**Sensory methods ensuring authenticity and fostering Mediterranean fish**

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The aim of this PhD project is to study and foster Mediterranean fish products, ensuring authenticity and improving subjects’ trust, by using sensory analysis. It was achieved through a multidisciplinary approach concerning the study of consumer behavior toward seafood products, and through the development and optimization of descriptive sensory methods to assess the authenticity and quality of Mediterranean seafood products. The results are focused on the reduction of fishing fraud and improving consumers’ trust in fish products by studying all the useful aspects, both information on the traceability and authenticity of fish and sensory and nutritional features.

**Metodi sensoriali per garantire l’autenticità e valorizzare i prodotti ittici del Mediterraneo**

Il presente progetto di dottorato ha l’obiettivo di studiare e valorizzare i prodotti ittici del Mediterraneo, mediante l’impiego di metodologie sensoriali. L’obiettivo è stato raggiunto attraverso un approccio multidisciplinare riguardante lo studio del comportamento del consumatore nei riguardi dei prodotti ittici, e attraverso lo sviluppo e l’ottimizzazione di metodi sensoriali descrittivi capaci di garantire autenticità e qualità ai prodotti ittici del Mediterraneo. I risultati si concentrano sulla riduzione delle frodi nel settore della pesca e sul miglioramento della fiducia dei consumatori nei confronti dei prodotti ittici, studiando tutti gli aspetti utili, sia riguardo le informazioni sulla tracciabilità e l'autenticità del pesce, sia le caratteristiche sensoriali e nutrizionali

**Key words**: Fish quality, reduction of fishing fraud, consumer science, descriptive sensory analysis.

# **1. Introduction**

Fish products are widely consumed all around the world thanks to their nutritional composition rich in protein, long-chain fatty acids (EPA and DHA), and vitamins, and poor in carbohydrates (Carlucci et al., 2015). Nowadays, global aquatic food consumption is estimated at 158 million tonnes, up from 28 million tonnes in 1961. Since 1961, consumption has increased by approximately 3% annually, this increase is due both to an increase in per capita consumption, but also to an average increase in world population (FAO, 2022). Increased consumption of seafood has created jobs for the community (Shamsuzzaman et al., 2020), but is reducing natural fish stocks in the sea, and could be dangerous for the environment (Verbeke et al., 2007). Over the years, subjects have become more sensitive to issues of environmental sustainability and traceability of the products they buy (Pucci et al., 2020). Hence, some brands have joined sustainability and traceability programs to inform and guide subjects toward sustainable purchasing choices (Van Loo *et al.*, 2015). Moreover, the increasing trend in fish consumption increase fraud related to fish authenticity and quality, especially for less experienced subjects (Giusti et al., 2019). Finally, subjects are not always able to assess the quality of the species they buy, as not all the specific attributes of each fish species are known, and furthermore, there are no standard methods for assessing the freshness of fish. Thereby, this process can be difficult during purchase (Freitas et al., 2021). Therefore, this PhD project aimed to valorise Mediterranean fish products through a multidisciplinary approach concerning the study of consumer behavior toward seafood products, and through the development and optimization of descriptive sensory methods to assess the authenticity and quality of Mediterranean seafood products. To achieve the set objectives, the following activities were conducted:

A1) Study of subjects’ behaviour towards fish products. This activity had a particular focus on fish product consumption habits, purchasing behaviour and the importance of fish traceability and sustainability.

A2) Consumer study to assess the effect of external variables provided to the subjects when purchasing or consuming fish products.

A3) Descriptive sensory analysis to attest to the authenticity of different fish species.

A4) Quality index method for assessing the quality and freshness of fish species during the purchase time.

A5) Study of subjects’ behaviour in northern Europe. This activity was carried out during the PhD student's time abroad at Nofima Research center in Tromsø and Ås (Norway). The activity focused on the perceptions of Northern European subjects towards the traceability and sustainability of red king crab. In addition, a descriptive analysis test was carried out with a trained panel to test the differences between crabs from capture-based aquaculture and wild.

**2. Materials and Methods**

First, an online questionnaire (A1) was filled out by 2000 subjects from both Italy and Spain. The questionnaire collected information on fish consumption and purchasing habits (frequency of consumption, types of purchased products, places of purchasing, etc.) and the perception and importance of fish traceability and sustainability (1-7 Likert scale). Subjects were equally distributed for social-demographic information. Then, a consumer test (A2) was conducted with 100 Italian and 100 Spanish subjects, by using a blind-info procedure: in the first session the subjects evaluated a sample of bluefin tuna (*Thunnus thynnus,* both raw and cooked) and rated their liking for specific sensory characteristics, using a 9-point Likert scale (1: Extremely disliked; 9: Extremely liked), without sample information; in the second one, one week later, the same subjects performed the same evaluation but having been informed that the sample had been caught according to the terms of the Marine Stewardship Council (MSC) sustainability label. Subsequently, a classical descriptive analysis (QDA) was performed (A3) both of yellowfin tuna (*Thunnus albacares)* and bluefin tuna (*Thunnus thynnus*), identifying their peculiar sensory characteristics. Finally, Quality Index Method (QIM) (A4) was applied to assess the quality and freshness of fresh anchovies (*Engraulis encrasicolus*), stored by using a static electric field generator (SEF). Fresh anchovies were stored in polystyrene containers covered with melted ice and placed in two refrigerated cells at 4±1 °C. Only one of the two cells was equipped with the SEF generator. The anchovies from shelf-life day 1 to day 9 were evaluated by 9 assessors who used an optimized QIM protocol (Fiorile et al., 2023).

To assess the perception of traceability and sustainability by Northern European subjects, an online questionnaire was sent out. Subjects were shown pictures of red king crab in different settings and then a list of attributes was provided to them. The CATA method was used to collect responses to this questionnaire. Finally, again a QDA was carried out to characterise the two samples (capture-based aquaculture and wild) and to highlight the differences between them (A5).

The respondents to the online questionnaire were grouped for provenance (Italy and Spain), gender, and age (4 age groups) for 16 observations. Multifactorial analysis (MFA) was used to study the relationship between the observations and all the collected variables (A1). Paired sample t-test was used to find differences between the two experimental conditions in the consumer test (A2), to find differences between the two tuna species in the QDA (A3) and finally to find differences between the two storage conditions in the QIM (A4). Linear regression was used to describe the increment of QI during storage time for both trials (A4). The confidence level was 95% in every statistical test used. XLSTAT statistical software (v.2016.02, Addinsoft) was used for data analysis.

The data analysis of A5 is still in progress, thus the results are not illustrated here. In this manuscript, only the main results are discussed.

# **3. Results and discussion**

## **3.1. Online questionnaire**

Figure 1a is a representation of the subjects on the first two dimensions extracted by MFA accounting for 62.94% of the variance. Subjects were well separated in terms of provenance and age, indeed Spanish subjects are located in the upper part of the graph, while the Italian subjects are located in the lower part of the graph; as well as, the younger subjects are located in the left part of the graph, while the adults are in the right part of the graph. Figure 1b allows observing the variables which characterize the subjects and the associations among them. Adult Spanish subjects consume more fish than Italian ones, on the other hand, Italian subjects like fish more than Spanish. Also, adult Spanish subjects consume more fresh fish, while adult Italian subjects are more familiar with frozen and canned fish. Focusing the attention on sustainability and traceability, young subjects resulted more familiar with sustainability labels than adult ones, while the adults were more interested in traceability. Although subjects have become more sensitive to environmental issues (Pucci et al., 2020), our results confirm the low awareness of fish sustainability labels due to a lack of information on this topic, as reported by Garcìa-Herrero *et al*. (2019).

**Figure 1***- Observation map (****a****) and Variables map (****b****) – MFA results*

## **3.2. Consumer test**

The consumer test carried out on 100 Italian and 100 Spanish subjects showed that liking scores for the attributes assessed on both raw and cooked tuna samples increased when the sustainability label information was provided (Figure 2a-b). Specifically, statistical analysis showed significant differences in overall liking in Italy (p≤0.05), and in overall liking and appearance in Spain (p≤0.05).

Despite the subjects demonstrated to have a limited knowledge of sustainability labels and the different aspects they cover (Hoek et al., 2021), the sustainability label information increased the evaluated scores. As reported by other authors, the addition of external information (brand, labels) provided at the time of purchase can greatly influence product perceptions and choices (Olsen, 2003; Altintzoglou and Heide, 2016).

**Figure 2***- Average liking score in Italy (****a)****and average liking score in Spain (****b****). Asterisks indicate significant differences (\* p<0.05; \*\* p<0.01; \*\*\* p<0.001)*

**b**

## **3.3. Descriptive analysis**

Classical descriptive analysis (QDA) was useful to characterise and discriminate the two tuna species treated. Preliminary focus groups were needed to draw up a final list of five descriptive attributes for raw tuna and eleven for cooked tuna. The attributes were standardised for the two tuna species to have a single list.

Results showed that the two evaluated species were significantly different from each other in all the descriptive attributes when evaluated as raw (p≤0.05). The cooking process, on the other hand, weakened the differences between the two species, in fact, of the eleven attributes assessed, only five showed statistically significant differences (p≤0.05) (Figure 3a-b). The results of the descriptive analysis allowed the identify peculiar sensory for two tuna species and discriminate between them. Although they may seem similar, yellowfin tuna (*Thunnus albacares*) and bluefin tuna (*Thunnus thynnus*) have substantial nutritional and economic differences. As reported by Cutarelli et al. (2014) one of the possible fraud in the fisheries sector is misleading species substitution (e.g. less valuable species sold in place of more valuable species).

**Figure 3***-Raw tuna evaluation (****a****)and Cooked tuna evaluation (****b****)*. *Asterisks indicate significant differences (\* p<0.05; \*\* p<0.01; \*\*\* p<0.001)*

## **3.4. Quality Index Method**

This activity aimed to assess the freshness of anchovies using the QIM and to compare the evolution of the quality index (QI) over time between two different storage conditions: classic refrigeration and refrigeration with a static electric field (SEF). As reported in Figure 4, the maximum score achieved by the anchovies was 20 in the classic storage condition and 15 in the trial with SEF. Describing the QI increment by using linear regression (R2=0.97 for the control sample, R2=0.96 for SEF samples), as required by the QI method, results clearly showed that the SEF technology was able to reduce the QI score increment rate (slope = 2.0 day-1) compared to the control sample (slope = 2.5 day-2). The results obtained by anchovies preserved in the classical condition are consistent with other studies on anchovies’ QIM (Massa, Manca and Yeannes, 2012; Pons-Sánchez-Cascado *et al.*, 2006). The improved condition of anchovies reported during storage with SEF is in agreement with other studies (Xanthakis *et al.*, 2013; Dalvi-Isfahan, Hamdami and Le-Bail, 2016). Moreover, as evidenced by the paired samples t-test, the two methods showed statistically significant differences (p≤0.05). There is a first difference after a three-day of shelf-life. But the differences are evident from day 7 onwards (Figure 4). Thus, since the scores of the two trials are similar for short shelf life, the preservative effect of the static electric field produced by SEF is more evident for longer shelf life.

**Figure 4***-QIM results, comparison between the two different trials*. *Asterisks indicate significant differences (\* p<0.05; \*\* p<0.01; \*\*\* p<0.001)*

**4. Conclusion and Future Perspectives**

This PhD project aimed to foster Mediterranean fish products. To achieve this, activities started with an online questionnaire to find out current knowledge about fish products in two developed countries, where fishing is a source of income and part of the culinary culture. The results of the questionnaire reported information on the consumption habits of both populations concerning fish products, and the subjects' interest in fish traceability and sustainability emerged, even though the topic is not fully known to all subjects. Indeed, the consumer test showed how the addition of external information can influence the subjects' final judgment of liking. The descriptive analysis, on the other hand, can improve the knowledge of the fish species commonly found on the market. Finally, the quality index method showed itself to be easy to use in assessing the freshness of fresh anchovies. Furthermore, by combining normal refrigeration with a static electric field, the quality index can be reduced and thus the shelf life of anchovies can be increased. Future activities can be concentrated on other Mediterranean fish species, and dissemination campaigns should be promoted to better inform people about what they are buying, and to promote the purchase of traceable, sustainable fish and above all avoid fraud.

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