONSSA's veterinary services. The boats from Larache mentioned that 150g/box (17kg) corresponds to the regulatory standard for sulfite use in crustaceans. The professionals of Mehdia surveyed are not aware of any alternatives to sulfites, and sometimes their crustaceans

are not subject to self monitoring. In contrast to sulfites, Iyengar *et al*. (1991) noted that the risk of excessive use of 4-hexylresorcinol is marginal but it does not possess the bleaching properties of sulfites. The one-minute immersion in a 50 ppm 4-hexylresorcinol solution resulted in an average residual of 1 ppm. However, exposure to excessive concentrations of 4-hexylresorcinol (100 ppm) or prolonged soaking times (15 minutes) led to an increase in residual values, with a maximum value of 2 ± 0.8 ppm. According to Regulation (EU) N° 2015/647 of April 24, 2015, amending Annexes II and III of Regulation (EC) N° 1333/2008 of the European Parliament and Council regarding the use of certain food additives, 4-hexylresorcinol (E586) is allowed as an antioxidant food additive for preventing melanosis in raw crustaceans, provided it is used as a complete substitute for sulfites and that the residual content in the edible part, either raw or cooked, does not exceed 2 mg/kg.

Collaboration and awareness: All the professionals surveyed expressed a strong willingness to deepen their knowledge of the hazards associated with the irrational use of sulfites. They showed a keen interest in improving their practices and behaviors to optimize the use of these additives. Among the professionals surveyed, 87.5% have already taken concrete steps to reduce their use of sulfites. These measures include reducing the amount of sulfites used and trying various sulfite-based products available on the market. All respondents showed a strong interest in using rapid strip test kits. This method would allow them to measure the sulfite levels in the captured crustaceans on board, in order to check their compliance with the regulations. Dahani et al. (2017b) conducted tests using the semi-quantitative rapid strip method on samples analyzed by the official Monier-Williams method. They observed that for low levels of SO_2, the results were accurate and nearly identical to those obtained by the Monier-Williams method. However, as the concentration of SO_2 increased, the method became less reliable. Despite this, these strips can still be used by fishermen on board due to their simplicity.

Scheduling training sessions on the rational use of sulfites has emerged as the primary suggestion made by the professionals surveyed. A lot of operators expressed a strong need to learn more about the potential dangers of excessive use of these additives, as well as the optimal application methods to ensure their safety and efficacy. These training sessions should cover topics such as current regulations regarding the use of sulfites and best practices to minimize their use while preserving the quality of the products.

A particular issue was raised regarding the compatibility between the sulfite quantities recommended by the regulations and the duration of the fishing trip. In fact, professionals at the Larache port expressed their difficulty in shortening the fishing trip duration in order to minimize the use of sulfites while avoiding deterioration in the commercial quality of their shrimp. This practice causes considerable economic losses, both in terms of fuel and labor costs, as well as substantial lost profits due to the reduction in fishing time and catch volume.

Sulfite Dosage Results

The analysis focused on 21 samples of whole pink shrimp (Parapenaeus longirostris) taken fresh from all boats that landed their products during the study period (April 3-16, 2024) in Mehdia and Larache fish markets, Samples are taken at the same time of the day, the time of the auction. The distribution of samples and the average mold are shown in Table 4.

Table 4: Sample distribution by origin and mold.

Port	Number of Samples	Mold (Units/Kg)
Larache	15	240
Mehdia	6	130

Evaluation of the organoleptic quality of samples: In accordance with the procedures outlined in the Codex Stan 92-1981 standard for frozen shrimp by Codex Alimentarius and the Guidelines for Organoleptic Evaluation of Fish and Crustaceans in Laboratories (CAC/GL 31-1999), the organoleptic quality of the samples was judged to be compliant, as shown in Figure 1.

Figure 1: Whole pink shrimp and after peeling.

Residual SO_2 Content

Table 5 summarizes the residual SO_2 content in the pink shrimp samples analyzed using the rapid kit. Table 6 presents the results of sulfur dioxide content in the analyzed pink shrimp samples.

The analysis of shrimp samples reveals a slight variation in the residual sulfur dioxide (SO_2) levels between the

Larache and Mehdia ports. On average, shrimp from the Larache fish market have a SO_2 content of 181,93 ppm, while those from Mehdia average 256.50 ppm, showing that the regulatory average in their fishing port is respected but differences are noted and also showing that at the port of Larache has good practices regarding the use of sulphites on board boats are well respected, unlike those at the port of Mehdia (in Larache, all sulphite values are below the regulatory limit).

Table 5: Plage of residual SO_2 content in analyzed samples.

Port	Number of Samples	Plage of SO_2 Content(mg/kg)
Larache	15	124 - 239
Mehdia	6	155 - 375

Table 6: Results of residual SO2 levels in analyzed shrimp.

Sample Origin	Number of Samples	Average (mg/kg)	Mini. (mg/kg)	Maxi. (mg/kg)	Standard Deviation
Larache	15	181.93	124	239	30.95
Mehdia	6	256.50	155	375	83.35

Although the averages are close, the data distribution is more heterogeneous, especially for the samples from the Mehdia market. The latter has a standard deviation of 83.35 ppm, compared to 30,95 ppm for the Larache samples. This disparity suggests gaps in the sulfite application practices for treating shrimp in port of Mehdia. Several factors could explain this variability, including the random and uneven use of sulfites, variability in practices and behaviors, non-compliance with dosing, and the unevenness of the dusting method, which can be imprecise and subject to significant variation, contributing to the dispersion of SO_2 levels observed. In samples from the Mehdia port, the maximum SO_2 content measured reached 375 ppm, while a sample from Larache had a maximum 239 ppm. These values of mehdia exceed the national standard of 300 ppm set for the mold (>120 units/kg) according to the joint decree of May 14, 2014, establishing the list and limits of food additives authorized for use in primary products and food products, as well as the required packaging indications.

When comparing the SO_2 levels in samples from the Mehdia and Larache ports, we find that some shrimp from mehdia ports may pose a risk to local consumer health due to high SO_2 levels in some samples. This raises concerns regarding the sulfiting practices on board the coastal fishing trawlers, which involve the random use of sulfites, potentially dangerous. Therefore, strengthening professional awareness regarding good practices in the use of sulphites and the implementation of robust self-control and control measures is crucial to ensure that all disembarked shrimp comply with current regulations.

An analysis of landings from the Tangier port, conducted by Dahani *et al.* (2017), was performed to determine sulfur dioxide levels in 22 samples of various crustacean species destined for export, including pink shrimp, red shrimp, and Norway lobster. The results obtained through the official method revealed that sulfite levels did not exceed 280.32 ppm for pink shrimp, thus confirming the compliance of the samples with current regulatory standards. This finding reflects the high awareness and training levels of offshore fishing professionals regarding sulfite use. It also emphasizes the importance of extending these good practices to the training of coastal fishery professionals to achieve similarly satisfactory health results in the future. A previous study conducted by Chemlal (2013) in Tangier focused on analyzing sulfur dioxide (SO_2) in 40 samples of whole raw pink shrimp. This study found a maximum SO_2 level of 2200 ppm, significantly above the national regulatory standards. Additionally, the recorded standard deviation was 491.77. These results suggest that additional sulfite additions may have occurred at retail points or that the shrimp could have been contaminated by excessive treatment on board the boats.

Table 7: Classification of sulfite levels found in the flesh of analyzed shrimp.

		Contamination Classes			
Port	Number of Samples	≤150 ppm	150<SO_2 ≤200 ppm	200<SO_2 ≤300 ppm	>300 ppm
Larache	15	1	10	4	0
Mehdia	6	0	2	2	2
Total	21	1	12	6	2
%	100	4.76	57.14	28.57	9.52

Classification into groups: Table 7 shows the classification of sulfite levels found in the flesh of the analyzed shrimp. By classifying the residual SO_2 levels in the samples from the Larache fish market, we observed a predominance of values in the 150<SO_2≤200 ppm class, followed by those in the 200<SO_2≤300 ppm class, with 66,6% and 26,6%, respectively. For the samples from the Mehdia port, the SO_2 levels in the 150<SO_2≤200 ppm, 200<SO_2≤300 ppm, and >300 ppm classes represent 33,33% each.

We notice that the proportion of samples exceeding 300 ppm is significantly lower at Larache than at Mehdia (0% versus 33,33%). Moreover, we observe the absence of samples with SO_2 levels below 150 ppm at Mehdia, although this category remains minimal in the samples from Larache (6.67%). We can therefore conclude that shrimp from the Larache fish market are safer than those from Mehdia.

Based on the regulatory standard setting a maximum limit of 300 ppm for SO_2 content according to the mold (>120

units/kg), the analyzed samples can be classified into two categories: compliant samples (≤300 ppm) and non-compliant samples (>300 ppm).

Figure 2: Total percentage of compliant and non-compliant samples.

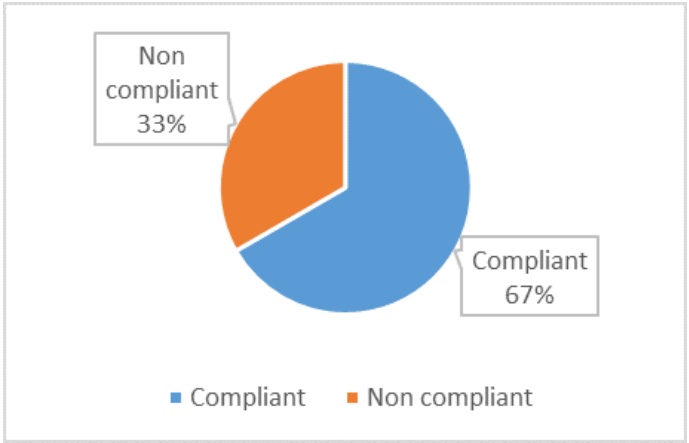

Figure 3: Compliance of mehdia samples.

Figures 2, 3, and 4 illustrate the compliance percentages of the analyzed samples. Analysis of the SO_2 content in the shrimp samples reveals a residual SO_2 issue, with an overall non-compliance rate of about 10%. Indeed, in sampling sites of mehdia, the results indicate a notable prevalence of non-compliant samples concerning the residual SO_2 content in crustaceans. Mehdia shows a particularly high non-compliance rate, with 33% of the samples exceeding the allowed limit. While the situation in Larache is conform. El Baraka (2009) revealed a very concerning profile in Agadir samples, where 100% of the analyzed samples were found non-compliant with the regulatory SO_2 residual levels in crustaceans, with a maximum concentration of 1146.66 ppm. These alarming results, consistent with our findings, inform about the extent of the SO_2 contamination problem in coastal shrimp and the potentially significant consumer exposure to these substances. In the same context, a sulfite exposure study conducted by Hajri *et al.* (2023) involved analyzing sulfite residues in various food products, including 8 shrimp samples prepared according to Moroccan culinary traditions to evaluate the actual exposure of Moroccan consumers. The 8 samples showed an average concentration of 42.2 mg/kg.

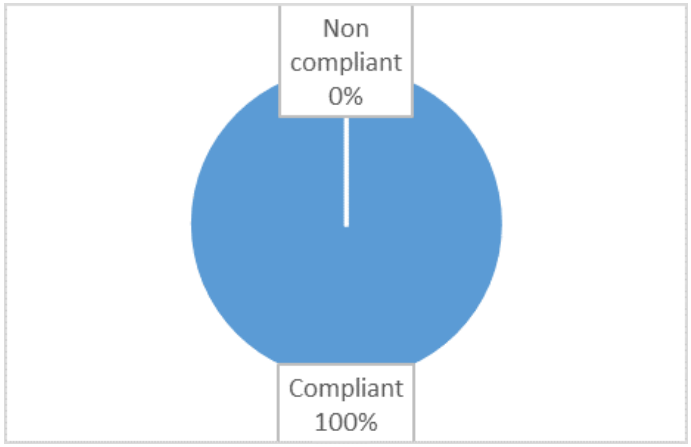

Figure 4: Compliance of larache samples.

Table 8: Relationships between residual so2 levels and the degree of blackening in shrimp.

SO_2 Levels	Degree of Blackening
<150 ppm	++
150<SO_2≤200 ppm	++
200<SO_2≤300 ppm	+
>300 ppm	-

The signs ++, + and - indicate the degree of blackening observed on the shrimp samples; **+:** the samples have discrete spots; **++:** the samples have moderate spots; **-:** the samples do not have any melanosis spots.

Relationship between blackening and SO_2 content: The sensory examination of the shrimp samples revealed slight variability in coloration, ranging from bright pink to melanosis spots at the cephalothorax junction with slight detachment. This observation led us to establish a potential relationship between the residual SO_2 content and the degree of blackening in shrimp. The results are summarized in Table 8.

- Samples showing discrete spots at the cephalothorax corresponded to the 200<SO_2≤300 ppm contamination class (Figure 5).
- Shrimp with moderate melanosis limited to the same

region belonged to the <150 ppm and 150-200 ppm SO_2 contamination classes (Figure 6).

- It is important to highlight that samples with SO_2 content above 300 ppm showed no signs of melanosis and had a uniform light pink color (Figure 7).

Figure 5: Shrimp from the 200 to 300 ppm class.

Figure 6: Shrimp from the 150 ppm and 150 to 200 ppm classes.

In light of the inefficiency of the authorized sulfite concentrations to inhibit melanosis in pink shrimp, Martínez-Álvarez *et al.* (2008) recommend the development of effective alternatives to prevent this phenomenon and extend the shelf life of shrimp without compromising consumer health. They suggest that future research should focus on exploring alternative methods to combat melanosis, identifying and developing new ecological anti-browning agents that are safe for health, to be incorporated into commercial formulations. The current sulfiting practices used by professionals are not always effective in preventing melanosis while respecting regulatory limits. Abandoning the dusting technique seems to be a crucial step. This uncontrolled method can lead to uneven distribution of the product and an increased risk of excessive exposure. Spraying, which involves preparing sulfite-based solutions and spraying them onto shrimp, emerges as a more precise and controlled alternative.

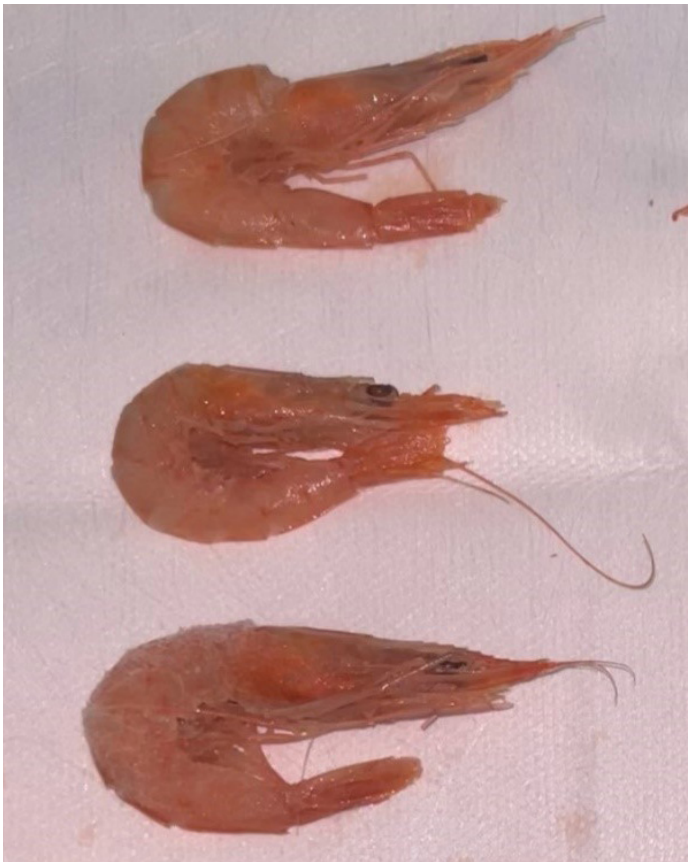

Figure 7: Shrimp from the 300 ppm class.

CONCLUSIONS AND RECOMMENDATIONS

The survey conducted with coastal fishery boat owners in Mehdia and Larache revealed that sulfiting is a common and widespread practice employed to prevent spoilage, inhibit enzymatic blackening, and extend the shelf life of their crustaceans.

The regulatory average in their fishing port is respected. At the port of Larache, the proper procedures for using sulfites aboard boats are highly valued, and all sulfite-found values are in compliance. Nevertheless, in contrast to those in the Port of Mahdia, where certain findings raise questions regarding their hygienic safety. The application of sulfites is often uneven, with different commercial products used and a lack of control over the quantities applied. While Product C appears to stand out as an effective and safe solution, its widespread adoption has not yet been achieved.

The laboratory analyses of 21 samples of pink shrimp showed 90% compliance with regulations, indicating ac-

ceptable but improvable sulfite application on board. The residual SO_2 levels varied between samples from Mehdia and Larache, possibly reflecting differences in sulfiting practices, the inherent unevenness of the dusting technique, and the uncontrolled application of random amounts of sulfites in the fish market of mehdia. In addition, in the event of non-compliance with the regulations in force, the control services proceed to the seizure and destruction of non-compliant batches of shrimp, the verbalization of the shipowners who committed the offense, and the prohibition of shrimp fishing by the boats concerned until the necessary corrective measures are put in place. These results highlight the need for strengthening professional awareness regarding good practices in the use of sulfites and the implementation of robust self-control and control measures for sulfite use in the coastal fishery crustacean industry. The adoption of good sulfiting practices and the use of products with lower sulfite content are essential to guarantee the safety of crustaceans.

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NOVELTY STATEMENTS

The study highlights the degree of awareness among fishermen regarding the use of sulphites in pink shrimp from northern Morocco and its relationship with their analytical compliance through the use of a quick, easy and effective method of dosgae sulphites.

AUTHOR'S CONTRIBUTIONS

Said Dahani: Conceptualized, conducted the research, and wrote the manuscript.
Said Dahani, Rachid Khatouf, Ghizlane Laarif, O. Oleya El Hariri and Nourredine Bouchriti: Conceptualized, analyzed data, supervised the research, and revised the final form.

All authors read and approved the final version of the manuscript.

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Availability of Data and Materials

The data of the current study are available.

Ethical Consideration

Ethical issues (including plagiarism, consent to publish, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancy) have been checked by all the authors before publication in this journal.

Conflict of Interest

The authors have not declared any conflict of interest.

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