DEVELOPMENT OF NEW PRODUCTS FROM AQUACULTURE FISH SPECIES

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DOCTORAL THESIS

DEVELOPMENT OF NEW PRODUCTS FROM AQUACULTURE FISH SPECIES

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Certificado de dirección de tesis

El Dr. Luis Guerrero Asorey, del Instituto de Investigación y Tecnologías Agroalimentarias IRTA

Declara:

Que el trabajo titulado: **DEVELOPMENT OF NEW PRODUCTS FROM AQUACULTURE FISH SPECIES**, que presenta **Oxana Lazo Zamalloa** para la obtención del título de doctora, se ha realizado bajo mi dirección y cumple los requisitos para poder optar a la opción de Mención internacional.

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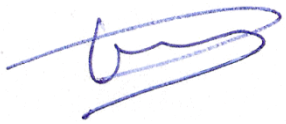

Dr. Luis Guerrero Asorey
Director de la Tesis

Monells, Girona a 4 de Diciembre del 2017

To my mom, who taught me that nothing is impossible if you truly want it...

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PUBLICATIONS

This thesis is presented as compendium of publications namely:

Publication 1: Lazo, O., Claret, A. and Guerrero, L. (2016). **A comparison of two methods for generating descriptive attributes with trained assessors: Check-All-That-Apply (CATA) vs. free choice profiling (FCP)**. *J. Sensory Studies, 31*, (2), 163-176. Impact factor: 1.54, Quartile 2.

Publication 2: Lazo, O., Guerrero, L., Alexi, N., Grigorakis, K., Claret, A., Pérez, J. and Bou, R. 2017. **Sensory characterization, physico-chemical properties and somatic yields of five emerging fish species**. *Food Research International, 100*, 396-406. Impact factor: 3.85, Quartile 1.

Publication 3: Lazo, O., Claret, A., Bou, R., Robles, R and Guerrero L. **Discriminant ability of Check All That Applies (CATA) technique performed with consumers and trained assessors compared to traditional Quantitative Analysis.** (Paper sent to *Food Qualtity and Preference*). Impact factor: 3.19, Quartile 1.

ABREVIATION LIST

AOAC Association of Official Analytical Chemists

ANOVA Analysis of Variance

ASC Aquaculture Stewardship Council

CATA Check All That Apply

CI Condition Index

DHA Docosahexaenoic acid

DE Deutshland

DY Dressing Yield

EATIP European Aquaculture Technology and Innovation Platform

EPA Eicosapentatenoic Acid

ES España

EU European Union

EUMOFA European Market Observatory for Fisheries and Aquaculture products

FAO Food and Agriculture Organization

FR France

FY Filleting Yield

FCP Free Choice Profiling

FDA Food and Drug Administration

FEAP Federation of European Aquaculture Producers

GHP Good Hygienic Practices

GNPD Global New Product Database

GPA Generalized Procrustes Analysis

GSI Gonadosomatic Index

HACCP Hazard Analysis and Critical Control Point

HSI Hepatosomatic Index

ISO International Standard Organization

IT Italia

MAP Modified Atmosphere Packaging

NPD New Product Development

PCA Principal Component Analysis

QA Quantitative Analysis

QDA Quantitative Descriptive Analysis

TPA Texture Profile Analysis

UK United Kingdom

USDA United States Department of Agriculture

VSI Viscerosomatic Index

WP Work Package

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GENERAL INDEX

Doctoral thesis presentation

The thesis has been developed within the project: "Diversification of fish species and products in European Aquaculture" (DIVERSIFY 2013-2018), financed by the European Union`s Seventh Framework Programme for Research, Technological development and demonstration (KBBE-2013-07 single stage, GA 03121), involving the participation of research institutes, universities and companies from eleven European Union (EU) countries. This project emerged with the purpose to diversify and increase the fish aquaculture production, and stimulate the demand for EU-cultured fish in Europe. Therefore five fish species namely: meagre, greater amberjack, pikeperch, wreckfish and grey mullet, were selected based on their potential to grow in the market and also to cover the entire European geographic area.

In addition, this project aims to achieve the diversification of European aquaculture by overcoming particular bottlenecks of the selected species. Consequently, enhancing their added value by starting product innovation, improving consumer acceptance, and developing the knowledge to expand current and create new markets.

The project DIVERSIFY was structured in eight groups or work Packages (WP) with the following general purposes:

- WP1 Project management
- WP2 Reproduction and genetics: To study reproductive dysfunctions, preventing the reliable production of eggs and, thus, juveniles for grow out.
- WP3 Nutrition of the selected species: To study feeding regimes identifying optimum dietary nutrient levels to optimize reproductive success in the species.
- WP4 Larval husbandry: To study larval performance, development and behavior at different developmental stages.
- WP5 Grow out husbandry: To improve existing and develop new methodologies, necessary for grow out husbandry of the selected species.
- WP6 Fish health: To improve the ability to diagnose and treat known diseases, and to increase knowledge on the immune system of the selected fish species.
- **WP7 Socioeconomics:** To analyze and understand overall value perceptions of consumers regarding cultured fish in general and towards the selected fish species in particular. To develop concepts for new products and screen the elicited ideas.

To Develop New products through a characterization of the fish species and the development of physical prototypes of new products. **To assess consumers perception** and make a quality evaluation study of the developed products. To develop a business model and marketing strategy for the developed products

- WP8 Dissemination: To organize workshops in approaching and working with the food industry and consumers federations, and in the production and revision of documents and actions.

This doctoral thesis was developed in the frames of WP7 Socioeconomics, and is specifically linked to the activities of Characterization of the fish species, New Product Development and the Consumer sensory perception of the developed products.

The activities performed in WP7 derived in the following publications included in this thesis:

1. Lazo, O., Claret, A. and Guerrero, L. (2016). A comparison of two methods for generating descriptive attributes with trained assessors: Check-All-That-Apply (CATA) vs. free choice profiling (FCP). *J. Sensory Studies, 31*, (2), 163-176. Impact factor: 1.54, Quartile 2.

2. Lazo, O., Guerrero, L., Alexi, N., Grigorakis, K., Claret, A., Pérez, J. and Bou, R. 2017. Sensory characterization, physico-chemical properties and somatic yields of five emerging fish species. *Food Research International, 100*, 396-406. Impact factor: 3.85, Quartile 1.

3. Lazo, O., Claret, A., Bou, R., Robles, R and Guerrero L. Discriminant ability of Check All That Applies (CATA) technique performed with consumers and trained assessors compared to traditional Quantitative Analysis. (Paper sent to *Food Qualtity and Preference*). Impact factor: 3.19, Quartile 1.

Resum

Els europeus, en general, són consumidors habituals de productes de la pesca i de l'aqüicultura i el seu consum continua augmentant. De fet, el 42% dels europeus ha augmentat el consum de peix i productes de la pesca en com a mínim una vegada a la setmana. No obstant això, a la UE només el 10% del peix que es consumeix de peix prové de l'aqüicultura. Aquesta situació pot atribuir-se en part a la manca de diversitat de productes d'aqüicultura i, potser més important encara, a la manca de productes processats procedents de l'aqüicultura. Tanmateix, tot i que algunes espècies aquàtiques es cultiven a Europa, la producció de peix d'aqüicultura està dominada tant pel que fa a volum com pel que fa a valor per espècies com el salmó atlàntic. Per tant, és necessari augmentar la diversificació de la indústria de l'aqüicultura, augmentar els seus productes i desenvolupar nous mercats. Una forma d'aconseguir-ho és mitjançant la introducció d'espècies emergents al mercat. Concretament, en el projecte en el que s'emmarca aquesta tesi es varen identificar cinc espècies d'aqüicultura amb potencial en aquest sentit: la llissa, la sandra, el reig, la círvia i el dot.

L'objectiu d'aquesta tesi va ser desenvolupar nous productes a partir d' espècies de peix seleccionades, incorporant opinions tant d'experts com de consumidors, incloent les seves demandes específiques i preferències, en determinats mercats de la Unió Europea (Regne Unit, Alemanya, Espanya, França i Itàlia).

En aquest treball es va realitzar una caracterització completa de les espècies de peixos mitjançant anàlisis sensorials i fisicoquímiques. En la caracterització sensorial, en primer lloc es varen generar descriptors sensorials (utilitzant vàries especies) mitjançant dues metodologies: Check-All- That- Apply (CATA) i Free Choice Profiling (FCP). Ambdós mètodes es van dur a terme mitjançant degustadors entrenats, la qual cosa, va garantir que el un perfil generat incloïa els atributs més rellevants. Una vegada obtinguts els descriptors apropiats, es va realitzar una caracterització sensorial de les 5 espècies. A més, es va realitzar una caracterització fisicoquímica mitjançant anàlisis somatomètriques, composicionals i de textura instrumental. Es van detectar diferències importants entre espècies. El contingut de greix va ser un dels aspectes discriminants més rellevants, mentre que la duresa va ser un dels atributs que millor diferenciava les espècies quant a la textura. La círvia es va descriure com àcida, la sandra va associar-se amb un gust terrós i la llisa es caracteritzava pel seu sabor amarg. La fermesa

sensorial va diferenciar clarament el dot de la resta de peixos avaluats, mentre que el reig presentava una textura més sucosa.

Per tal de generar idees potencials pel desenvolupament de productes, es varen realitzar 10 sessions entrevistes grupals en els cinc països europeus seleccionats. A partir d'aquestes sessions es van construir nou conceptes de productes que varen servir com a base pel desenvolupament de nous productes de peix. Posteriorment, es van desenvolupar un total de 43 idees de productes a partir d'aquests conceptes les quals varen ser examinades subseqüentment per experts els quals varen avaluar la seva aplicabilitat.

A partir de les espècies seleccionades i de les seves propietats fisicoquímiques i sensorials es van desenvolupar dotze prototips . D'aquests se'n varen escollir sis tenint en compte el seu nivell de processament i tipus de mercat al que anaven dirigits. Així doncs els productes seleccionats que posteriorment es varen caracteritzar tant amb degustadors entrenats com amb consumidors es varen ser els següents: amanida de peix, hamburguesa en forma de peix, paté de peix, filet fumat, conserva de peix amb oli d'oliva i filet per coure a la paella.

La caracterització dels productes es va dur a terme mitjançant CATA, per la qual cosa es va comparar la capacitat discriminant d'un CATA realitzat amb degustadors entrenats i d'un CATA realitzat amb consumidors amb la d'una Anàlisi Quantitativa tradicional. Totes tres metodologies van demostrar tenir una bona capacitat discriminant separant clarament les sis mostres. No obstant això, els consumidors tenien la major variabilitat entre ells en comparació amb els degustadors entrenats, fins i tot al descriure mostres molt diferents.

A més a m de la caracterització dels productes, també es va avaluar la percepció dels consumidors en els cinc països seleccionats. Es van mesurar les expectatives d'acceptabilitat general d'acord amb la percepció del producte (només amb la informació i sense tastar-lo), una degustació a cegues i finalment una degustació del producte en la que els participants de l'estudi disposaven de la informació completa sobre cada producte. La probabilitat de compra també es va incloure en l'estudi. La imatge / percepció dels diferents productes, diferia de forma important entre països, així com el seu impacte en la probabilitat d'acceptació i compra de productes.

Resumen

Los europeos son consumidores regulares de productos de la pesca y de la acuicultura y continúan aumentando su consumo. De hecho, el 42% de ellos ha aumentado el consumo de pescado o productos acuáticos al menos una vez a la semana en sus hogares. Sin embargo, en la UE sólo el 10% del consumo de pescado proviene de acuicultura. Esta situación puede atribuirse en parte a la falta de diversidad de los productos de acuicultura y quizás aún más importante, a la falta de productos procesados de acuicultura. Sin embargo, aunque algunas especies acuáticas se cultivan en Europa, la producción acuícola de peces está dominada tanto en volumen como en valor por especies como el salmón del Atlántico. Por lo tanto, es necesario aumentar la diversificación de la industria proveniente de acuicultura, aumentar sus productos y desarrollar nuevos mercados. Una manera lograrlo es a través de la introducción de especies emergentes en el mercado. Así pues, el proyecto en el que esta tesis está enmarcada identificó cinco especies potencial acuícola llamadas: corvina, lucioperca, mújol, seriola y cherna.

El objetivo de esta tesis fue desarrollar nuevos productos de las especies de pescado seleccionadas, incorporando opiniones tanto de expertos como de consumidores, incluyendo demandas específicas y preferencias de estos en mercados seleccionados de la Unión Europea (Reino Unido, Alemania, España, Francia e Italia).

En este trabajo se realizó una caracterización completa de las especies seleccionadas mediante un análisis sensorial y físico-químico. Para poder llevar a cabo la caracterización sensorial, primeramente se buscó la generación descriptores sensoriales (en distintas especies de pescado) aplicando dos metodologías: Check-All-That-Apply (CATA) y Free Choice Profiling (FCP). Ambos métodos se realizaron con catadores entrenados lo cual garantizó que se incluyeran los atributos más relevantes. Una vez obtenidos los descriptores apropiados se realizó el análisis sensorial de las 5 especies. La caracterización fisicoquímica se realizó mediante análisis somatométricos, composicionales y de textura instrumental. Se encontraron diferencias importantes entre las especies. El contenido de grasa fue uno de los aspectos discriminantes más relevantes, mientras que la dureza fue uno de los más diferenciales cuando se trató de textura. La seriola fue descrita con sabor ácido, la lucioperca fue asociada a un sabor terroso y el mújol se caracterizó por un sabor amargo. La firmeza sensorial fue

claramente distintiva para la cherna, mientras que la corvina estuvo más relacionada con una textura jugosa.

Con el fin de crear ideas para el desarrollo de productos 10 sesiones de entrevistas grupales se realizaron en los cinco países seleccionados. A partir de estas sesiones se construyeron nueve conceptos que sirvieron de base para el desarrollo de nuevos productos de pescado. Posteriormente, se desarrollaron un total de 43 ideas de productos a partir de estos conceptos las cuales fueron examinadas subsecuentemente por expertos para evaluar su aplicabilidad.

Doce prototipos de productos de pescado fueron desarrollados de acuerdo con las ideas previamente sugeridas a partir de las especies seleccionadas, basándose en sus propiedades fisicoquímicas y sensoriales. Seis de estos productos fueron elegidos, con base en su nivel de procesamiento y tipo de mercado dirigido. Así, entonces los productos seleccionados fueron: una ensalada de pescado, una hamburguesa con forma de pescado, un pate de pescado, filetes ahumados, filetes en aceite de oliva y un filete para asar a la parrilla estos productos fueron posteriormente caracterizados tanto por catadores entrenados como por consumidores.

La caracterización de los productos se logró mediante el uso del método CATA, para lo cual se comparó la capacidad discriminante de un CATA realizado con catadores entrenados y de un CATA realizado con consumidores con la de un Análisis Cuantitativo tradicional. Las tres metodologías demostraron tener una buena capacidad discriminante separando claramente las seis muestras. Sin embargo, los consumidores tuvieron una mayor variabilidad entre ellos en comparación con los catadores entrenados, incluso al describir muestras muy diferentes.

Además de la caracterización de los 6 productos, se evaluó la percepción de los consumidores en los cinco países seleccionados. Se midieron las expectativas de aceptabilidad de acuerdo a la percepción del producto (sin probarlo), se realizó una cata a ciegas y una evaluación posterior del producto con la información completa sobre cada producto. La probabilidad de compra también fue incluida en la evaluación. La imagen / percepción de los diferentes productos, difirió de manera importante entre países, así como su impacto en la aceptación del producto y la probabilidad de compra.

Summary

Europeans are regular consumers of fish and aquaculture products and they continue increasing their consumption. In fact, 42% of them have increased eating fish or aquatic products at least once a week in their homes. Nevertheless, in the EU only 10% of the seafood consumption has been originated from EU aquaculture. This situation can be attributed partially to a lack of diversity of aquaculture products and, perhaps more importantly, a lack of processed aquaculture products. In addition, even though some aquatic species are cultured in Europe, finfish aquaculture production is dominated both in volume and value by a handful of species such as Atlantic salmon. Therefore, there is a need to rise the diversification of the aquaculture industry, increasing aquaculture products and developing new markets. One way to make this approach is through the introduction of emerging species in the market. Therefore the project in which this thesis in immersed identified five species of potential aquaculture rearing named: Meagre, Pikeperch, Grey Mullet, Greater Amberjack and Wreckfish.

The aim of this thesis was to develop new products from the selected fish species, incorporating opinions of both experts and naïve assessors thus, including specific demands and consumer preferences, in selected markets of the European Union (UK, Germany, Spain, France and Italy).

In this work a full characterization of the fish species was performed through sensory and physicochemical analyses. In order to acquire the tools for the sensory characterization, two methodologies were applied to generate sensory descriptors for different fish species: Check- All- That- Apply (CATA) and Free Choice Profiling (FCP). Both methods were performed with trained assessors which helped to obtain a reliable profile ensuring that the most relevant attributes were included. Once the appropriate descriptors were obtained a sensory evaluation of the 5 species was performed. In addition a physicochemical characterization was performed through somatic, compositional and instrumental texture analyses. Important differences were found between species. Fat content was among the most relevant discriminating aspects, while hardness was among the most differentiating ones when dealing with texture. Greater amberjack was described with sour flavor, pikeperch was associated to an earthy flavor and grey mullet was characterized by bitter flavor. Sensory firmness was clearly distinctive for wreckfish, while meagre related to juicy texture.

In order to create ideas for the product development 10 focus groups sessions were performed in the five selected countries. Nine concepts were built from these sessions to be used as a basis for the new product development of fish products. Afterwards, a total of 43 product ideas were developed from these concepts and were subsequently screened by experts to assess their suitability.

Twelve fish product prototypes were developed from the fish species accordingly with the previously suggested ideas and based on the physicochemical and sensory properties of the selected species. Six of these products were chosen, based on their level of processing and addressed market. Thus a ready to eat salad with fish, a fish burger shaped as fish, a fish pate, smoked fillets, fillets in olive oil and a fillet for grilling were the selected products to be further characterized by trained assessors and consumers.

The products characterization was achieved through the use of CATA, therefore the discriminant ability of CATA performed with trained assessors and CATA performed with consumers was compared with a traditional Quantitative Analysis. All three methodologies proved to have a good discriminant ability clearly separating all six samples. Nevertheless, consumers had the highest variability among them compared to the trained assessors even when describing very different samples.

In addition to the product characterization, consumers perception of all six of them was also assessed in the five selected countries. Expectations of the overall liking according to a product perception, a blind tasting and a subsequent product assessment with full informed condition on each product were measured. Purchase probability was also included in the evaluation. As it turned out the image/perception of the different products, differed in an important way between countries, as well as their impact on the product acceptance and purchase probability.

1. INTRODUCTION

1.1 Fish and fish products

Fish and fish products are a fundamental source of nutrients for a healthy and balanced diet. Fish is low in saturated fat, carbohydrates and cholesterol, and contributes with high quality value proteins and vitamins (D, A and B2 riboflavin). Fish is also rich in minerals such as calcium, iodine, zinc, iron, selenium, magnesium, and potassium, particularly if eaten whole. Fish is an important source of polyunsaturated fatty acids omega-3 (FAO, 2016). Two of the main omega-3 fatty acids found in fish are EPA (eicosapentaenoic acid) and DHA (docosahexaenoic acid). Omega-3 fatty acids are found in every kind of fish (being especially high in fatty species), and have proven to have a protector role towards cardiovascular diseases (Kris-Etherton et al., 2003; Cahu et al., 2004; Piñeiro-Corrales et al., 2013).

A significant growth in fish consumption has enhanced people's diets around the world making them more nutritious. In 2013, fish accounted for about 17 percent of the global population's intake of animal protein and 6.7 percent of all protein consumed. Moreover, fish provided more than 3.1 billion people with almost 20 percent of their average per capita intake of animal protein. (FAO, 2016). Even small quantities of fish can have a significant positive nutritional impact on plant based diets, and this is the case in many low income food-deficit countries and least-developed countries. Global total capture fishery production in 2014 was 93.4 million tons, of which 81.5 million tons came from marine waters and 11.9 million tons from inland waters (FAO 2016). With this evidently elevated consumption, it is not surprising that the world's wild fish stocks are now limited. In addition, unsustainable fishing practices and other factors such as habitat destruction, pollution, climate change or invasive species have led to fish stock depletion (FAO 2012). Therefore, consumers are being proposed with aquaculture fish as an alternative to satisfy the current demands (Cahu et al., 2004).

1.2 Aquaculture

1.2.1 Aquaculture production

Aquaculture is the farming of aquatic organisms in both coastal and inland areas involving interventions in the rearing process to enhance production (FAO, 2016). Large shares of fish entering global markets derive from aquaculture. It already produces nearly half of the world's food fish, and its volume keeps increasing since it has become the world's fastest growing food production sector for more than four decades (Tveterås et al., 2012) (Fig. 1). With more than 90% of all aquaculture output produced in the developing countries, its economic, nutritional and social impact is also likely to grow (Hishamunda et al., 2009). This worldwide expansion and marine-based production may have potential in helping meet the needs and demands of the ever-expanding appetite of the human population. (Kobayashi et al., 2015; FA0, 2016).

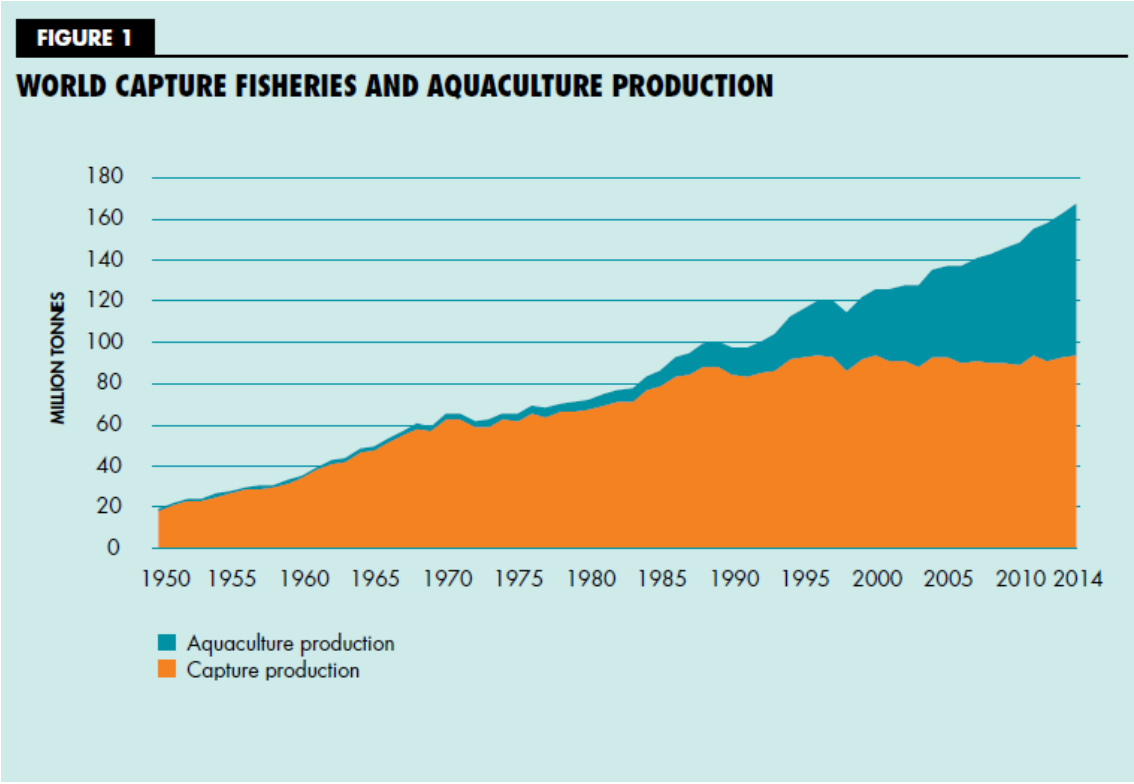

Fig. 1 world capture and aquaculture production (FAO, 2016)

Now a days, fisheries policies are increasingly articulated around value-creation through export to urban and international markets. Capture fisheries institutions concentrate ownership and use of fishing assets to maximize economic output which may bring

benefits to resource conservation and trade, but decreases the quantity of fish available on local markets (Béné et al., 2010). On the other hand, aquaculture policies tend to focus on maximizing productivity and economic efficiency (Hishamunda et al., 2009).

1.2.1.1 Aquaculture production in Europe.

The EU is the largest trader of fishery and aquaculture products in the world in terms of value. In 2015, the trade flow amounted to 54 billion EUR for these products and 13.8 million tons. Fish alone represents almost 20% of the overall 120 billion EUR worth of food products imported by the EU. The trade balance deficit (exports minus imports) of 2015 was the largest ever, confirming the EU as a net importer of fisheries and aquaculture products. The value of imported fish grew 6% from 2014 due to the growing imports of both frozen and fresh products and reached 22.3 billion EUR. Both farmed and wild production increased during 2013 -2014, farmed by 2% and wild by 11%.

In 2015, total European aquaculture production reached 2,350,278 tons, a very small rise (0.4%) when compared to 2014. Cold water marine species now represent 71.4% of the total production, fresh water species 15.1% and the marine Mediterranean species 13.5%. Norway alone represents 58% of this total production; the other countries that produce more than 100,000 t. annually are Turkey, United Kingdom and Greece. The main species produced are: salmon, trout, seabream, seabass and carp, which represented 94% of the total European production in 2015, (FEAP 2016).

1.2.2 Aquaculture Consumption in Europe

Europeans are regular consumers of fish and aquaculture products and they continue increasing the consumption (Fig. 2). In fact, 42% of them have increased eating fish or aquatic products at least once a week in their homes, most of them eat fish because it is healthy.

Annual per capita fish consumption has increased in recent years to 25.5 kg, as EU consumers ate one kg of fish more than in 2013. This rise was more significant for farmed products (+6%) than for fisheries products (+2.7%). However, consumption in the EU market is still dominated by products originating from fishing activities and

imported products (FEAP, 2016). Therefore, there is also a need to guarantee sustainable supply to the fish market form the EU. When it comes to aquaculture, there is a strong preference for the region of origin both national and European (80%) (Claret et al., 2012). According to IPAC (2017), 68% of consumers that usually buy fish products showed that they will eat more fish if prices were lower. Main factors influencing consumer demand and purchasing behavior are: cost (price) appearance and geographical origin. At EU level, appearance is the factor with the highest impact on purchasing decisions (58%); the cost and geographical origin factors follow, at 55% and 42% respectively (EUMOFA, 2016). EU consumers spent 54 billion euro for buying fisheries and aquaculture products in 2015, reaching the highest amount ever recorded.

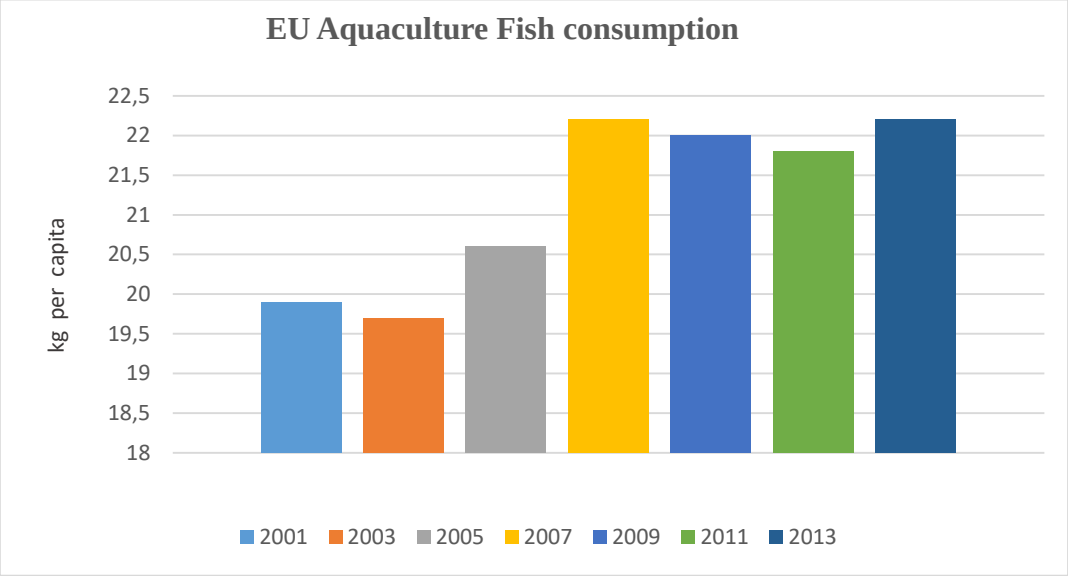

Fig. 2 E.U. Aquaculture fish consumption (EUMOFA, 2016)

1.2.3 Aquaculture economic value

Europe has an increasing demand for a diverse range of fish products especially for fish fillets or processed products (Failler, 2007; FAO, 2012). However, while the worldwide contribution of aquaculture towards fish consumption (63.6 million t) is of 50% (131 million t in total) (FAO, 2012). In the EU only 10% of the seafood consumption has been originated from EU aquaculture (Bianci, 2012), 25% from EU catches and the consumption of imported seafood from third countries is currently at 65% (both capture fisheries and aquaculture) (EATIP, 2012; FEAP, 2014). This situation can be attributed partially to a lack of diversity of aquaculture products and, perhaps more importantly, a lack of processed aquaculture products (Mylonas and Robles, 2016). An efficient,

sustainable and market-oriented expansion of the EU aquaculture sector based on new species and products will reduce the dependence of the EU consumer on imports from countries of questionable, often, production, health, environmental and social standards, and reduce the pressure on over-exploited fisheries in the EU. (EUMOFA, 2016). One of the personal factors that can impact diversification in Fish Aquaculture Products' consumption is people's willingness to experience new products, which is shown by 60% of consumers (buyers) in the EU (EUMOFA, 2016). In addition, consumers have pointed out that they like to taste new products and species which demonstrates how important is to have the potential of a diverse supply and therefore the reduction of fish imports through a sustainable development of aquaculture fish in the European Union (FEAP, 2016). EU trade balance deficit (exports minus imports) of 2015 was the largest ever, confirming the EU as a net importer of fisheries and aquaculture products. Extra-EU imports of processed tuna are mostly absorbed by Spain, Italy and the UK.

Even though some aquatic species are cultured in Europe, finfish aquaculture production is dominated both in volume and value by a handful of species --such as Atlantic salmon (*Salmo salar*), rainbow trout (*Oncorhynchus mykiss*), common carp (*Cyprinus carpio*), European sea bass (*Dicentrarchus labrax*) and gilthead sea bream (*Sparus aurata*) that in turn limit the number of aquaculture products available in the market. All these species have experienced periods of pricing problems when production had surpassed demand resulting in price decreases, often close to or below the cost of production. Combined with less expensive imports, these pricing problems have slowed or even decreased the growth of aquaculture in the EU. At the same time, imports have been increasing steadily (EATIP, 2012). Periods of pricing problems are common for perishable products that have high production. Common solutions to this situation are to (a) reduce production costs to offer a lower market price, (b) increase marketing to expand the market or (c) transform the product into new products that are demanded by the market (Mishra, 2015). Atlantic salmon has been one of successstories of European aquaculture, probably because it has used these three solutions to surpass many periods of pricing problems and continues to increase production and market share (FAO, 2015). The most consumed farmed species is salmon. It is also the species with the highest production value in the EU. Salmon ranked 3rd among the most consumed fish species in the EU and, for the first time, its consumption surpassed 2 kg per capita in 2014 (IPAC, 2017). In order to fully develop aquaculture, there is a need to

fully comprehend what is inhibiting or enabling growth, and public perception is part of that understanding. Perceptions can influence the acceptance and implementation of aquaculture (Knapp et al., 2016; Verbeke, 2007; Claret et al., 2014; Thilsted et al., 2016). An important bottleneck in aquaculture consumption is that in many countries and/or segments of the EU market, aquaculture fish have a weaker image than wild fish (Claret et al., 2014; Verbeke, Vermeir & Brunso, 2016). Table 1 shows the main beliefs of farmed *vs* aquaculture fish. This threatens the expansion of the aquaculture sector and it must be recognized and addressed in parallel to any technological improvement of production methods, or the addition of new fish species or products by the aquaculture industry (Mylonas & Robles, 2016).

Table 1. Beliefs about farmed and wild fish (Claret et al., 2014)

Category	Belief rated to	Item
Safety	Safety	Wild fish is safer than farmed fish
	Marine pollution	Wild fish is more affected by marine pollution (spillages) than farmed fish
	Heavy metals	Wild fish contains more heavy metals than farmed fish
	Antibiotics	Wild fish contains less antibiotics than farmed fish
	Parasites	Wild fish is more affected by parasites (anisakis) than farmed fish
	Healthy and animal feeding	Wild fish has healthier diet than farmed fish
	Healthiness	Wild fish is healthier than farmed fish
Qualtiy	Qualtity	Wild fish is of better quality than farmed fish
	Freshness	Wild fish is fresher than farmed fish
	Nutitional value	Wild fish is more nutritious than farmed fish
	Fat	Wild fish is less fatty than farmed fish
	Flavor	Wild fish tastes better than farmed fish
	Firmness	Wild fish is firmer than farmed fish
Control	Control	Wild fish is less controlled than farmed fish
	Handling	Wild fish is less handled than farmed fish
	Artificiality	Wild fish is less artificial than farmed fish
	Guarantees	Wild fish provides more guarantees than farmed fish
When buying fish	Availability	Wild fish is harder to find than farmed fish
	Price	Wild fish is more expensive than farmed fish

Therefore, there is a need to support the diversification of the aquaculture industry and help in expanding production, increasing aquaculture products and development of new markets.

1.3 Species selection

The project in which this thesis is immersed (DIVERSIFY) identified new/emerging, large and/or fast growing finfish species, which are believed to be excellent candidates for the expansion of the aquaculture industry of Europe. The emphasis was based on the Mediterranean or warm-water cage culture industry, but is also addressed to pond/extensive culture, fresh water recirculation systems and cold-water species. These new/emerging species can be marketed at a large size and could be easily processed into a range of products to provide the consumer with both a greater diversity of fish species and new processed products.

Therefore, the species selected to work with were meagre (*Argyrosomus regius*) and greater amberjack (*Seriola dumerili*) for marine warm-water cage culture, wreckfish (*Polyprion americanus*) for warm- and cool-water marine cage culture, grey mullet (*Mugil cephalus*) a euryhaline herbivore for warm-water pond, extensive and integrated culture, and pikeperch (*Sanders lucioperca*) for freshwater intensive culture using Recirculation Aquaculture Systems (RAS). These species were also selected based both on their biological and economical potential, and to cover the entire European geographic area and stimulate different aquaculture types.

Firstly, given their large size and/or fast growth, they provide for high dress-out and fillet yield, short time to market and suitability for product diversification and development of value-added products. Secondly, since aquaculture is of interest to European countries, where different aquaculture methods are employed in diverse environmental and climatic conditions, species selection included a freshwater fish of high demand for RAS culture (pikeperch), and a euryhaline warm-water fish suitable for extensive aquaculture in earthen ponds, coastal lagoons, "valli" or "Salinas" (grey mullet). Finally, all selected species are either cosmopolitan species found and cultured in some cases throughout the world or their very similar congeners are fished or cultured around the world. As a result, these species or their congeners have existing markets and the potential exist for the EU aquaculture production of these species to reduce imports to the EU, as well as supply global markets.

Each of the selected species has the potential to grow in the market and to be perceived as an added value product, and their biological and economical potential is expected to

stimulate the growth of the European aquaculture sector. Below are the main economic potential for each species.

1.3.1 Meagre

Meagre (*Argyrosomus regius*) is a species from the Sciaenidae family from the Southern European area whose farming has won economic importance over the past years (Ribeiro et al., 2013). The meagre is found in the Mediterranean and Black Sea and along the Atlantic coasts of Europe and the west coast of Africa. Meagre lives in inshore and shelf waters, close to the bottom or near the surface (depth range 15–200 m); it also enters estuaries and coastal lagoons (Chao 1986; Griffiths and Heemstra 1995). The fish can reach over 50 kg in the wild, the largest size recorded being 182 cm total length and 103 kg of body weight (Quéro & Vayne 1987). It is a fast grower and has a lot of desirable characteristics, such as large size, good dressing yield and low muscle fat and firm texture (Grigorakis, Fountoulaki, Vasilaki, Mittakos, & Nathanailides, 2011, Monfort, 2010).

This species also has the biological characteristics required for commercial aquaculture. These characteristics include a fast growth of ~1 Kg per year (Duncan et al., 2013), a low feed intake (Monfort, 2010; Duncan et al., 2013) and established induced spawning protocols for the production of viable eggs (Duncan et al., 2012). It can adapt to very diverse environments, making even land based cultivation possible in brackish water media. It withstands tank captivity effectively well, reaching high growth rates during on-growing, with good feed conversion rates (Jiménez et al., 2005; Pastor, Grau, Massutí, & Sánchez-Madrid, 2002). Furthermore, it exhibits high fertility rates.

Its farming, since it was first introduced in 1997 has exhibited a significant production growth, from 231 tons in 2002, reaching a total production of 2730 tons in 2010 (FAO, 2013). All of these, produced mainly in Spain and Egypt, but also Turkey, France, Portugal, Italy, Greece, Cyprus and Croatia (Monfort, 2010; FAO 2010; EUROFISH, 2013).

Meagre is endowed with intrinsic values since it has an attractive fish shape, good processing yield, good nutritional values, low fat content and excellent taste (Monfort, 2010). As it is rather rare to exist in fishery captures in the Mediterranean, it is not well known by consumers and the European market is still a niche product. Thus, a good market strategy, with the relevant choice of messages, channels, targets and partners

would contribute to prepare the markets for the arrival of this new aquaculture species and try to create some demand for it.

1.3.2 Greater amberjack

The greater amberjack (*Seriola dumerili*) is a jack of the genus *Seriola*. *S. dumerili* grows rapidly, reaching a maximum length of 180–190 cm and 80 kg of weight. The greater amberjack is a pelagic and epibenthic fish that inhabits both nearshore reef habitats as well as the open sea, usually found between 18 and 360 m depth (FAO, 2017).

The farming of *S. dumerili* has a long history in the Mediterranean (Lovatelli & Holthus, 2008). In the 1980s aquaculture of this species started with the fattening (grow-out) of wild caught juveniles (starting at about 90 g) using fish aggregating devices and subsequently cultured in tanks and cages in Italy and Spain. Fish of ~90 g have reached ~1 kg in a year, and 6 kg in a period of 2.5 years (Jover et al., 1999; Mazzola et al., 2000). The high growth rate of cultured greater amberjack and its feeding on fish of low commercial value shows potential for a profitable activity.

The greater amberjack is an important commercial fish, this species has gained popularity, in Europe and North America. It has been an important basis for many coastal communities where it is highly appreciated because of the high quality meat and commercial value. The total worldwide wild catch of *Seriola dumerili* has increased since 1990, about 17 percent was taken by United State of America and around 80 percent was fished in the Mediterranean and Black Sea by European (Greece, Italy and Spain), African (Algeria and Tunisia) and Asiatic countries (Cyprus, Israel and Syria) (FAO, 2017). Still, the Mediterranean production in 2012 was only near 2tons, while market price mainly for capture fisheries catches reached values >14 € kg-1. Today, a very limited commercial activity with hatchery produced individuals exists in Malta, though interest exists and efforts have been made by various aquaculture companies in Spain, Greece, Italy and Cyprus.

The greater amberjack is a large fish with high flesh quality and market value. In addition to its economic potential in the EU market, cultured greater amberjack has a significant potential for exports (Nakada, 2000). This cultured fish has proven its potential in other markets like Japan (Thakur, Morioka, Itoh, Wada & Itoh, 2009). Its rapid growth (*i.e.*, short time to market size) and large size makes this species very

suitable for product diversification and development of value added products. In Europe, there has recently been an intense interest from the aquaculture sector for this species, but production levels are miniscule. Therefore, a consumer oriented market introduction of cultured amberjack is necessary. Also, market development is necessary for growth with preservation of the added value and price, once production increases.

1.3.3 Pikeperch

Pikeperch (*Sander lucioperca*) carries this name, as it resembles the pike with its elongated body and head, and the perch with its spiny dorsal fin. This species generally has lengths of 50-70 cm and body weights of 2-5 kg but it can reach a maximum length of 130 cm and weights of 12-18 kg have been reported. Males reach sexual maturity at 2-3 years, females at 3-4 years. This species inhabits lakes, rivers, reservoirs and the coastal marine. It is now widespread in France and western Europe, is rapidly extending its range and cab be acclimated to the waters of northern Africa, North America, and Asia (FAO, 2017).

The beginnings of pikeperch culture date to the nineteenth century and are linked to carp (*Cyprinus carpio*) culture in earthen ponds in Central and Eastern Europe. Pike-perch was produced in insignificant quantities. In the early twentieth century, pikeperch´s production began of stocking material (monoculture or polyculture) in earthen ponds (natural spawning) for stocking open waters (FAO, 2017). This freshwater fish is considered to have the highest potential for inland aquaculture diversification in Europe (Wang et al., 2008). It is a valuable species, reproductive control and bio-economic feasibility have been undertaken to improve rearing methods (Fontaine et al., 2008; Zakęś, 2009; (Kucharczyk et al., 2007; Steenfeldt & Lund, 2008; Steenfeldt et al., 2010). Over the last decade, new farms have been built in Europe to produce pikeperch using recirculation aquaculture systems (RAS) (Fontaine et al., 2012). Year-round production of pikeperch requires constant high temperatures (24-26°C), which is only feasible in RAS to ensure relatively high growth rates (*i.e.*, production of 1.2 kg fish in 15 -18 months from non-selected strains). Currently, the main producing countries are the Czech Republic, Denmark, Hungary, Romania, Tunisia and Ukraine (FAO, 2017).

Pikeperch is a medium size freshwater fish, with a good neutral taste and a high market value. There is already a market in Europe and North America, showing strong demand.

The production capacity of this fish is expected to grow fast in the coming years. The market value is high at 8-11 € kg-1 at farm gate, whole fish. To keep up the high market value, product development and market development is necessary for coordinated growth. Therefore, potential markets and consumer segments have to be identified to maintain or increase the added value.

1.3.4 Wreckfish

The wreckfish (*Polyprion americanus*), belongs to the Polyprionidae family. This species is characterized by a massive head and a stocky body. Individuals may reach a body length of 2 m, and weigh up to 100 kg, although on average individuals reach 45–55 cm body when they are between 1–7 years old (Rocarati, Cappuccinelli Stocchi & Melotti, 2014). It is a deep-water fish found almost throughout the world and is characterized by an extended pelagic juvenile phase (Sedberry et al., 1999; Ball et al., 2000; Deudero et al., 2000). Demersal wreckfish individuals inhabit rocky and muddy bottoms, at depths of 40–200m, however, individuals are more frequently found in waters deeper than 300 m, with a maximum recorded depth of 1000 m (Fischer et al., 1987).

Wreckfish is one of the most interesting new species for aquaculture, due to its fast growth (Suquet & La Pomélie, 2002; Rodriguez-Villanueva et al., 2011), late reproductive maturation (Sedberry et al., 1999) and ease of manipulation in captivity (Papandroulakis et al., 2008; Rodriguez-Villanueva et al., 2011). Wreckfish acclimatizes easily to captivity and, despite its large size, no mortalities have been reported due to handling. It accepts inert food easily, being a very voracious carnivore. The slow reproductive maturation of wreckfish, which occurs at an age of 5-10 years in captivity, may be a problem for broodstock development and management. On the contrary, its long juvenile stage is a great advantage from the aquaculture viewpoint, allowing for commercialization before sexual maturity, and thus avoiding problems linked to maturation, such as reduction in growth, or loss of flesh quality and organoleptic properties.

Wreckfish is a large fish with excellent flesh, but not available as a cultured fish. It is distributed throughout the world and products from the capture fishery are highly regarded. Its large size could be useful for the processing and development of value added products, and its cosmopolitan distribution may enable EU exports. Because of

this potential excellence, wreckfish could be interesting for the European market. For this species technical bottlenecks have to be solved first. So, only market positioning in relation to other species is necessary for the short run, and for the long run the market potential will be identified.

1.3.5 Grey mullet

Grey mullet (*Mugil cephalus*), is an important food fish species in the mullet family (mugilidae). These species common length goes from 32 to 50cm in young adults (2 years old) with an average weight from 1-2kg, however individuals could reach a maximum of 100cm with 8kg. It is a euryhaline species, found throughout the world (Oren, 1981). This cosmopolitan species can be found in the coastal waters of most tropical and subtropical zones. In the western Atlantic Ocean, it is found from Nova Scotia, Canada south to Brazil, including the Gulf of Mexico. In the eastern Atlantic Ocean, the striped mullet is present from the Bay of Biscay (France) to South Africa, including the Mediterranean Sea and the Black Sea. The grey mullet occupies fresh, brackish and marine habitats in depths ranging between 0–120m and with temperatures between 8–24 °C and is a rapid-growing, herbivorous species that can be reared over the wide geographical and temperature range of the Mediterranean basin (FAO, 2017).

Farming of grey mullet has been practiced for centuries, but production of this species in Europe has been small and non-intensive (Nash & Koningsberg, 1981; Pillay, 1993). Most of the flathead grey mullet fry used in commercial aquaculture are collected from the wild, especially in the Eastern and Southern Mediterranean. It has been stocked in fish ponds to improve sediment quality and avoid oxygen depletion (Milstein et al., 1991). Therefore, it can be an excellent candidate for the enhancement of aquaculture in earthen ponds, coastal lagoons, and deserted Salinas that exist throughout the EU Mediterranean countries.

In general, this is a potential species for aquaculture diversification, because of its good adaptation to captivity, rapid growth, omnivorous feeding habits and high market price of its salt-cured and dried eggs named “bottarga” a high value product (>100 € kg-1), whose market is expanding around the Mediterranean (Whitfield et al., 2012).

Therefore, grey mullet has a great biological and economical potential for fish species and product diversification, and development of value added products. Since, grey mullet is a medium size herbivorous fish, cultured extensively throughout the world, it

has a niche market in the Mediterranean for its flesh and high priced eggs. Due to its good taste and low cost of rearing, grey mullet could have large potential market all over Europe, especially within segments of population of North African, Middle Eastern or Asian origin. Market and new product development are necessary for growth in the middle-long term in the native European market and the immigrant market.

In order to introduce these afore mentioned species to the aquaculture sector and to a successful market, it is necessary to characterize them and to develop new products with them thus a diversification can be achieved.

1.4 New Product Development

New product development (NPD) is the motor of sustainable success for every firm. It can be described as the transformation of a market opportunity and a set of norms about product technology into a product available for sale (Krishnan and Ulrich, 2001). It starts by generating a pool of new product ideas and continues by developing the most promising ones, step by step into successful products, taking into account strategic considerations (Urban and Hausser, 1993).

1.4.1 Stages of NPD

The basic stages of the NPD process are defined as: a) Opportunity Identification and Idea Generation, b) Concept Development, c) Concept Testing, d) Design and Engineering and e) Prototype Development and Testing products (Trott, 2008).

1.4.1.1 Stage 1 Opportunity identification and idea generation

Successful NPD strongly depends on the quality of the opportunity identification stage (Cooper, 1998; McGuinness and Conway, 1989). The goal of this stage is to search for new areas of opportunities, which typically involve the unmet needs and wants of consumers. Accordingly, it has been recognized that involving the consumer in co-creation represents a critical success factor in the new product idea generation (Füller, Hutter, & Faullant, 2011; O'hern & Rindfleisch, 2010).

1.4.1.2 Stage 2 Product concept development

NPD can use one or more techniques to generate product concepts. Therefore, qualitative research is an appropriate approach to understand how consumers see and perceive new concepts through projective and creative techniques (Dahan and Hausser, 2002). One technique to create ideas is brainstorming. This is a method of shared problem solving, in which all members of a group spontaneously contribute ideas, including seemingly unrealistic ideas – which often serve as a catalyst that stimulates the generation of additional, more-realistic ideas. A key rule is that criticism of any generated idea – regardless of how unrealistic it may be – is expressly forbidden.

In the same vein, Higgins (1996) and Osterwalder and Pigneur (2010) have shown that creative techniques, such as storyboarding, empathy design, and brainstorming, are vital in product creation and design. Storyboarding and empathy design are structured creativity processes grounded on brainstorming that can be easily adapted to an intended context. (Banovic et al., 2016).

1.4.1.3 Stage 3 Concept testing

Here, new product concepts are screened with potential customers using both quantitative and qualitative research methods. Evaluations on such measures as consumer relevance (how important is the consumer need being addressed by the concept), consumer purchase interest, and dissatisfaction with currently available products are used to prioritize ideas for further testing and evaluation.

1.4.1.4 Stage 4: Designing and engineering products

Once few high-potential concepts have been chosen, these have to be designed and engineered to meet customer needs at a cost that is profitable to the company.

1.4.1.5 Stage 5: Prototype development and testing

In this last stage of the NPD process, the goal is to evaluate the designed concepts so that any launch is likely to succeed. Marketing's role in this phase is to simultaneously test multiple designs with customers (Dahan and Hausser, 2002).

1.4.2 NPD process: consumer feedback

New product development can originate from new technology or new market opportunities (Eliashberg et al., 1997). But irrespective of where opportunities originate, when it comes to successful new products it is the consumer who is the ultimate judge (Brown and Eisenhardt, 1995; Cooper and Kleinschmidt, 1987). Thus, in order to develop successful new products, it is important to gain a deep understanding of consumer needs and include them in every stage of the process.

The product concept development phase can use several techniques as mention above, however, only those used in the frame of this thesis will be mentioned. An efficient way to obtain a first approach to a product concept is through the consumer`s perspective, thus employing a different qualitative techniques such as focus groups (Krueger, 1988).

1.4.2.1 Focus groups

Focus group is a qualitative research technique. It is generally used in the early stages of product development and marketing research to discuss a set of new product concepts (Langford and Mc Donagh 2003; Dransfield et al. 2004; Van Kleef et al. 2005).

A focus group is a meeting of 8-10 respondents recruited according to predefined specifications, who meet in an informal setting to talk about a particular topic that has been set by the researcher. The respondents engage in a discussion led by a qualified moderator (Cardinal et al., 2002). The duration of the meetings should be between 90-100min and the participants must not know among each other. Respondents are usually rewarded with a gift after the session to avoid conflict towards money gratification (Canales and Peinado, 1995). Sessions are usually recorded with audio and video cameras placed in different room areas to facilitate posterior analysis. A total of 4-6 groups is recommended thus relevant information would be obtained (Morgan, 1996). The main advantage of focus groups is that panelists are able to select the manner in which they respond, interact to, debate or change their opinions about products during discussion with others (Dransfield et al. 2004; Chung et al 2011). Focus groups can be an effective method for capturing opinions, gathering feedback on programs, and identifying local needs, challenges and opportunities. (Greci et al., 2012).

According to Stewart and Shamdasani (2015), there are eight sequential stages when performing a focus group:

- Problem definition / Formulation of the research question

Requires a clear statement of what kind of information are desirable and from whom this information should be obtained. A clear understanding of the problem or general research question is critical because it gives rise to the specific questions that should be raised by the moderator and identifies the population of interest.

What problem is being addressed what information is sought and for what purpose. A well defined research question that clearly identifies the topic of the research

- Identification of participants

Operational definition of the population, the sampling frame: list of people that the researcher has reasons to believe are representative of the larger population of interest. The recruitment process requires identification of time and place for the group. Persons are informed of the general topic of the interview to increase probability of participation. A few brief screening questions can be used to determine whether individuals meet the requirements for participation in the focus groups. Most focus groups are comprised by 6-12 persons Fewer than 6 participants makes for a rather dull discussion and more than 12 are difficult for the moderator to manage.

- Identification of the moderator

Moderator must have leadership style, use pre-determined questions and create a relaxed atmosphere. The moderator should be skilled in stimulating discussion, encouraging quiet people to state opinions, and monitoring or limiting outspoken people who try to monopolize the meeting. The moderator should understand the objectives and keep the discussion on track. The moderator should have adequate background knowledge on the topic of interest to place all comments in perspectives and follow up on critical areas of concern.

- Generation and pre-testing of interview guide

It establishes the agenda for the group discussion and provides a structure within which participants may interact and articulate their thoughts and feelings.

Questions order should be from general to more specific. Thus questions of greatest importance should be placed early near the top of the guide whereas those of lesser significance near the end, and around twelve questions total. The development of this guide should be developed in collaboration with all parties interested in the research at hand. The purpose is to provide direction for the group discussion.

- Recruiting the sample

A few of the strategies used to recruit participants include: Random telephone screening, the list (Clients can provide an existing list of customers, clients, members, and employees), on location. Focus groups can be held on location where people tend to frequent (e.g., shopping mall, recreational events).

- Conducting the group

Moderators in focus groups have to use persuasion and tact to encourage group participation and maintain interest in the topic. Some general strategies to conduct the group include leadership style, degree of structure and good sequencing of questions.

A focus group is directed by a moderator who explains the purpose of the group, establishes ground rules for participation, facilitates the exchange of ideas among the participants, and creates a non-threatening and non-evaluative environment in which group members feel free to express themselves openly. Audio and/or video equipment may be used for recording the session. It is customary to inform participants if the session will be recorded

- Analysis and data interpretation

The interpretation of the data must be practical and manageable to the analyst. Interpretation of data can be viewed as being on a continuum. On one end is the raw data, in the middle is descriptive information, and at the other end pure interpretation. The raw data are the exact statements of the participants as they responded to questions during the focus group. They can be ordered within categories by what was most often to least often said.

- Writing the report

It is important to consider the audience and purpose for reporting. The report should meet the needs of the user and answer the research questions. The report should also reflect the focus groups process and present participants' responses as truthfully and accurately as possible (Krueger, 1998).

Generally speaking, focus groups allow to study the main ideas of consumers about a product form a rational perspective, all though, this can often be influenced by their own social aspects.

After having developed the new product it is important to consider the consumers point of view and therefore their opinion about the product. Even though consumers may not always be able to express their desires, it is important to understand how they perceive products, how their needs are shaped and influenced and how they make product choices based on them (Van Kleef et al., 2004). In this sense, there are numerous research techniques that allow to study and understand consumer`s perception and behavior towards specific food products from different views (Lawless and Heymann 1998), among these techniques are the acceptance test and the measurement of individual expectations.

1.4.2.2 Affective or hedonic tests

These tests are used to assess a product or group of products characteristics, its main purpose is to study the potential or real consumers response (reaction, preference or acceptance) depending on their like or dislike (Sosa, 2011). Hedonic tests are classified in preference tests and acceptability test (Liria, 2007). The acceptability test is the experience characterized by a positive attitude (pleasant) or level of likeness of a product compared to an internal reference, while in the preference test a set of samples is ordered in sequence based on the assessor`s degree of liking.

These tests use consumers who have not been trained to participate in research studies and who normally consume or use the food products. The main purpose of affective studies is to assess the response to a product, or a product idea. These hedonic tests purpose is to ask: What is the acceptability of a product? Is the product liked? Ask degree of liking (how much do they like it). Is one product preferred over another?

(preference questions). These type of studies are essential for the industry during the product development stage to be able to determine the potential market for a certain product, so as to be able to optimize processes, assess new ingredients and technologies as well as to decide whether or not to keep a product in the market.

Consumers are recruited according to certain gender, age, social and economic level and consumption frequency variables and they are asked how much they liked a certain product and asked to use hedonic scales or to choose a certain sample through the use of preference tests (Gámbaro, 2012).

Samples may be served one at a time, a response is required after each sample and then sample is returned to the preparation area. Alternatively the samples can be placed all on one tray, but this would require the panelist to match the correct test sample to the correct three digit code written on the questionnaire.

Usually the sample is compared to a well-liked product or one from competition and an hedonic scale is used to indicate degrees of unacceptable to acceptable or dislike to like. From acceptance scores preference can also be inferred, the sample with the higher score tends to be the one preferred. The most discriminating results are usually obtained with scales that are balanced, i.e. have an equal number of positive and negative categories and have steps of equal size (Meilgaard, Civille and Carr, 2007).

The consumers' acceptance of a certain product can be determined on how much they say they like it when they are consuming it. In 1940 and with the objective of measuring food acceptability, the 9-point hedonic scale (also called degree of liking scale) was developed at Quartermaster Food and Container Institute of the US Armed Forces. This scale was developed for the purpose of measuring the food preferences of certain canteen food products by soldiers. The scale was quickly adopted by the food industry (Peryam and Pilgrim, 1957). The hedonic scale assumes consumer preferences exist on a continuum and that reference can be categorized by responses based on like and dislike.

The scale consists of nine labeled categories which range from 'Extremely Dislike' to 'Extremely Like', and have a neutral category in the middle: 9 – Extremely Like 8 – 9- 9- Like extremely, 8- Like Very Much, 7 –Like Moderately, 6 –Like Slightly, 5 – Neither Like nor Dislike, 4 – Dislike Slightly, 3 –Dislike Moderately, 2 – Dislike Very Much, 1 –Dislike Extremely.

The data from the 9 point scales are analyzed using parametric statistics (Lawless and Heymann, 2010). Thus, data analysis can be performed by Friedman test, t-test on means of two products, or usually Analysis of Variance (ANOVA), followed by comparisons of means for more than two products (Singh-Ackbarali1, D. & Maharaj, R., 2014). ANOVA compares several means of samples and tests whether they are all the same or whether one or more of them are significantly different (O`Mahony, 1986).

There are several types of hedonic scales: unstructured line scales just anchored by like and dislike on each end (Hough et al, 1992; Rohm and Raaber, 1991), Label Affective Magnitude scale (LAM), with eleven anchors from greatest imaginable like to greatest imaginable dislike including point from -100 to 100 in each end of the scale (Schutz and Cardello, 2001) or pictorial face scales for children using smiley faces (Chen et al., 1996) among others. However, the 9 point scale is the one used and thus discussed in this work.

1.4.2.3 Expectations

Expectations can be defined as subjective notions of things to come or in a simpler way as a type of hypothesis formulated by the consumer. Consumer product expectations may be regarded as pre-trial beliefs about the product, thus playing an important role by improving or degrading the perception of a product, even before it is tasted (Deliza and MacFie, 1996).

Before testing a product, consumers have an idea of what its sensory characteristics are and how much they will like or dislike it (Cardello, 1994). Expectations imply anticipation and some degree of rational thinking, and they thus include the evaluation of similar or related past experiences and available information and are, by definition, subjective in nature (Fonts i Furnols and Guerrero, 2014). When the product is tasted, the expected sensory and hedonic characteristics are compared with the real ones, leading to confirmation or disconfirmation (Deliza and MacFie 1996). Thus, after selecting a product, the individual will test and use it, and consequently his/her expectation will be confirmed (agreement with what was expected) or not confirmed (disagreement with what was expected, either in a positive or in a negative sense) (Font i Furnols and Guerrero, 2014; Cardello (1994).

According to Brown et al, (2014) and Michalco et al, (2015) there are two main theories explaining how expectations can influence the individual`s experiences. *Assimilation theory* states that people adapt their experiences to match their expectations. The theory is based on the cognitive dissonance theory (Festinger, 1962), which argues that people adjust their evaluations to be more consistent with their initial expectations. Thus stating that in order to diminish the "mental discomfort" created by an unconfirmed expectation, any discrepancy between expectation and product performance will be minimized or assimilated by the consumer (Deliza and MacFie, 1996). The second theory: *Contrast theory*, focuses on the difference between expectations and subsequent evaluations. This theory predicts that evaluations that exceed expectations result in greater satisfaction whereas failing to meet expectations results in lower satisfaction.

Expectations play an important role in forming acceptance structures, which are key factors in the success of food products in the market. Sensory expectations have a powerful influence on food selection and purchase decisions (Ares et al., 2010). In order to assure consumer acceptance, manufacturers should gather information about what they expect from their products. This could be particularly important in the case of novel products such as new fish products.

It is also important to consider that much of the information that consumers receive regarding food quality is provided through marketing tools (advertising, information campaigns and labels). This information is also used by consumers, to create their quality expectations, which can influence the choice of the product, purchasing decisions and willingness to pay (Verbeke and Ward, 2006). Thus expectations should be considered when choosing the most appropriate marketing strategy when introducing fish products in the market.

1.5 Products characterization

In order to have a successful NPD is important to focus on generating analytical knowledge on the product properties (Khan, Grigor, Winger, & Win, 2013). This can be accomplished by developing the technical know-how of the raw materials used, hence a characterization of the fish species.

Characterizing the raw materials of a product will increase the chances to have an appropriate product for each fish species. By analyzing raw materials it is often possible to predict their subsequent behavior during processing so that their conditions can be addressed to produce a final product with the desired properties. In the case of this study it is important to align the raw material properties with the developing products. Thus, an adequate prototype can be developed according to the species characteristics.

1.5.1 Physicochemical characterization

Physical properties data, specifically of raw materials, is of great importance in order to have a knowledge-based domain on the final product. Thus physical properties data is useful to design better experimental strategies during the search for product solutions (Flöter, 2009). The control of the physicochemical parameters in the finished product is of great importance, since they affect shelf life and sensory features (Fuentes, Fernández-Segovia, Barat and Serra, 2010).

The physiochemical properties of foods (rheological, optical, stability, flavor) ultimately determine their perceived quality, sensory attributes and behavior during production, storage and consumption. The stability of a food is a measure of its ability to resist changes in its properties over time. These changes may be chemical, physical or biological in origin. Chemical stability refers to the change in the type of molecules present in a food with time due to chemical or biochemical reactions, *e.g.*, fat rancidity or non-enzymatic browning. Physical stability refers to the change in the spatial distribution of the molecules present in a food with time due to movement of molecules from one location to another.

Foods must therefore be carefully designed so that they have the required physicochemical properties over the range of environmental conditions that they will experience during processing, storage and consumption, *e.g.*, variations in temperature or mechanical stress. Consequently, analytical techniques are needed to test foods to ensure that they have the appropriate physicochemical properties.

Specifically in fish products it is important to characterize the fish as the raw material. Therefore, somatic measures can be taken into account to be used as an index of their growth and quality (such as liver size, gonads size and filleting yields), these can also be

indicative of the feeding condition of the fish. Filleting yields is among the most important parameters, especially for species where filleting is among their usual processing, because it describes their actual edible part. In addition their chemical composition (fat, protein and water content) should also be taken in to account. Parameters such as lipid content along with fatty acids profile in fish flesh directly affects odor and flavor intensity and are also indexes for shelf life determination that can also influence the final quality of the developed product.

1.5.2 Sensory characterization

Sensory analysis is commonly used in product development and optimization. In addition, it plays an important role in quality control and quality assurance in the fish sector. Descriptive sensory analysis is the most resourceful method to be used to characterize all kind of food. Descriptive tests are capable of providing quantitative data and can be very simple and used for assessment of a single attribute or a more complex group and give a total characterization of sensory quality (Nollet, 2007). One of the main methodologies used in sensory characterization is Quantitative Descriptive Analysis (QDA). There are other methodologies used for sensory characterization, that require less training, however, only Free Choice Profiling and Check All That Apply will be addressed since these are the ones used in the frame of this thesis.

1.5.2.1 QDA

Quantitative Descriptive Analysis was developed in 1974 with collaboration of the Department of Food Science at the University of California Davis. This method relies on statistical analysis to determine the appropriate terms, procedures and panelists to be used for analysis of a specific product. It represents the intelligent use of human subjects as measuring instruments (Meilgaard, Civille and Carr, 2007).

This methodology requires as a first step the selection, training and maintenance of a panel of 8–20 assessors. Trained assessor panels have been strongly recommended to provide actionable information in new product development and quality control, as well as to fully characterize the sensory properties of food and non-food products (Stone and Sidel, 1974).

The principle of QDA is based on the ability to train panelists to measure specific attributes of a product in a reproducible manner to yield a comprehensive quantitative product description agreeable to statistical analyses. The attributes to be assessed must be clearly defined and understood. In a QDA approach, panelists recruited from the general public work together in a group process to identify key product attributes and appropriate intensity scales specific to a product. This group of panelists is then trained to identify and score product attributes (Chapman et al., 2001).

Once the assessors panel is selected for each project or sample group it would: (a) generate specific attributes that describe the similarities and differences between products, (b) determine and agree on the evaluation procedure for each of the selected attributes, (c) be trained in the evaluation and scaling of the selected attributes for the particular sample set, and (d) would finally quantitatively evaluate the samples, generally with the use of 10–15 cm unstructured line scales, where samples would be evaluated individually in a sequential monadic, balanced randomized presentation (Varela and Ares, 2012).

Products are evaluated for intensity of the characteristics on the scorecard. Panelists rate the intensity of each attribute by marking a vertical mark across the appropriate horizontal rating line. These marks are converted to numerical data by measuring the distance from the origin ("weak") of the line to the vertical mark.

The obtained data would be in the form of intensity scores of all the attributes, which can be analyzed individually, by attribute and sample as a sensory signature or profile of each product (Varela and Ares, 2012).

The use of the graphic scale (visual analog scale) that reduces the part of the bias in scaling resulting from the use of numbers, the statistical treatment of the data, the separation of panelists during evaluation and the graphic approach to presentation of data helped to change the way scientists view descriptive methodology (Meilgaard, Civille and Carr, 2007).

Data analysis is completed using a mixed model Analysis of Variance for treatment by subject, with replication (Hootman, 1992). To determine individual panelists' abilities to perceive differences among products, a one-way analysis of variance is completed for each panelist. This analysis can also be used to determine if an attribute is helpful in differentiating among samples. Subsequent analysis, using a two-way analysis of

variance design, is needed to determine product differences and interactions by the panel (Hootman, 1992). An independent statistical analysis is completed for each characteristic that is measured.

1.5.2.2 FCP

Free Choice Profiling was originally developed to allow the understanding of different words by consumers when describing the same characteristic (Williams and Langron, 1984). As such it is an ideal technique to use in order to know all the words different consumers use to describe a product set and how they perceive the inter-sample differences.

Free-choice profiling (FCP), developed in 1984 by Williams and Langron, is a sensory analysis method that can be carried out by untrained panels. The participants need only to be able to use a scale and be consumers of the product under evaluation (Perez et al., 2007). FCP encourages the personal generation of descriptors, as free as possible, wherein panelists are not expected to agree on the number, type or interpretation of elicited attributes.

Free-choice profiling (FCP) is a sensory methodology that differs from other descriptive methods because it is not necessary to use a common vocabulary of attributes to describe the samples, nor are the panelists expected to agree on their interpretation of the terms used. By means of FCP, each participant produces their own descriptive profiles of the products, without having to explain the exact meaning (Williams and Langron, 1984). These individually generated terms need only to be understood by the specific panelist. However, the individual must use the terms consistently when evaluating the products (Lawless and Heymann, 2010). Regarding the number of attributes generated, this is limited only by the perceptual and descriptive skills of the consumer (Oreskovich et al., 1991).

The exceptional quality of FCP is the individual development of the vocabulary for description and scoring of the products by each panel member. This means that the number, order and meaning of the terms used can be determined without further discussion (Lachnit et al., 2003). This is based on the assumption that panelists do not differ in their perceptions, but merely in the way in which they describe them. FCP is similar to traditional profiling in that assessors must be able to detect differences

between the samples, verbally describe the perceived attributes and quantify them (Oreskovich, Klein, & Sutherland, 1991).

This methodology has been successfully used by sensory analysts in order to get sample information on one or more characteristics, as well as on panelists and attributes information. Free-choice profiling was developed to assist the demands of marketing and product development teams, who required information on target consumers' perceptions of product rather than a more technical description of the product typically produced by trained sensory panels (Elmore and Heymann, 1999; Murray et al., 2001).

Free Choice Profiling should be carried out in two or more sessions: an attribute generation session and one or more rating sessions depending if replicates of scores are needed. In the attribute generation session: All samples must be presented (either simultaneously or one at a time) to the assessors. Participants must evaluate each sample and record all the attributes they perceive in each one of them. Once they have evaluated all the samples, all the descriptive terms generated should be grouped by modality (appearance, aroma, flavor and texture). When this technique is performed with consumers, it is better to assist them with this step to ensure all the words are listed in the correct modality. In the rating session: A ballot (questionnaire) should be created for each assessor using their unique list of descriptive terms. Afterwards, participants are asked to associate each term (previously generated) with a defined intensity using a line 10cm scale. In order to avoid confusion when using the line scales a category could be added; 0 = not at all intense to 10 = extremely intense.

The FCP strategy can yield important insights into consumer differentiation of products and establish relationships between consumer preferences and sensory characteristics (Jack & Piggott, 1992). The analysis of the data collected from FCP is normally carried out by means of Generalized Procrustes Analysis (Gower, 1975; Langrom, 1983). This technique allows one to scale, reflect and rotate multiple data matrices (one for each panelist on each replication). This allows to determine the terms used by individual panelists that appear to be measuring the same sensory attributes as other judges. With this technique each judge´s data are transformed into individual spatial configurations. These configurations are then matched by the Procrustes analysis to a consensus configuration.

The Procrustes analysis usually provides a consensus picture of the data from each individual panelist in two or three dimensional space (Lawless and Heymann, 2010). This consensus configuration reveals the interrelationships between the samples for the panel as a whole (Williams & Langron, 1984).

1.5.2.3 CATA

A check-all-that-apply (CATA) question is one of the methodologies based on the evaluation of specific attributes (Adams, Williams, Lancaster, & Foley, 2007. The relevance of each term is determined by calculating its frequency of use. The main advantage of this type of question is that it allows multiple options to be selected, instead of limiting respondents to select only one answer (Smyth, Dillman, Christian, & Stern, 2006).

Consumers are presented with a set of products and a CATA questionnaire to characterize them. Afterwards, they are asked to try the products and to answer the CATA question by selecting all the terms that they consider appropriate to describe each of the samples without any constraint on the number of attributes that can be selected. The list of words includes the possible characteristics of the product (Meyners and Castura, 2014; Ares and Jaeger, 2013).

This methodology has been reported to be a simple, valid and reproducible alternative for gathering information about the sensory characteristics of a wide range of products, without requiring scaling, allowing for a slightly less contrived description of the main sensory properties of the product tested (Bruzzone *et al*., 2012; Dooley *et al*., 2010; Jaeger *et al*., 2013; Meyners *et al*., 2013; Parente *et al*., 2011 ; Plaehn, 2012). Cadena et al 2014.

Furthermore this methodology could be a more practical approach than intensity scaling from the standpoint of consumer-led product development. Since CATA responses can be directly linked to consumers' perception of product characteristics, these responses could be utilized as supplemental data to maximize acceptance of the targeted products by consumers. CATA provides information on which attributes are detectable according to consumers and how that may relate to their overall liking and acceptance (Dooley el al., 2010).

The actual generation of CATA terms can be performed in many ways: the consumers can choose words to describe the product during the test, terms can be given by a trained panel, or terms can be generated by consumers not testing the product (i.e. a focus group) (Dooley et al., 2010).

The selection of the terms used in CATA questions, should be easy for consumers to understand and preferably related to the vocabulary they commonly use for describing the products Meillenet 2014. The number of samples to be used ranges from 1 to 12 depending on the aim of the study and the number of consumers ranges from 50 and up.

Binary data is obtained from the CATA questions indicating if consumers have selected or not the terms for describing the samples. For each term of the CATA question a data matrix is created containing samples in columns, consumers in rows. In this matrix each cell indicates if the term was checked or not (1/0 respectively) by each consumer to describe each simple (Varela and Ares, 2012). The frequency of use of each CATA term is determined by counting the number of consumers that used that term to describe each sample. A contingency table with the summarized information is elaborated. The table contains counts of the number of assessors that checked each respective attribute for each product (Varela and Ares 2014).

The first step when analyzing data from CATA questions is determining if consumers detected significant differences between samples for each of the terms of the CATA question. This analysis is performed using Cochran's Q test (Manoukian, 1986) (Parente, Manzoni, & Ares, 2011), which is a nonparametric statistical test used in the analysis of two-way randomized block designs, to check whether k treatments have identical effects, when the response variable is binary like it is in the CATA method (O'Mahoney, 1986 Manoukian , 1986).

Afterwards, a Correspondence analysis (CA) is performed on the frequency table from each experimental treatment. CA is a multidimensional approach that enables a clear visualization of the relationship between products (questions or concepts) and the words used by consumers to answer the open-ended question. Correspondence analysis creates a map of the data generated from a contingency table showing rows and columns in the same geometric space. The obtained representation will be similar to those traditionally used in sensory science depicting comments and products on a same graph where the closer a word and a product are, the more frequently consumers used this word to

describe it (Varela and Ares, 2014). Thus similarities and differences between samples and terms are shown in this map.

When using CATA questions for sensory characterization with consumers, replication is not usually performed due to cost, time, and resource constrains (Ares, 2014). Therefore, it is necessary to ensure that CATA questions when used by consumers provide reproducible results (Jaeger et al, 2013).

This methodology provides a description of the most relevant sensory characteristics of the products. However, it is important to take into account that despite the fact that frequency of mention of the terms from CATA questions have been reported to be closely related to attribute intensity, they do not provide quantitative information since consumers only evaluate if a term is appropriate or not to describe the product (Varela and Ares, 2012).

Due to its easiness to use and perform, CATA questions is a methodology that has usually been performed with naïve assessors. However, it could also be performed with trained assessors. This thesis addresses some experiments with this challenge.

2. OBJECTIVES

New product development requires a series of steps to accomplish, so products can be properly addressed to the existing markets. Therefore, this study has one principal objective and five secondary objectives.

2.1 Principal objective

The aim of this thesis was to develop new products from fish species of potential aquaculture rearing, incorporating opinions of both experts and naïve assessors thus, including specific demands and consumer preferences, in selected markets of the European Union (UK, Germany, Spain, France and Italy).

2.2 Secondary objectives

The following secondary objectives were raised as follows:

1. To characterize five selected fish species of potential aquaculture rearing, through a physicochemical and sensory evaluation with trained assessors.
2. To create concepts for new product development (with the selected fish species), through focus groups with consumers in five European Union countries. To screen and select the most suitable ideas for the fish products taking in to account a combination of the market perceptions.
3. To develop physical product prototypes from a selection of ideas (derived from focus groups) based on the technological and sensory characteristics of the selected species.
4. To sensory characterize the new developed products by means of trained and naïve assessors
5. To evaluate consumer perceptions of the newly developed products, in the five selected countries, thus assessing their overall acceptability, expectations and purchase intention.

3. METHODOLOGY

Five fish species of potential aquaculture rearing were used in this study (Greater amberjack, grey mullet, meagre, pikeperch and wreckfish).This study was performed in five stages which led to a total of three different scientific publications. All the methodological procedures that derived in a publication are summarized in this section, whereas the other stages are fully described. In the first stage, in order to characterize the five selected fish species, sensory descriptors (that could cover a wide range of species), were developed previous to the full characterization. Therefore, sensory attributes for 23 visually different fish species were generated through trained assessors. In order to accomplish this task, two rapid methods were used: CATA and FCP (First publication). This task allowed to have the sensory attributes needed to perform the further sensory characterization of the selected species in this study. Once the sensory descriptors were generated, a full characterization of the five selected fish species was carried out (stage 2). This characterization included physicochemical (somatometric, compositional, instrumental texture) and sensory analysis (using the descriptors obtained in stage 1) to have a complete profile for each one of the species (Second publication).

In the third stage, after the species were characterized, new ideas of fish products were developed to be applied in all the selected species. Ideas were created through focus groups executed in five countries from EU. All the new generated ideas were screened afterwards (according to qualitative and quantitative criteria), in order to keep the concepts that could be more appropriate for the afore-mentioned species. In the fourth stage, a selection of product prototypes was developed out of the previous screened concepts. In stage five, six products were selected (based on three different levels of processing) to be sensory characterized with trained and naïve assessors. Products were characterized by trained panelists through Quantitative Analysis and CATA method. In addition, 105 consumers (from a total of 510, only those from Spain) assessed the attributes that sensory characterized the samples with CATA method (third publication). In addition, these products were also tested in five different countries to assess the consumer`s acceptability expectations, image perception and purchase intention. Figure 3 shows the experimental process in a scheme.

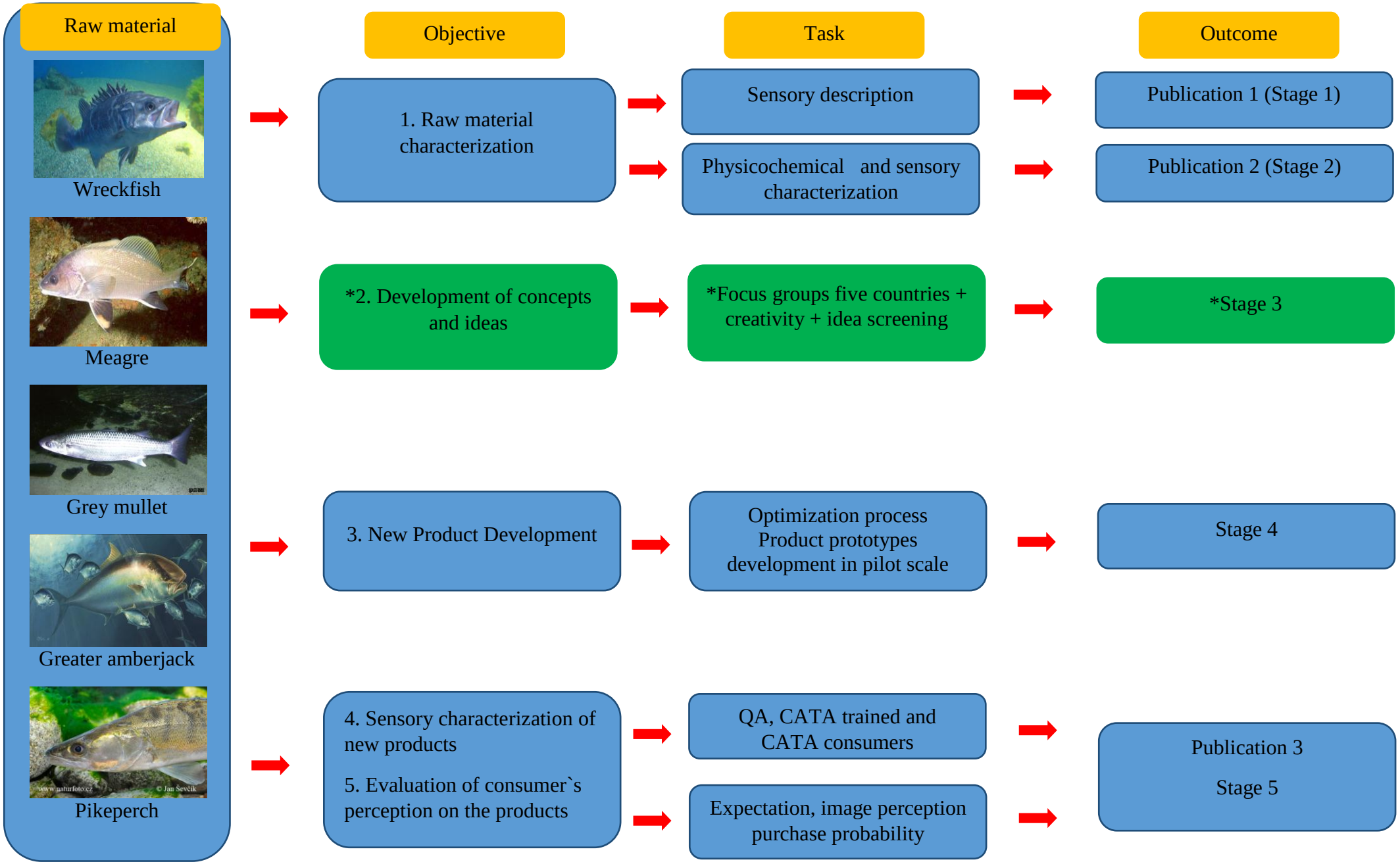

Fig 3.Scheme methodology

*This stage was made in collaboration with other researchers and its design and execution was instructed by them

3.1 Objective 1 Raw material characterization

3.1.1 Generation of sensory descriptors

An extensive bibliographical review was conducted, creating a list of potential fish descriptors. In addition, a group of nine trained panelists assessed 23 different fish species, selected at the fish market based on visual differences (size, color, shape), expected mouth characteristics (texture and flavor) and availability throughout the duration of the study. Assessors were asked to individually elicit as many sensory attributes as possible to describe those fish samples provided. A list of 103 descriptors was assembled, this list included the attributes from the bibliographical review and some additional attributes that had been obtained from the panelist`s tasting sessions (removing those terms considered redundant by means of a triangulation process) (Guerrero et al. 2010).

This 103 list of descriptors was used in a second stage, so a second group of trained panelists (nine assessors) could perform a Check-All-That-Apply method with 19 different fish species and select the appropriate descriptors for them. In addition, a different group of nine trained assessors performed a Free Choice Profiling technique over eight different fish species (those selected according to the higher sensory differences previously obtained with the CATA data) in three sessions. In the first session, panelists evaluated the eight samples to generate the personal attributes they could perceive as relevant when describing each fish species. In the next two sessions, panelists had to rate the same eight samples using their own attributes. This was performed in a lineal scale where assessors scored from 0 to 10, low intensity/absence (0) and high intensity (10).

A comparison between the CATA and FCP techniques with the same 8 fish species was drawn by calculating the overall number of attributes elicited in each method and sensory modality (appearance, odor, flavor and texture attributes). In the case of FCP the consensual coordinates for each assessor and for all the samples, after performing the corrections done by the GPA (translation, scaling and rotation), were kept. For CATA data a Multiple Factorial Analysis was performed and again the consensual coordinates for each assessor and for all the samples were kept. Consensual configurations were always kept for the two methods and were compared by means of

discriminant analysis. All statistical analyses were performed using XLSTAT software 2015 (Addinsoft, Paris).

3.1.2 Physichochemical and sensory characterization of the species

Fillets of meagre, greater amberjack, pikeperch, wreckfish and grey mullet were used for a complete characterization of the species.

The following somatometric indexes were calculated individually from 10 specimens of each species: Condition index (CI) Dressing yield (DY) Filleting yield (FY), Hepatosomatic index (HSI), Gonadosomatic index (GSI) and Viscerosomatic index (VSI).

Proximate composition analysis was also performed over three different samples of each species, including: protein, lipid, moisture and ash contents, which were determined according to standard AOAC (2005) methods.

Instrumental texture analyses were also determined on five samples of each species, where two different tests were carried out: a non-destructive compression test (compression rate 30%) with a spherical probe for raw and cooked samples and a Texture Profile Analysis (TPA, compression rate 75%) with a cylindrical probe performed only with the cooked samples.

Finally for the sensory characterization of all species, a group of eight assessors was trained using an extensive list of attributes (that described fish species) from a previous work (3.1.1). The most relevant attributes were selected after performing CATA on the five selected fish species to use more adequate descriptors.

Twenty two attributes were used to develop sensory references for the panel training in order for them to acknowledge low and high intensities of each one of them. Once panelists were familiarized and trained with the sensory descriptors, quantitative analysis of the fish samples was carried out five times in five different sessions.

The descriptive data of the different species were submitted to a three way ANOVA including as fixed factors the fish species. A Principal Component Analysis was performed over the mean values of somatometric, compositional, instrumental texture and sensory data in order to examine the main relationship between all the information available. The Pearson moment correlation matrix was also retained from this analysis.

All statistical analysis were performed using XLSTAT 2017 software (Addinsoft, Paris, France).

3.2 Objective 2: Development of concepts and ideas for new products

3.2.1 Focus groups

A series of focus groups with consumers in five selected countries (*i.e.*, UK, Germany, Spain, France and Italy) were performed to generate ideas for new product development of farmed fish species. The countries choice was determined based on the following characteristics: largest EU markets for cultured fish (*i.e.*, Spain, France and Italy) and important growing EU markets for cultured fish (UK and Germany).

Two focus groups were conducted per country (10 focus groups in total). Each focus group included six participants, three from each of the two main psychographic egments previously identified in an extensive survey (Krystallis ,Banovic, Guerrero, & Reinders 2015): the '*involved traditionals*' and the '*involved innovators*'. The '*involved innovators'* represented consumers who were very involved and knowledgeable about fish products, but at the same time quite innovative, when it came to trying new farmed fish species. On the other hand, even though the '*involved traditionals'* were involved and knowledgeable about fish consumption, they saw new farmed fish as the extra 'cost' that this type of consumption could bring, being more concerned about the safety issues and efforts attached to the fish products. Thus, in general, this segment was much more conservative and reserved regarding the new experiences in fish products.

All focus groups contained participants of different age (between 30 and 60 years), gender (3 male and 3 female participants in each group), educational and general socio-economic background (for eliciting opinions and points of view as wide as possible). Furthermore, participants were farmed/wild fish consumers and had bought fish (farmed and/or wild) at least once during the previous month to the interviews.

The moderator used a protocol (discussion guide) to ensure consistency and uniformity of the process in both focus groups. Through this qualitative methodology, the moderator was allowed to ask the participants about their views and experiences, facilitating a better understanding of why the participants agreed or disagreed on specific subjects. Moreover, whenever the discussion got off-track or whenever it was

insufficiently covered, the moderator could consult this protocol. The focus groups were performed in the three following stages (according to the discussion guide):

Step1: Exploration of new food products (time duration: 10')

In step 1, informants were encouraged to discuss about their personal experiences, preferences, attitudes and perceptions towards new food products in general. They were requested to express their opinion on a number of themes (posed to them orally by the interviewer in the 'free' flow of the discussion) accordingly, such as (indicatively):

- *Can you give examples of new food products that you bought lately?*
- *What specific features of the new food product impress/disappoint you?*
- *Use free words to describe the most positive experience you had with the new food product?*

Step2: Exploration of new fish products (time duration: 20'-30')

In step 2, informants were invited to explore new fish products and re-design them. This stage was accomplished through three steps: a) defining the product – personification associations; b) free association task, and c) pictures of new fish products – role playing.

a) Defining the product – personification associations

In this step, a simple exercise with participants was undertaken, this permitted to define a fish product by associating it with other products or living beings. These personification associations also allowed participants to give human characteristics to fish products. Examples of questions are listed below:

- *If fish were a person, what would he or she look like?*
- *If this fish could talk, what would it say to you?*
- *How would this fish feel about you?*
- *If you were a fish, which fish would you be?*
- *How would you describe yourself in this role?*

b) Free association task

In this step, informants were more involved in the process by being prompted to undertake a free association task. Participants were invited to say what came up to their mind using the following thoughts:

- *When you think of new fish products, what is the first thing that comes to mind?*
- *When you see new fish species, what image comes to mind?*

Not only these questions trigger the participants' interest, but they also generate valuable insight on how informants perceive, interpret, and associate new fish products. The free association task was made in an unstructured way and in a non-judgmental atmosphere, following pathways defined by emotional motivations, rather than rational intentions, confronting in that way the participants' anxiety.

c) Pictures of new fish products – role playing

Participants were provided with concrete examples assisted by pictorial material of new fish products that could come out. Informants were thus invited to express their general opinion on these products. Afterwards, they were also encouraged to do some role-playing and to discuss what features they would add/remove or what features they would emphasize added value to these products and made them more convenient, healthy, among other things. Examples of questions are listed below:

- If you were the product manager, what specific features of the new fish product would you add/remove?
- If you were the product manager, what would you do to improve the new fish product?
- If you were the creative director, what would your ad say?
- If you were buying this product, what would you like to see to make up your mind?

Step 3: Exploration of new creative ideas for fish products (time duration: 60'-90')

The goal of this stage was to create new ideas for fish products by gaining the deeper understanding of the consumer and digging more deeply into consumer perceptions. In this step, brainstorming was aided with an empathy map (Fig. 4). This stage included the following steps:

a) Brainstorming with empathy map (20’-30’)

b) Creating new ideas (15’-30’) and building presentation for a new idea (10’-15’)

c) Presentations (2’ each group) and voting for best ideas (15’-20’)

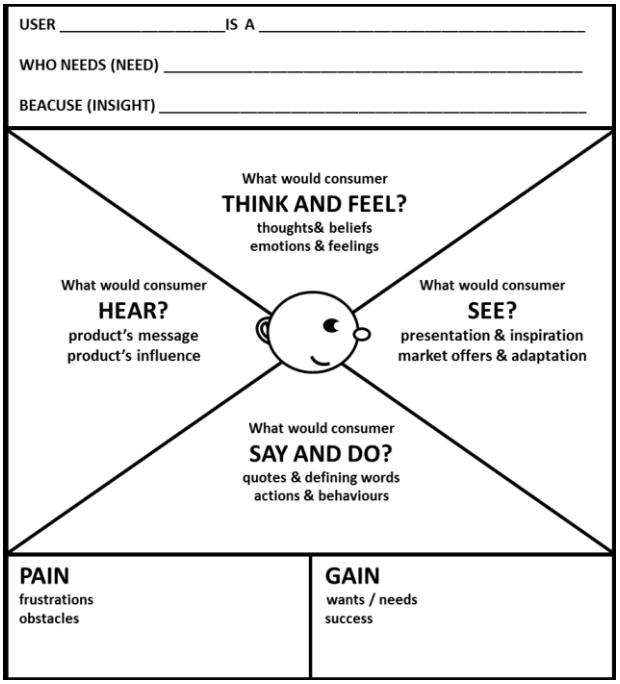

Fig. 4 Empathy map

a) Brainstorming with empathy map

In the brainstorming session, the interviewer explained the protocol to the participants making sure that the brainstorming sequence was well understood. Participants in each focus group were asked to form three groups of two participants (one from each psychographic segment). Participants were divided into groups in order to get the best results by combining group brainstorming. By dividing participants into groups, people could focus on specific issues without interruption. In this way a number of ideas were generated and maximized and team bonding was achieved. The empathy map diagram allowed to keep the participants focused on the problem. During this session, the interviewer made sure that all ideas were recorded and also checked within each group (every five minutes) that the session was going in the right direction.

The protocol for each group was the same. Participants were asked to define their point of view on who in their opinion, could be a consumer of new fish products (those presented in the previous steps). Thus, pictures of the fish products shown earlier were shown again at this stage. Brainstorming session proceeded by using an empathy map that was already printed out or drawn on the whiteboard.

By using the diagram in Figure 4, participants were highly encouraged to give their presented consumer a name and some demographic characteristics, such as occupation, marital status, etc. Furthermore, they were asked to define a consumer *need* to consume fish products and give an *insight* or the main reason behind consuming fish products (e.g., Sarah is a nurse and mother of two, boy and girl; *who needs* fresh fish to feed the kids and to serve it for a special occasion; *because* she wants a tasty and quality meal with lower fat content that gives brainy food for her kids, she watches her line and eats a quality meal for family gatherings). Then, by using the empathy map, participants were compelled to explain what would this consumer - *see - hear - think & feel - say & do* - regarding the product he/she *needs* and what could be *pains* and *gains* of this process. Participants were given post-it notes and markers to write and draw their ideas and thoughts regarding the different questions and place them accordingly to the empathy map diagram. Participants were encouraged to use quotes, keywords and drawings that tell a story about each idea. Each group worked separately on their ideas (this part lasted up to 30 minutes). Participants were instructed to write and draw ideas on post-it notes and clip as many as possible on the diagram.

b) Creating new ideas (15'-30') and building presentation for a new idea

In the creative session, the interviewer asked all groups to continue with brainstorming by asking themselves a simple question: "How might we…"? (e.g., *How might we help Sarah to get the fish product that is fresh, low fat, tasty and that is a quality meal choice for her, her family and friends?*). After the first part of the brainstorming session was completed, each group was asked to choose idea(s) that want to carry forward to presentation and evaluation. Ideas were presented by using another board or a large paper. The interviewer encouraged each group to *tell* or *draw* or *make* a story, song or similar (e.g., cartoon) about their idea(s) and emphasize 3 strengths and 3 weaknesses for each selected idea(s). Each group built their ideas by simple brainstorming and

board game, looking at the empathy map and post-it notes, and adding or rearranging them as a story. Participants were encouraged to: look for ideas drawings and thoughts on the empathy map that they could link to the challenge of '*how might we*' and to try to force relationships and free associations while recording each idea arrangement on the board or a large paper.

The interviewer made sure that no one criticized or evaluated ideas during the building phase, as criticism can introduce risks of putting off some ideas and can cripple creativity and the free flow of the brainstorming session. The interviewer encouraged participants to talk about one idea at the time, inspiring wild and provocative ideas (from solidly practical to wildly impractical ones). The interviewer ensured that participants stayed on topic and built on existing ideas. Building ideas presentation lasted up to 45 minutes. First 20-30 minutes were used for ideas creation and last 10-15 minutes were used for building presentation. The participants were informed at the beginning of this session that they would have to present an idea or ideas when the board game and idea (s) were completed. As previously mentioned, presentations varied and were presented in various ways depending on the group's preference (e.g., cartoon on a large paper).

c) Presentations (2' each group) and voting for best ideas

In this session, each group presented their ideas the way they preferred (e.g., story, drawing, cartoon, song). Each presentation lasted no longer than 2 minutes. Thus, each group presented their ideas at the end of the creative session. After each group presentation was completed, everyone voted for the *best* and *worst* ideas. Besides voting, participants were encouraged by the interviewer to comment and make additions to the existing ideas. This final section was useful for producing rankings for the individual ideas/offerings, along with conclusions. First of all, each respondent rated the concept using a marking system. Each participant had 12 points to give out, this way they could stick them all into one concept/fish product or distribute them according to personal preference. All the points were distributed in order to allow comparisons. In addition to ranking, participants were also encouraged by the moderator to comment and add to the best existing ideas.

3.2.1.1 Experts opinions on the focus groups overall ideas

Expert`s opinions were retrieved to explore the possibility of creating new fish products from the general concepts gathered from the focus groups from five focal fish markets (*i.e.*, UK, Germany, Spain, France and Italy). Thus, expert interviews were conducted using a structured questionnaire in each of the five selected countries. Four expert`s interviews were conducted in UK, one in Germany, two in Spain and three in France and Italy. The following questions were performed on each expert regarding the main developed ideas.

1. How attractive you think this product idea will be for consumers in your country?

2. Is this product unique for the current assortment of fish products in your country?

3. What is an acceptable price range for this product idea?

4. Which of the following species would be most interesting in [your country] for this product idea:

- Meagre
- Greater amberjack
- Pikeperch
- Grey mullet
- Wreckfish

5. For what type of distribution channel is this product interesting:

- Supermarket
- Specialty store
- Out of home market (e.g. catering, restaurants)

Furtherly, all experts opinions were taken in to account within the developed concepts.

3.2.2 Screening ideas of new products

3.2.2.1 Qualitative criteria used for the screening

All ideas obtained from focus groups sessions were screened by experts, following a list of 19 criteria (derived from the consumer`s concerns). Thus, specific, technical,

economic and market assessment criteria, among others, were established to identify the ideas that could be attractive for consumer`s demands and generate more addressed concepts for product development. The selection criteria are described as follows.

a. Nutritional benefit: Nutritional value may alter subject to processing (e.g. thermal processing may result to alterations in nutritional value like destruction of heat–sensitive nutrients). Nutritional benefit is a strong consumption criterion for consumers especially regarding fish, since it is scientifically supported and therefore used as a strong marketing aspect.

b. Healthiness: Turn in healthy food reflects a current trend in food consumption; Healthiness of consumed food was included since it resides among the current European trends in animal protein consumption as shown in trend mapping. Healthiness as a trend incorporates notions such as low calorie, low-saturated fat (rich in polyunsaturated), rich in vitamins, alleged health-protecting or health promoting properties, minimum additives, etc. Therefore the concepts were rated with respect to how consumers will evaluate the healthiness of a product as well as the amount of product aspects that can be used for marketing this product as healthy. Healthiness and nutritional value were included as separate criteria, since the former can be connected to several factors, such as product processing, additives used, preservatives, cooking method required, etc., while the latter is defined by the nutritional benefit of the product.

c. Convenience: is a current consumer need in the majority of the aimed countries involved in this study. this criterion was divided in *easy to cook and ready-to-eat*

c.1 Convenience in preparation (easy-to-cook): One factor that can have a negative effect on the intention of buying a fish product is the complexity in preparing the respective dishes (*e.g.*, deboning, scaling, gutting). Nowadays the majority of the consumers have less time to spend in preparing meals. Therefore, offering them a convenient product which requires short preparation time, while still allows them to be involved in the preparation process can create a market advantage over other competitive products.

c.2 Convenience in consumption (ready-to-eat): Creating a ready to eat product that can be consumed outside the household in different occasions by itself, or incorporated in existing meals (e.g. sandwiches, salads) can increase the existing market for fish and

solve a real problem for the consumer who wants to retain a healthy diet even when there is no available time for cooking.

d. Cost for consumer (price): The final price of the product on the market (price for the consumer) is of outmost importance, for consumers´ choice. More specifically, price lies among the 4 most important factors, which affect buying preferences in all aimed markets (UK, D, ES, F, I). Moreover, fish in general is considered an expensive commodity (when compared to most meat and plant foods). Therefore the price of the products must be retained in a reasonable level, in order to be competitive and successful towards similar products like unprocessed fish or processed meat products.

e. Technical feasibility: The timeframe as well as the resources for realizing each product concept are limited. Thus, an important criterion for evaluating each product concept is the feasibility with respect to available equipment, raw materials and know-how; it is expected that research will be needed in order to realize each product still, the expectations should not be unrealistic since a lot of resources, and therefore money, and time could be spend on creating a product which may not succeed in the market place. Therefore technical feasibility is among the most common criteria that industries use for evaluating a product in this stage of new product development (Rochford, 1991).

e.1 Technical feasibility (equipment & raw material): The right equipment for processing must be available or must be designed and created within the timeframe of the study in order to ensure a stable and efficient production of the designed products. Thus, small commercial sizes may result into certain technical limitations in aspects of processing (*e.g*., a fish species with commercial sizes of <1 kg cannot be suitable for cuts). Besides, all the designed products must be based on a realistic commercial fish size (a fish size for which there is stability in production). If this is not the case, it could create bottlenecks and delays in the production process since the actual size of the raw material would differentiate from the designed one for the products.

e.2. Technical feasibility (know-how): While creating a new product, a very important thing to consider is the feasibility of production within the frames of current know-how, without the need of designing completely new and untested methods. Products based on completely novel methods of processing can be time consuming (depending on the method and extend of novelty), create uncertain results, or lead to increased overall production cost.

f. Specific consumer targeting: Specific consumer targeting is one of the key steps to successful designing of products. The designed products must reflect the needs and desires of the targeted group(s) in order to make them feel that the products fulfil their expectations and solve a real problem for them. The seafood market has a lot of potential for products that can be considered as delicacies or can target special groups of people with special requests (*e.g.*, ethnic or religious minorities).

g. Familiarity: Fish consumption strongly differentiates based on the familiarity of consumers to certain species/products (unlike meat where market is universally more uniform). The experience with certain products and types of processing can affect final choice, since it is easier for a consumer to purchase products for which he understands the concept, the production method as well as certain flavor characteristics, rather than unfamiliar ones. Familiarity on some aspects of the product on the other hand, can help consumers to accept more easily a newly introduced product. Therefore, a balance between familiarity and innovativeness should exist.

h. Newness/ innovativeness: The effect of innovativeness of a newly developed product with respect to its impact on the market success is difficult to evaluate (Arts et al., 2011). Still, innovativeness is required when a product has to separate its place from competitive ones (become unique) and to excite the consumer. Moreover, innovative looks for products has been among the most important supplier selection criteria in the majority of the aimed markets. Therefore a new product should differentiate itself from other available products of the same category. This differentiation could be expressed in different ways, such as concept behind the product, production process, flavor characteristics, etc. In general, the buyer should feel that this product brings something new to the table and a balance must exist between the novelty in some aspects of the product and familiarity in some others.

i. Existence of similar/competitive products: Product competitiveness is among the prerequisites for market success. This notion includes the level of existing competition (substitute products within the fish product category and similar products within the general protein source category), as well as the products advantage (the degree to which the newly developed product is perceived as being better than competitive ones). These are acknowledged as a prerequisite for success (Rogers, 2003; Arts et al., 2011). Thus, evaluating the level of competitiveness can reveal a lot of important information regarding the chances of success such as saturation of market or market gap, where a

newly developed product can infiltrate. In this criterion, positive ratings (>4) are given to products that will have to face a low level of competition, while negative ratings (<4) are given to the products that will face a high level of competition in the market place.

j. Shares characteristics of successful products: Several successful or failed examples of introduction of new fish products in a market are available. Taking advantage of that information, and since the safest way to infiltrate a market is to replicate the characteristics of already successful products in the respective markets, a criterion of "shares characteristics of successful products" was included. This criterion would examine if suggested products share certain qualities of already successful products on specific markets. Identifying those qualities and incorporating them on the product design could significantly increase the acceptance rate of the new product by consumers.

k. Perceived consumer freshness: In the majority of the targeted market, a consumer orientation towards fresh products was identified. Thus, freshness is a key criterion in consumers' choice regarding a product and it was included within the screening factors for evaluating product success. Therefore, creating a product for which perceived freshness can be ensured, can create an advantage for the product in the targeted market. It is important to note that actual freshness of the product is not necessarily expressed within this criterion, but rather the impression a product gives to the consumers. Products of specific nature, *i.e.*, high degree of processing, low similarity to initial raw material, deep-freezing or long-life preservation methods such as canning, give low scores in perceived freshness. In highly perishable food products such as fish, safety issues are of great importance. Thus, creating processed fish products with a low risk of safety hazards was included as a criterion.

l. Safety: When designing a product, one should keep in mind that some types of raw materials, product formulations and processing can create safety issues. Prevention of safety threats in the manufacture and preparation of food products is essential for lowering the risk for consumers. Therefore safety principles should be timely applied in the development process. This will allow to identify potential food-safety incidences and options for effectively addressing those issues, since a number of products have specific nuances and characteristics that need to be addressed (*e.g.*, some ingredients are of a higher microbiological or allergen risk than alternatives).

m. Shelf life: When referring to highly perishable foods, as fish is by nature, anything beneficial in prolonging shelf life can be considered as a significant benefit for the consumer's option to maintain before consumption. Moreover increased shelf life can result to higher benefit for the industry, since it can decrease the waste (off-date products) and therefore the production cost.

n. Packaging: There are several functions a packaging should acquire; maintaining product quality, protection against environment, right portion sizes, convenience. Moreover packaging could act as a marketing tool. The evaluation of packaging function is based on how it covers the aforementioned criteria.

o. Added value: Since whole fresh fish are often marketed close to their actual production cost, the profit margin of the industry is low in these cases. Processing increases the added value, since the product can be marketed in a higher price, thus providing higher profits. Added-value is furthermore created by utilizing fish parts otherwise considered of low value, by-products or waste.

p. Attractiveness (Appearance/ presentation): Attractiveness of a product is a major criterion for consumer choice in the market. This factor can give an important advantage on the product over existing ones and play a significant role in the first contact of a consumer, before consumers have the chance to evaluate the actual taste of a product. Within the frames of the screening process, attractiveness ratings are based on how appealing are the concepts' intrinsic and extrinsic characteristics to a consumer.

q. Recipes: it was stated that "ignorance of how to prepare dishes containing fish" is one of the reasons for low fish consumption. Providing recipes with the packaging, besides potential induction of product acceptance by cooking more convenient, will also educate the consumers on the subject. Therefore, the existence of variable recipes to offer versatility in choices is regarded as a positive aspect for a product. Moreover, a recipes criterion was included due to the fact that ignorance in preparing meals including fish seems to affect negatively the buying process.

3.2.2.2 Quantitative screening of the concepts

A quantitative method was used to screen the new ideas for products, this method was performed using each one of the 19 qualitative criteria mentioned in point 3.2.2.1. Thus, a scale was developed using scores 1-7 (Table XX), to rate each product concept on each of the developed criteria. A group of experts was called specifically to develop this task. These specialists scored only the criteria they believed corresponded to their expertise. The average value for each score was calculated summing up the individual scores, given by the experts, and dividing this value by the number of times the specific criterion was scored.

Table 2: Rating values for screening the new product concepts

	Extremely bad	Really bad	Bad	Neutral	Good	Really good	Excellent
Rating scale*	1	2	3	4	5	6	7

*(1, 2, 3= negative scoring, 4= average scoring, 5, 6, 7= positive scoring)

All concepts were ranked according to their total rating scores**.** Top rated concepts represented those who were considered as having more potential of being successful in the market place, while the opposite applied for concepts that were found in the lower ranking places. The negative ratings (<4) were not used to reject the idea completely, but rather to indicate a weak point in the concept.

3.2.2.3 Analysis of the screened concepts (product feasibility)

In addition to the ideas screening, the commercial sizes and technical fillet characteristics (point 3.1.2) of the selected fish species were also considered for the development of prototypes. Thus proper suggestions for specific use, according to their technical feasibility and possible potentially success, were developed so they could be forwarded to later product development stages. Having a technical compatibility between the species and the product concept.

3.3 Objective 3: New Product Development

3.3.1 Developing physical prototypes

The development of the new fish products was made taking in to account three main aspects:

1. The analysis of the fish species: physicochemical and sensory characteristics.
2. The ranking positions of the generated ideas in the focus groups: obtained as the result of the total score (generated by different experts) on the 19 different criteria used in all the generated ideas. Only those products with scores higher than 95 were considered for this task.
3. Product suitability based on specific existing markets.

The selection of the ideas for developing the product prototypes was also based on: the simplicity of their ingredients (number of ingredients and their availability in the market), ease and/or rapid preparation, maximum product acceptance (mass market or with minimum constraints due to cultural or age differences) and safety.

Furthermore, a search for similar products was also taken in to account in order to obtain additional information to improve the product design. Various retail markets were visited to seek similar products and the Mintel GNPD database (http://www.mintel.com/global-new-products-database) was also used to search new fish products in Europe.

Products were developed in a pilot plant using diverse equipment such as: industrial and electrical oven, mincer, blender, auto clave, freezer etc., under sanitary conditions for preparation processes.

To improve shelf life, Modified atmosphere packaging machines, skin packed and sealed containers were also used.

In order to have a full description of the developed products these were assessed by means of sensory, physicochemical, compositional, microbiological, and shelf life analyses.

3.3.1.1 Sensory evaluation of product prototypes

Prototypes were sensory evaluated during their development process. These products were assessed by trained panelists (ISO 1994), with a minimum of 5 years of experience in fish descriptive analysis. Products were assessed in an evaluating sheet (Figure 5), where general sensory characteristics were described. Overall quality and key attributes of appearance, aroma, flavor, and texture for each product were measured by panelist`s consensus using a 10 points scale.

EVALUATION SHEET

IDEA 1: Frozen fish fillets with different recipes (recipe number 1)	
APPEARENCE (Scale from 0 to 10, where 10 is the highest score)	
SUGGESTIONS FOR IMPROVEMENT:	
AROMA (Scale from 0 to 10, where 10 is the highest score)	
SUGGESTIONS FOR IMPROVEMENT:	
FLAVOUR (Scale from 0 to 10, where 10 is the highest score)	
SUGGESTIONS FOR IMPROVEMENT:	
TEXTURE (Scale from 0 to 10, where 10 is the highest score)	
SUGGESTIONS FOR IMPROVEMENT:	
OVERAL ACCEPTABILITY (Scale from 0 to 10, where 10 is the highest score)	
GENERAL REMARKS:	

Fig. 5 Sensory evaluation sheet for product development

3.3.1.2 Physicochemical properties of product prototypes

Physicochemical analysis such as pH, water activity and proximate compositional analysis (protein, fat, moisture and ash content) were performed according to AOAC Official methods (AOAC, 2005). Carbohydrates, fatty acids, sugar content, salt content and total calories were also determined for each one of the developed products.

Shelf life, microbiological and quality control

In order to verify a good hygiene practice (GHP) and the Hazardous Analysis of Critical Control Points (HACCP) of the production process, products were submitted to different microbiological and sensory analyses. These analyses were carried out at the initial conditions of the product development during the development of the prototypes and once products were finished to test the shelf life of these prototypes.

These analyses included detection of: *Salmonella spp, Listeria monocytogenes,* Enterobacteriaceae counts, Mesophilic bacteria counts, Psycrophylic bacteria counts and Lactic acid bacteria count.

Assessment of changes (quality loss) during the prototype`s storage, was performed at chilling temperatures in different time lines (for the products preserved under refrigeration). The shelf life of these refrigerated products was determined storing them at 4 °C for one third of the total estimated shelf life (based on the ones from similar products) and the other two thirds at 8 ºC. Four degrees temperature was set as the maximum that needs to be ensured during manufacture and until arrival to the display cabinet. Thus, these storage conditions could mimic those before the product can be sold. Subsequently, when the prototypes were stored at 8 °C for the remaining shelf life, it was to mimic maximum temperature conditions at retail and consumer storage (Betts, Brown et al. 2004).

The shelf life of the frozen products, was determined through histamine measurements.

Sensory analysis of products

Changes in the products across time storage were also assessed by means of sensory evaluation, this task was performed by three trained assessors. Sensory descriptors (i.e. appearance, odor, flavor and texture intensity and off odor or flavors) were used to describe the product quality deterioration. A three point scale ranging from 0 (similar to a fresh product) to 2 (unacceptable) was established to determine these changes. This scale was defined and based on the panel expertise. Descriptors were measured at different time lines, during the product´s storage. Product prototypes showing scores between to 0-1, were considered to reach the shelf life acceptability limit (in sensory terms). As for those products with score 2, these were considered as deteriorated and out of their shelf life.

3.4. Objective 4: Sensory characterization of the new products

Once all product prototypes were developed and analyzed, six out of twelve were chosen to be sensory characterized. This products were chosen based on their technological complexity, shelf-life, easiness to handle or prepare, consumption context and shipment convenience. Consequently, a more practical and realistic amount of products would be tested, reducing the loss of interest, concentration and sensory fatigue of participants (Amerine et al., 1965). Products were chosen by the researchers based on three different levels of processing (high, medium and low). This characterization was performed with both trained and naïve assessors.

3.4.1 Trained assessors characterization

A group of nine trained assessors with more than four years of experience in descriptive sensory profiling of different food products including fish, performed a Quantitative Analysis (QA) using 28 descriptors (obtained from a previous work, Lazo, Claret & Guerrero, 2016) over the six selected products in three different tasting sessions. Another group of sixteen trained assessors (same characteristics as described above) performed a Check-all-that-apply (CATA) test over the six selected products in only one tasting session using a list of the same 28 descriptors.

3.4.2 Consumer`s (naïve assessors) characterization

One hundred and five fish consumers (at least once a month) were recruited in Barcelona (Spain), by means of a probabilistic sampling by quotas (age and gender), to evaluate six fish products (same as trained panelists). Groups of 10-12 participants were convened every 1-1.5h, thus having a total of ten tasting sessions in two consecutive days. Consumers received the samples in a monadic presentation and filled a CATA questionnaire with a list of 28 sensory descriptors (same as trained panelists). Consumers had to tick the options that they considered applicable to each product using this questionnaire.

Statistical analysis

Data from QA were analyzed by means of Analysis of Variance (ANOVA) over the assessors' mean values for each product. CATA data for both trained and consumers, were analyzed by means of Simple Correspondence Analysis. A Multiple Factor Analysis was performed in order to test the similarity between the sensory spaces obtained in the three different methodologies (CATA with trained assessors, CATA with consumers and QA). Afterwards, the consensual coordinates from the MFA for each panel were submitted to a Discriminant Analysis (DA) in order to assess the discriminant ability for each one of the three methods.

All the statistical analyses were performed with the software XLSTAT, version 2017 (Addinsoft, Paris).

3.5 Objective 5: Evaluating consumers perception on the developed products

3.5.1 Expectations, acceptability, and purchase probability tests

The six fish products selected for sensory characterization (point 3.4) were also used to assess consumer`s expectations and purchase probability.

A total of 510 participants (approximately 100 consumers per country) were recruited in the five selected countries; France, Germany, Italy, Spain and UK (105 of these consumers were the ones from Spain, taken in to account in point 3.4.2). The selection of participants was made by means of a probabilistic sampling by quotas (age, gender, studies, family members, financial situation and fish consumption). In addition, 50% of the individuals per country belonged to the segment of consumers named, "Involved innovators" and 50% to the "Involved traditional". Participants having any type of food allergy or food intolerance were screened out.

All the tests were performed under controlled conditions in a central location for all five countries. Each laboratory involved in this study provided a testing room equipped with sensory booths, designed according to ISO regulations (ISO, 2007), with capacity for a minimum of 10 participants. In addition, they had a preparation room equipped with a kitchen where to cook the different fish samples (grill and pan), a fridge for storing fresh samples (4-6ºC), a freezer to keep some of the samples frozen (-18ºC) and generic kitchen cookware. Mineral water and standard apple pieces (Golden delicious) were provided to each consumer to clean their mouths between samples.

Six products were assessed in this stage (same from point 3.4). All the samples were shipped in advance to each location in the right conditions and guaranteeing the cold chain. Samples were sent with detailed instructions about the right procedure to store them until analysis. Some of the samples were stored at 4-6ºC in a fridge and some of them at -18ºC in a freezer.

A total of ten tasting sessions were held in each location in two consecutive days. All participants assessed six product concepts and six actual products (same from point 3.4). Each tasting session was divided in three main stages:

a) Overall expectation acceptability: consumers assessed the expected acceptability for six product ideas without any additional information (no pictures were provided in this stage since they could bias the answer) on a structured 9-point

liking scale (From 1: I think I would like it extremely to, 9: I think I would dislike it extremely (Fig. 6)). In addition the product perception was assessed using a list of 18 parameters (Fig. 7), thus an overall image on the product concept could be obtained.

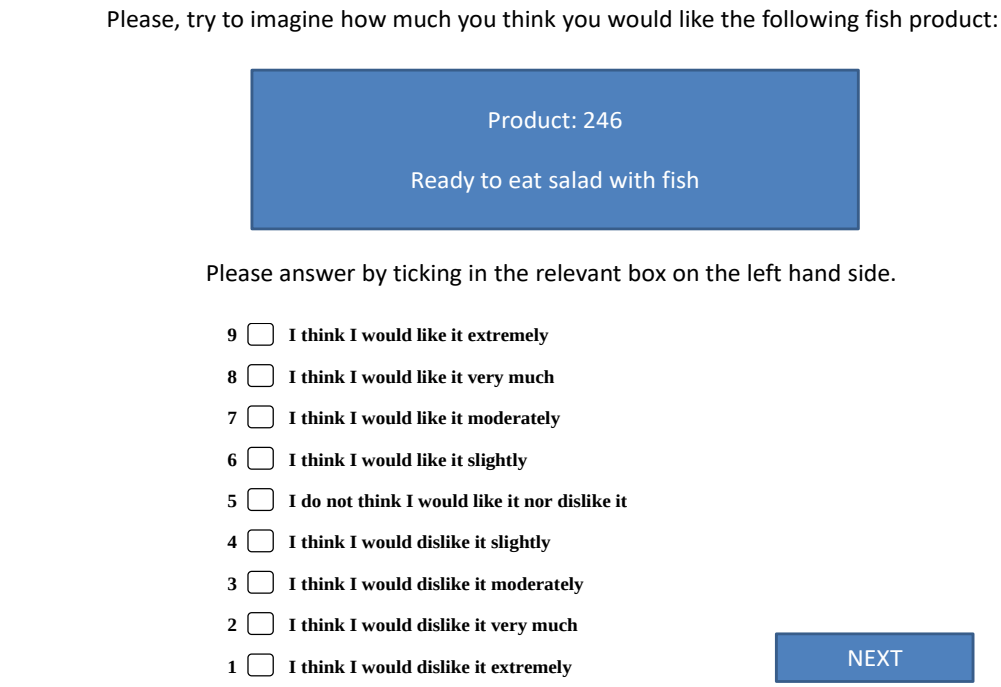

Fig. 6 Nine point expected liking scale

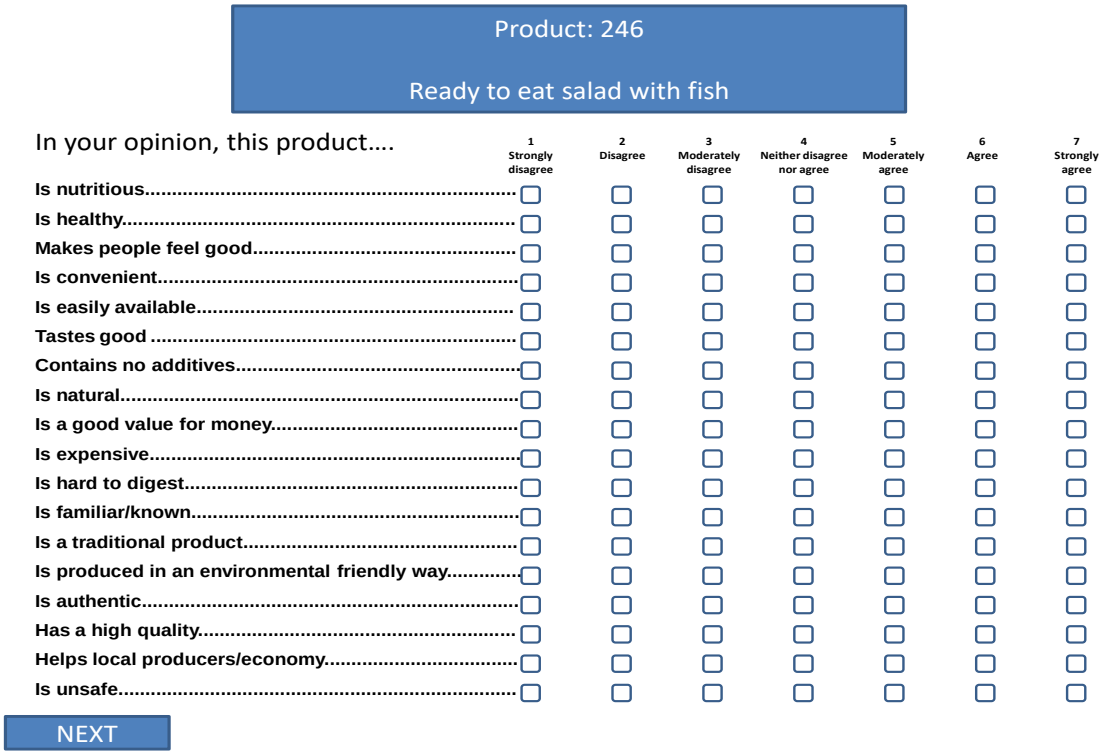

Fig. 7 Parameters for assessing product image perception

b) Blind tasting: participants evaluated the overall acceptability for each product after having tasted it in a 9 point scale (Fig. 8). In addition, they assessed the acceptability of odor, flavor and texture separately. Finally, respondents received a multiple-choice questionnaire with a list of 28 sensory descriptors (Fig. 9) where they had to tick the options that they considered applicable to each product (Check-all-that-apply or CATA) (Adams et al. 2007). All these tasks were performed product-by-product according to a balanced order (Mac Fie et al,1989).

Fig. 8. Nine point liking scale

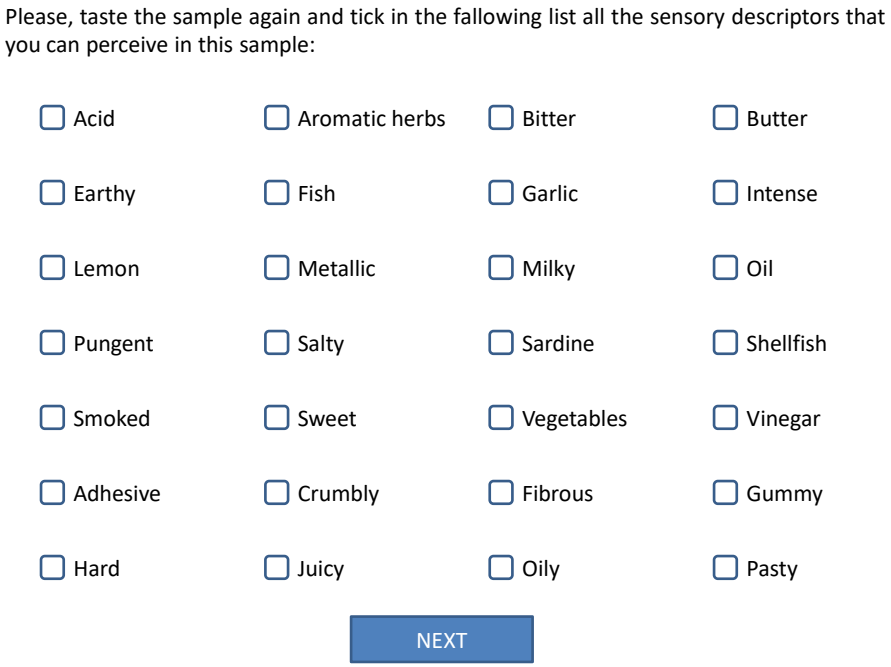

Fig. 9 CATA questionnaire with 28 descriptors

c) Overall acceptability in informed condition: participants received written description of each sample that included the full product information. They had to taste the product and assess their overall acceptability in a structured 9-points liking scale. Afterwards, for each product, participants had to indicate their purchase intention by means of an 11-point probability scale (Juster, 1966) (Fig. 10). Finally, respondents evaluated their personal perception of each product by means of a semantic differential scale made up of 11 adjectives (Fig. 11) (Osgood et al., 1957). Again, products were shown one by one in a pre-established order.

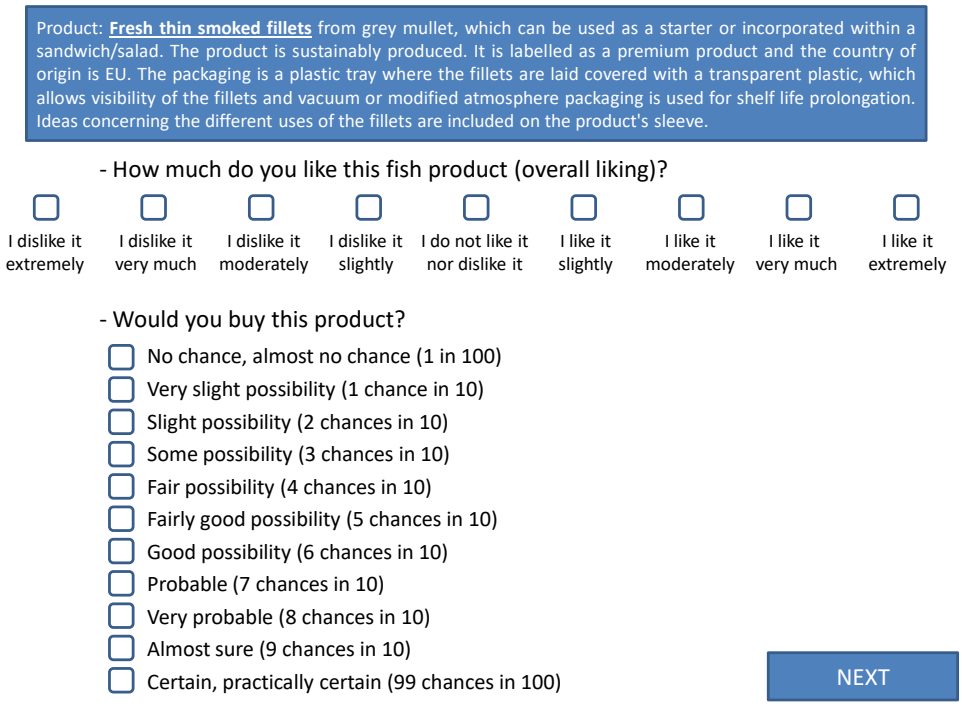

Fig. 10 Nine point probability scale for product acceptability in full informed condition and 11-point scale for purchase probability.

Fig. 11. Eleven attributes used in the semantic differential scale

All the products in these three different stages, were presented in the same order within a tasting session. This presentation order was different for each session, but the same in all the different locations in order to facilitate the comparison between countries (Table 3).

Session	**Order of presentation**					
	1st	2nd	3rd	4th	5th	6th
Session 1	A	F	B	E	C	D
Session 2	B	A	C	F	D	E
Session 3	C	B	D	A	E	F
Session 4	D	C	E	B	F	A
Session 5	E	D	F	C	A	B
Session 6	F	E	A	D	B	C
Session 7	B	A	C	F	D	E
Session 8	A	F	B	E	C	D
Session 9	D	C	E	B	F	A
Session 10	F	E	A	D	B	C

Table 3 Order of presentation in each session in all five countries

Data analysis

CATA data were analyzed by means of Simple Correspondence Analysis. Pairwise comparison of multiple proportions values between products was done with the Cochran's Q test and the Marascuilo test. The mean values of overall acceptability (expectations, blind tasting and informed condition) were obtained. In order to identify those quality aspects with a higher impact in the overall acceptability of the different tested products and on the purchase probability, different multiple regression analyses were performed. All the statistical analyses were performed with the software XLSTAT, version 2017 (Addinsoft, Paris).

4. PUBICATIONS GENERAL RESULTS AND DISCUSSION

4.1 Stage 1: Generation of sensory descriptors with trained panelists. Publication 1

Lazo, O., Claret, A. and Guerrero, L. (2016). A comparison of two methods for generating descriptive attributes with trained assessors: Check-All-That-Apply (CATA) vs. free choice profiling (FCP). *J. Sensory Studies, 31*, (2), 163-176.

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A COMPARISON OF TWO METHODS FOR GENERATING DESCRIPTIVE ATTRIBUTES WITH TRAINED ASSESSORS: CHECK-ALL-THAT-APPLY (CATA) VS. FREE CHOICE PROFILING (FCP)

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ABSTRACT

The quality and reliability of descriptive profiles are closely linked to an accurate selection of the attributes included therein. Descriptive profiles with trained assessors often face challenges stemming from consensual procedures and the risk of forgetting some relevant descriptors. To overcome these problems, the suitability of two nonconsensual methods performed by trained assessors, namely free choice profiling (FCP) and check-all-that-apply (CATA), are examined and compared when building a sensory profile for fish.

Eighteen trained panelists having similar training were randomly split into two groups of nine assessors each. One group evaluated different fish species using CATA and the other using FCP, with both groups adopting the same experimental design.

Although both methodologies generated an important number of sensory descriptors for the tested products, noticeable differences among methods were observed. CATA performed better than FCP in terms of the descriptive ability and slightly better regarding the discriminant capacity. Both methods provided similar product location in the multidimensional space. The RV coefficient was significantly different from zero for all the sensory modalities except for odor and texture. However, noticeable differences were observed in product description. The main limitations of the study were also discussed.

PRACTICAL APPLICATIONS

Sensory descriptive analysis is normally the first step in the characterization of a food product, thus providing valuable information for food companies when designing and/or improving a product. This study shows and compares the usefulness of two methods, namely CATA and FCP, to obtain descriptive profiles, thus avoiding some of the bias linked to consensual procedures. Both methods are suitable for product discrimination, although they provide different sensory characterization for the different samples. The use of trained assessors, both with CATA and FCP, might increase the quality of a descriptive profile by avoiding useless terms and, especially in the case of CATA, ensuring that the most relevant descriptors are included.

INTRODUCTION

Sensory descriptive analysis is normally the first step in the characterization of a food product. It provides valuable information for food companies when designing and/or improving a product throughout the different steps involved, from formulating a product to tracking its shelf life. Sensory descriptive analysis also helps researchers to better understand the sensory response resulting from the consumption or use of a product and the relationship between sensory and other physicochemical characteristics (Varela and Ares 2012).

Descriptive methods consist of different steps depending on the technique chosen; however, all methods include a step involving the selection of the most appropriate sensory descriptors to assess (Murray *et al.* 2001). The quality and reliability of a descriptive profile is closely linked to an accurate selection of the attributes included in it (Montouto *et al.* 2002). As stated by Stampanoni (1994), sensory terminology is a determinant factor in descriptive analysis because perceptions are greatly influenced by language.

Traditionally, the generation and selection of descriptors have been accomplished by means of trained assessors. Methods including flavor profile (Cairncross and Sjöström 1950), texture profile (Brandt *et al.* 1963), quantitative descriptive analysis (Stone *et al.* 1974) and the spectrum method (Meilgaard *et al.* 1991) have been used for this purpose; meanwhile, other techniques such as quantitative flavor profiling delegate this task to a reduced group of experts (Stampanoni *et al.* 1996). Although these techniques have proven to be both powerful and highly effective in sensory profiling (Guerrero 1996; Murray *et al.* 2001, Varela and Ares 2012), sometimes the assessors' lack of product-oriented expertise and training or time constraints constitute a handicap for obtaining a satisfactory list of sensory descriptors. In most traditional descriptive techniques, attribute elicitation can be affected by weaknesses such as time requirement and elevated costs, low product knowledge, and need for consensus.

To elaborate an appropriate descriptive profile, a good knowledge of the product is recommended. Normally, conceptual associations are founded on self-experiences (Stolzenbach *et al.* 2013); thus, familiarity with previous concepts and product definitions makes it easier for assessors to elicit attributes when writing descriptions (Tuorila *et al.* 1998). In addition, the ease with which a person draws an association between a stimulus and its defining concept is highly influenced by prior experience with the same stimulus (Giacalone *et al.* 2015).

Sensory consensual methods may run the risk of producing unreliable results, often in situations involving a panel leader with a dominant personality (Walker 2004; Lawless and Heymann 2010). In addition, assessors could make mistakes such as sensitivity errors, which occur when some panelists are more sensitive than others to a determined attribute, thus, affecting the panel consensus (Meullenet 2008a). The selection of attributes to be included in a final profile by consensus procedure could be prone to different biases originating within the group dynamic itself. Factors such as a lack of agreement on which attributes to select (Murray *et al.* 2001) or the existence of disagreements regarding the individual meaning of some sensory characteristics (Delarue and Sieffermann 2004) might influence the validity of the final consensus. In fact, even after extensive panel training aimed to obtain agreement over attribute meaning, small differences between assessors are unavoidable (Lea *et al.* 2001, Martens and Martens 2001, Granitto *et al.* 2008). On occasion, even trained panelists seem to hold different conceptions of the same stimulus (Moskowitz 2003), thus, implying a certain communication deficiency related to vocabulary (Fichet *et al.* 2011). As stated by Lawless (1999), a stimulus may elicit responses that are quantitatively and qualitatively different from one subject to another, especially when chemical senses are involved. The risk of forgetting one or several important descriptors might also be an additional inconvenience in these consensual methods (Perrin and Pagès 2009).

One possible solution to solve some of these problems is to encourage the personal generation of descriptors, as free as possible, by means of techniques such as free choice profiling (FCP) (Williams and Langron 1984), wherein panelists are not expected to agree on the number, type or interpretation of elicited attributes. This method is even faster and more economical than traditional procedures (Jack and Piggott 1991; Reinbach *et al.* 2014), although, it has some disadvantages when performed with consumers using terms that are too personal or difficult to interpret because of their quantity or diversity (Piggott and Watson 1992). A majority of those terms elicited from consumers are usually not linked with any specific definitions or references, thus, making it difficult to deduce a consensual use of terms (Sieffermann 2000). In addition, some terms could be related to benefits that are consequences of consuming the product (e.g., thirst quenching, filling up) and that seem to be linked to hedonic issues (Veinand *et al.* 2011). Consequently, the use of this technique, usually reserved for naïve individuals, could be enhanced when used with trained panelists (Guerrero *et al.* 2001). The use of FCP among trained panelists offers the advantages of both traditional descriptive techniques and free eliciting techniques, thus eliminating a number of extant inconveniences linked to consensual procedures.

Another method that might be useful in overcoming some of the biases previously mentioned is CATA or the Check-All-That-Apply test (Adams *et al.* 2007; Meullenet *et al.* 2008b, Varela and Ares 2012). The CATA method is a form of multiple choice survey wherein a list of answer alternatives is presented and respondents tick the options that they consider applicable to the product. The CATA method requires minimal instruction, is relatively easy to perform and is completed quickly (Dooley *et al.* 2010). CATA's

TABLE 1. FISH SPECIES USED FOR DIFFERENT DESCRIPTIVE ANALYSES

Scientific Name	Commercial name	Free attribute generation	CATA test	FCP test
Salmo salar	Salmon	X	X	X
Argyosomus regius	Meagre	X	X	X
Perca fluviatilis	Eurasian perch	X	X	
Xiphias gladius	Swordfish	X	X	
Merluccius merluccius	European hake	X	X	
Lophius piscatorius	Anglerfish (monkfish)	X	X	X
Scomber scombrus	Atlantic mackerel	X	X	
Gadus morhua	Atlantic cod	X	X	X
Sparus auratus	Gilthead seabream	X	X	
Pangasius hypophthalmus	Iridescent shark	X	X	
Hippoglossus hippoglossus	Atlantic Halibut	X	X	X
Zeus faber	John Dory or Peters fish	X	X	
Pagrus pagrus	Red porgy	X		
Sanders lucioperca	Pikeperch	X	X	X
Lithognathus Mormyrus	Sand steenbras	X		
Etmopterus pusillus	Smooth lanternshark	X		
Psetta maxima	Turbot	X	X	X
Dicentrarchus labrax	European seabass	X	X	
Diplodus sargus sargus)	White seabream	X		
Conger conger	Conger Eel	X	X	
Solea solea	Sole	X	X	
Lepidorhombus boscii	Four spot megrim	X	X	
Salmo trutta	Brown trout	X	X	X

potential for eliciting reliable product characterizations has come mostly from consumers (Ares *et al.* 2014, Ares *et al.* 2015), with a similar procedure having reportedly been used with trained assessors (Campo *et al.* 2010). To our knowledge, this technique has not been previously used when performing free selection of descriptive terms by trained panelists. Theoretically, the use of CATA should allow tasters to select the most appropriate terms to describe a product without a consensus bias, thus reducing the risk of forgetting relevant attributes if the selected terms included in the test have been chosen based on an extensive bibliographic search when available. When little previous descriptive information exists, the initial list of descriptors can be freely generated by means of trained assessors, similarly to the procedure used in the first stage of a FCP (individual free generation of descriptors).

The aim of this study is to verify and compare the ability of two nonconsensual methods, namely CATA and FCP, to elicit sensory descriptive attributes in terms of the quantity and quality (i.e., assessed by their discriminant power) of descriptors generated by trained assessors.

MATERIALS AND METHODS

Sampling and Cooking Procedure

Twenty-three different fish species were selected at the fish market based on visual differences (size, color, shape), expected mouth characteristics (texture and flavor) and availability throughout the duration of this study (Table 1).

Fresh samples were acquired in fillet presentation (boneless and without the skin). Each fillet was vacuum-packed and stored frozen (−20C) until evaluation for a maximum of 15 days. Twenty-four hours before analysis, samples were thawed at 4C.

In all cases, samples were cooked in a convection oven at 115C for 20 min in individual transparent glass jars designed to make samples easy to visualize. Jar lids were used to keep the samples' odor from disappearing (Model B-250, Juvasa, Spain). Jars were then placed inside electrical heaters at 60C to keep them warm while being tasted.

Elicitation of Descriptive Terms

The descriptive terms to be analyzed and compared were obtained by means of two different methodologies: CATA and FCP.

CATA Test. To select the attributes to be included in the checklist, an extensive bibliographical review was conducted, creating a list of potential fish descriptors (Table 2). Then, panelists assessed the 23 different species (Table 1) in four different sessions (one for odor, one for appearance, one for flavor and one for texture), where they were asked to individually elicit as many sensory attributes as possible to describe those fish samples provided. In each session or for each sensory modality panelists evaluated five sets of four

TABLE 2. SENSORY ATTRIBUTES OBTAINED FROM THE BIBLIOGRAPHY

Attribute	Specie tested	Description	Reference	Country
Odor				
Acetic	Atlantic cod	Acetic acid	Sveinsdottir *et al.* (2009)	Iceland
Ammonia	Cod	TMA concentrated	Cardenas *et al.* (2007)	Iceland
Butter	Atlantic cod	Popcorn	Sveinsdottir *et al.* (2009)	Iceland
Dairy	Sea bream	Boiled milk	Cardinal *et al.* (2011)	France
Earthy	Sea bream	Intense odor	Cardinal *et al.* (2011)	France
Manure	Salmon	Barn cow manure	Farmer *et al.* (2000)	Ireland
Meat	Cod	Boiled meat	Sveinsdottir *et al.* (2009)	Iceland
Metallic	Salmon	Iron, blood sulfate	Rødbotten *et al.* (2009)	Norway
Potato	Cod	Cooked potato	Sveinsdottir *et al.* (2010)	Iceland
Rancid	Meagre	Oxidized fat	Hernández *et al.* (2009)	Spain
Rotten	Cod	Old fish	Cardenas *et al.* (2007)	Iceland
Sea water	Salmon	Fresh salty ocean	Rødbotten *et al.* (2009)	Norway
Sea weed	Cod	Seafood, alga	Sveinsdottir *et al.* (2010)	Iceland
Sour	Salmon	Organic acids	Rødbotten *et al.* (2009)	Norway
Stagnant water	Salmon	Intensity of the attribute	Farmer *et al.* (2000)	Ireland
Sulfur	Cod	Phosphorus Sulfur	Sveinsdottir *et al.* (2009)	Iceland
Vanilla	Cod	Milky vanilla	Sveinsdottir *et al.* (2010)	Iceland
Appearance				
Black veins	Sea bream	Black grooves	Cardinal *et al.* (2011)	France
Coagulated proteins	Sea bream	Brown spots	Cardinal *et al.* (2011)	France
Color ivory	Salmon	Yellow notes	Rødbotten *et al.* (2009)	Norway
Color white	Halibut	Intensity pure color	Olsson *et al.* (2003)	Norway
Color homogeneity	Cod	Color uniformity	Sveinsdottir *et al.* (2009)	Iceland
Exudates presence	Salmon	Released liquid	Farmer *et al.* (2000)	Ireland
Fat droplets in exudates	Salmon	Fat released in fish exudates	Farmer *et al.* (2000)	Ireland
Laminar structure	Salmon	Visual flake openings	Veiseth-Kent *et al.* (2010)	Norway
Shine	Sea bream	Bright surface	Orban *et al.* (1997)	Italy
Suspended particles	Cod	Precipitation of meat	Sveinsdottir *et al.* (2010)	Iceland
Flavor				
Acid	Cod	Flavor intensity	Rødbotten *et al.* (2009)	Norway
Ammonia	Cod	Amine flavor	Sveinsdottir *et al.* (2009)	Iceland
Bitter	Salmon	Intensity quinine	Rødbotten *et al.* (2009)	Norway
Butter	Cod	Popcorn like	Sveinsdottir *et al.* (2009)	Iceland
Earthy	Sea bream	Flavor Intensity	Cardinal *et al.* (2011)	France
Fish oil	Salmon	Oily Intensity	Farmer *et al.* (2000)	Ireland
Meat	Cod	Boiled meat	Sveinsdottir *et al.* (2009)	Iceland
Manure	Salmon	Intensity barn	Farmer *et al.* (2000)	Ireland
Metallic	Sea bream	Flavor Intensity	Cardinal *et al.* (2011)	France
Nutty	Salmon	Almond hazelnut	Veiseth-Kent *et al.* (2010)	Norway
Old	Salmon	Not fresh	Rødbotten *et al.* (2009)	Norway
Potato	Sea bream	Flavor Intensity	Cardinal *et al.* (2011)	France
Pungent	Cod	Intense	Cardenas *et al.* (2007)	Iceland
Rancid	Salmon	Oxidized fat	Bencze *et al.* (1998)	Norway
Rotten	Cod	Putrid	Sveinsdottir *et al.* (2009)	Iceland
Salty	Salmon	Intensity	Farmer *et al.* (2000)	Ireland
Sea water	Salmon	Fresh, ocean	Rødbotten *et al.* (2009)	Norway
Sour	Cod	Deteriorated	Sveinsdottir *et al.* (2009)	Iceland
Smoked	Salmon	Intensity	Bencze *et al.* (1998)	Norway
Sweet	Cod	Intensity	Cardenas *et al.* (2007)	Iceland
Texture				
Chewiness	Meager	Number of chews before swallowing	Hernández *et al.* (2009)	Spain
Cohesiveness	Meager	Fish structure	Giogios *et al.* (2013)	Greece
Elastic	Salmon Perch	Degree of recovery when applying Biting force	Veiseth-Kent *et al.* (2010)	Norway

TABLE 2. CONTINUED

Attribute	Specie tested	Description	Reference	Country
Flakes	Cod	Fish breaks in flakes when pressing	Sveinsdottir *et al.* (2009)	Iceland
Film palate	Salmon	Degree in which fish sticks to mouth	Farmer *et al.* (2000)	Ireland
Firmness	Halibut	Hardness in the first bite	Olsson *et al.* (2003)	Norway
Gummy	Perch	Like chewing gum	Stejskal *et al.* (2011)	Czech Republic
T-Juicy	Salmon Halibut	Water released after chewing	Veiseth-Kent *et al.* (2010)	Norway
Mouth residue	Salmon	Intensity	Farmer *et al.* (2000)	Ireland
Stringiness	Meager Sea bream Cod	Fibred tissue	Giogios *et al.* (2013)	Greece
Teeth adherence	Salmon Cod Sea bream	Degree in which fish sticks to teeth	Farmer *et al.* (2000)	Ireland

samples and one set of three samples. Assessors had a short break of 5 min between each set of samples. Finally, a list of attributes was revealed to the panelists. This list included the attributes from the bibliographical review and some additional attributes that had been obtained from the previous four different sessions after removing those terms considered redundant by means of a triangulation process (Guerrero *et al.* 2010). CATA analysis was carried out over this final checklist, which had a total of 103 descriptors that included odor, appearance, flavor and texture attributes. To reduce the number of samples requiring assessment, and based on the previous descriptive task (the four different sessions mentioned above), 19 fish species (those presenting the highest sensory diversity) were evaluated in one session (in four sets of four samples each and one set of three samples, thus allowing assessors to have a short break of 5 min between each set of samples). Due to the large amount of attributes to evaluate, they were grouped by sensory modality and presented to the assessors in separated paper sheets. To make the task easier, the order of the descriptors was always the same for all the assessors and for the five sets of samples in order to reduce the effort spent on locating and checking the attributes on the ballot. Panelists were asked to smell samples at the beginning of the test so that the odor would not disappear before they completed the task. For every sample, panelists were instructed to mark in the checklist only those attributes that were clearly perceived to more effectively capture the relevant differences among selected fish species. This procedure was performed species by species within each set of sample, so for each assessor each specific attribute could be ticked up to a maximum of 19 times. Panelists also had the opportunity to add new descriptors if they considered it necessary.

FCP. Eight fish species were selected from among the previous 19 species assessed in the CATA sessions. Selection was designed to choose those that were most different from each other from a sensory point of view in the CATA test. Species selected for this technique were salmon, meager, angler fish, Atlantic cod, halibut, turbot, pikeperch and brown trout (sea trout). The FCP technique was performed in three sessions. In the first session, panelists evaluated the eight samples to generate the personal attributes they could perceive as relevant when describing each fish species. In the next two sessions, panelists had to rate the same eight samples in each of them using their own attributes in a lineal scale from 0 to 10, anchored with the words low intensity/absence (0) and high intensity (10).

Panelists and Procedure

Eighteen panelists with more than 4 years of experience in the sensory profiling of food products (previously selected and trained according to ISO regulations) were recruited for this study. Nine panelists were randomly selected to participate in the CATA analysis and the other nine in the FCP method. All of them had similar descriptive and quantitative sensory performance and were between 31–52 years old.

In each session, the order of sample presentation and the first order and carry-over effects (Macfie *et al.* 1989) were blocked. In all cases, the generation of descriptors was performed in isolated sensory testing booths (ISO, 2007). All assessors were provided with mineral water to cleanse their palates between samples.

Data Analysis

To analyze and visualize the CATA data, a Factorial Correspondence analysis was performed over the contingency matrix obtained (frequency of each selected term for each species). Previously, only those descriptors being cited eight or more times (taking into account all assessors and the 19 products) were kept. FCP data were analyzed using the Generalized Procrustes Analysis (GPA) (Gower 1975). In this case, only discriminant descriptors after performing a two-

way ANOVA (fish species and tasting session) for each assessor ($P < 0.25$) were retained. The mean value of the two replicates performed was submitted to the GPA analysis. Using these two selecting criteria (frequency of elicitation equal or higher than 8 for CATA and discriminant ability of $P < 0.25$) a similar reduction of the initial number of descriptors were obtained (70.9% for CATA and 70.0% for FCP), thus, being both methods easier to compare.

A comparison between the CATA and FCP techniques was drawn by calculating the overall number of attributes elicited in each method and sensory modality (appearance, odor, flavor and texture attributes). Differences between the 8 fish samples were examined to check the discriminant ability of each method, thus, involving all the selected descriptors in each of them. In the case of FCP the consensual coordinates for each assessor and for all the samples, after performing the corrections done by the GPA (translation, scaling and rotation), were kept, thus obtaining the consensual results for each individual. For CATA data a Multiple Factorial Analysis was performed and again the consensual coordinates for each assessor and for all the samples were kept. In both cases, all the factors obtained were retained to cover 100% of the variability. Consensual configurations were always compared for the two methods. The consensual coordinates obtained in each method for the 8 fish species were submitted to an Analysis of Variance, a Discriminant analysis and a RV coefficient test for each sensory modality.

All statistical analyses were performed using XLSTAT software (2014).

RESULTS AND DISCUSSION

The results and discussion are presented in two differentiated parts. In the first section, the differences between the CATA and FCP methods are discussed, with a focus on the number of descriptors selected in general and by sensory modality. The second section examines and compares the discriminant ability of these two methods.

Attributes Selected

Both CATA questions and the FCP technique proved to be effective in generating an important number of sensory attributes for the products tested. As shown in Table 3, trained panelists selected, on average, 22 terms to describe the samples provided using the FCP technique, whereas the average number of selected terms was 50 when dealing with the CATA procedure. The differences observed regarding the final number of retained attributes between both methods are probably due to the greater ease and simplicity with which panelists selected relevant terms when using the CATA procedure, compared with the FCP test wherein panelists had to generate their own descriptors. According to Budiu (2014), showing panelists stimuli that they recognize improves their ability to select and use terminology, whereas panelists not prompted by stimuli must recall items from scratch. This phenomenon can be explained by looking at human memory processing. Neural activity can be activated

TABLE 3. FREQUENCY OF DIFFERENT SELECTED ATTRIBUTES IN CHECK-ALL-THAT-APPLY (CATA) AND IN FREE CHOICE PROFILING (FCP) METHODS FOR THE SAME EIGHT SPECIES

Sensory modality	Panelist ID	CATA	FCP
Appearance	P1	18	5
	P2	18	5
	P3	14	6
	P4	17	10
	P5	15	8
	P6	14	3
	P7	17	9
	P8	11	4
	P9	14	10
Average		15 (30%) CV = 15.29%*	7 (32%) CV=39.69%*
Odor	P1	9	5
	P2	11	1
	P3	13	6
	P4	8	5
	P5	9	4
	P6	9	6
	P7	13	5
	P8	13	4
	P9	9	4
Average		10 (20%) CV = 19.80%*	4 (18%) CV = 33.96%*
Flavor	P1	14	1
	P2	14	2
	P3	14	5
	P4	9	5
	P5	10	6
	P6	17	4
	P7	11	9
	P8	11	3
	P9	11	9
Average		12 (24%) CV = 20.67%*	5 (23%) CV = 57.35%*
Texture	P1	11	5
	P2	14	6
	P3	13	9
	P4	14	6
	P5	15	6
	P6	11	5
	P7	15	9
	P8	12	2
	P9	13	6
Average		13 (26%) CV = 11.72%*	6 (27%) CV = 35.36%*
Total Average		50 (100%)	22 (100%)

* CV, coefficient of variation (%) for each sensory modality and method.

in two ways: through recognition and through recall processes (Johnson 2010). In recognition activities, the information to be analyzed is already available along with options to choose from, and individuals select an answer from different alternatives, thus mirroring the CATA method. In recall processes, no answers are available to choose from and respondents must generate terms from the own individual memory (Cabeza *et al.* 1997, Krishnan *et al.* 1999), a process that occurs also in FCP. When the recognition process occurs, long-term memory is accessed and perception is involved; however, when a recall process occurs, neural patterns must be reactivated without any perceptual input. In general, more brain areas are activated during recall than during recognition processes because more activity is needed to generate a response in recall processes. Because fewer brain areas are activated by recognition than by recall, recognition is indeed easier (Cabeza *et al.* 1997), thus, explaining why attribute elicitation seems to be more straightforward in CATA than in FCP (Johnson 2010). As stated by Nevid (2012), an individual is more likely to remember the name of the author of a book when seeing it in a multiple choice list than when the individual has to write it from memory on a blank paper.

The percentages of selected attributes in the four different modalities, both in CATA and in FCP, were very similar (30% and 32% for appearance, 20% and 18% in odor, 24% and 23% in flavor and 26% and 27% in texture, respectively). A balanced distribution of descriptors among sensory modalities is expected when dealing with trained subjects (Losó *et al.* 2012). By contrast, nontrained assessors utilize attributes that tend to favor those modalities that are easier and more familiar for them (Hersleth *et al.* 2013).

Even though these two methods were performed with similarly trained assessors, a noticeable variability among individuals was observed with regard to the number of selected attributes within the same sensory modality. This finding is probably a consequence of personal factors (e.g., minimum and maximum of 1 and 9 attributes selected, respectively, for flavor in the FCP method). As stated by Fichet *et al.* (2011) well-trained assessors are susceptible to variation over time and a lack of agreement among themselves despite their skills and expertise. The results having the highest variability (based on the coefficient of variation) within members of the same panel, both in CATA and FCP, were found in the flavor modality (CV = 20.67% and CV = 57.35%, respectively).

Odor judgments in descriptive analysis tend to be more difficult than visual, textural or taste judgments (Lawless and Heymann 2010). Successful odor identification depends on commonly encountered substances, a connection between the odor and its name, and assistance in odor name recall. The absence of any one of these three components impedes performance drastically (Cain 1979). However, in this study, agreement over the number of elicited odor attributes was higher than in corresponding flavor, and the existence of the recalling process in the CATA method did not seem to increase the relative number of selected descriptors. The existence of clear odor differences between fish samples assessed could possibly have favored the total number of attributes elicited. Varying degrees of personal skills in the recall process might explain the highest discrepancy observed in the number of selected attributes when using FCP compared with CATA (expressed as coefficient of variation).

A total of 94 different sensory descriptors were selected for both methods and the same eight fish species (Table 4), from which 52% were selected simultaneously in both CATA and FCP. These attributes may be more relevant in describing the products assessed, as these attributes are generated through both recognition and recall processes. The observed concordance between both methods can also be explained by the fact that all assessors were trained together and by the same panel leader. Consequently a similar vocabulary and descriptive sensory knowledge should be expected (Stone *et al.* 2012). The remaining 48% of elicited attributes corresponded to those only being selected by the CATA method (25.5%) or by the FCP method (22.3%). The difference between the number of attributes that were selected with both methods (49 out of 94) and the number of descriptors selected only in the CATA method (24 out of 94) or in the FCP method (21 out of 94) was quite different. This difference could be due to the personal variability among individuals or, more likely, to the effect of the methodology applied.

With regard to the four sensory modalities for descriptors shared by both methods, the most noticeable difference was observed in the odor category, which presents less agreement between panels and methods (only eight odor descriptors were selected simultaneously in both methods, compared to the 15 agreed on for appearance). As already mentioned, odor description tends to be more complex than the other sensory modalities. Accordingly, more odor attributes were only selected in the CATA method when compared to those only selected in FCP method (11 vs. 5), probably because in the CATA method, panelists were provided with assistance (i.e., a checklist) when recalling the possible descriptors to choose. Evident differences between the two methods were also observed in the appearance category. However, it is important to remark that the majority of those descriptors only selected in the FCP method (7 out of 9) corresponded to a visual texture (dry, firm, gelatinous, greasy, juicy, rubbery and shrinkage).

The agreement between assessors for the descriptors in common was higher for the CATA method. In all cases – except for the earthy odor – the number of panelists that agreed on the presence of a certain descriptor was lower in the FCP method (see frequency values in brackets in Table 4). Similar values were only observed for sour odor and

TABLE 4. SELECTED ATTRIBUTES IN CHECK-ALL-THAT-APPLY (CATA) AND FREE CHOICE PROFILING (FCP) TECHNIQUES FOR THE SAME EIGHT SPECIES*

Appearance	Odor	Flavor	Texture
CATA and FCP			
Black streaks (9,4)	Ammoniac (8,7)	Bitter (6,1)	Chewiness (8,3)
Coagulated proteins (6,1)	Butter (5,2)	Butter (5,3)	Cohesiveness (7,2)
Color brown (5,1)	Dairy (2,1)	Cooked vegetable (5,2)	Crumbliness (9,6)
Color uniformity (6,1)	Earthy (5,7)	Dairy (5,1)	Elastic (7,3)
Color ivory (8,1)	Sardine (4,3)	Earthy moist (6,2)	Firmness (8,8)
Color salmon (9,4)	Seafood (5,3)	Nutty (4,1)	Flakes (9,2)
Color white (9,3)	Sour (2,2)	Rancid (2,1)	Gelatinous (6,3)
Exudate presence (9,4)	Vanilla (5,1)	Salty (9,5)	Juicy (8,1)
Fat droplets (9,4)		Seafood (7,3)	Mouth residue (8,1)
Laminar structure (8,2)		Sea water (6,2)	Oily (9,2)
Shine (9,1)		Sweet (8,5)	Pasty (5,4)
Suspended particles (8,3)		Wet rag (5,1)	Rubbery (9,3)
Transparent exudate (9,1)			Stringy (8,4)
Turbid exudate (9,3)			Teeth adherence (9,4)
White spots (5,2)			
CATA			
Color grey (5,0)	Acetic (4,0)	Acid (7,0)	Floury (2,0)
White exudate (7,0)	Biscuit (3,0)	Ammonia (7,0)	Roughness (1,0)
Yellow exudate (8,0)	Cardboard (3,0)	Beef (3,0)	Film palate (3,0)
	Fish oil (9,0)	Fish oil (9,0)	
	Mold (6,0)	Mold (6,0)	
	Nutty (2,0)	Old (2,0)	
	Sea water (4,0)	Potato (5,0)	
	Stagnant water (3,0)		
	Thinner (2,0)		
	Toasted cereal (4,0)		
	Wet rag (5,0)		
FCP			
Color intensity (0,4)	Cookie (0,1)	Greasy (0,2)	Dry (0,1)
Dry (0,1)	Greasy (0,2)	Herbal (0,1)	Soft (0,2)
Firm (0,1)	Odor intensity (0,1)	Intensity (0,5)	
Gelatinous (0,4)	Rotten fish (0,1)	Spicy hot (0,1)	
Greasy (0,2)	Sweet (0,2)	Toasted cereal (0,1)	
Juicy (0,2)			
Mucus presence (0,1)			
Rubbery (0,1)			
Shrinkage (0,1)			

* Digits in brackets correspond to the number of panelists that elicited each descriptor in CATA and FCP analyses, respectively.

firmness in texture. In the same vein, it is worth highlighting that 12 out of 21 descriptors only selected in the FCP method were elicited by just one assessor.

Discriminant Ability

Due to the large amount of descriptors selected in both methods, the comparison between them was done separately for each sensory modality. Generally speaking, both the CATA and FCP techniques allow for the observation of differences among fish species.

Figure 1 shows results for the appearance attributes. Salmon and brown trout were located together in both FCP and CATA graphs, clearly differentiated from the remaining fish species, and were described as being pink in color and having fat droplets in their transparent exudates.

For odor attributes (Fig. 2), species location was clearly different for both methods. Salmon and brown trout were placed together in FCP and separately in CATA. These differences might be explained by the statistical technique used in each approach. The correspondence analysis used in the CATA test highlights the main differences between samples (Greenacre and Blasius 1994) and not their similarities, whereas FCP (principal component analysis) takes into consideration all elicited attributes, both similarities and differences, and their intensity. Salmon was mainly described by

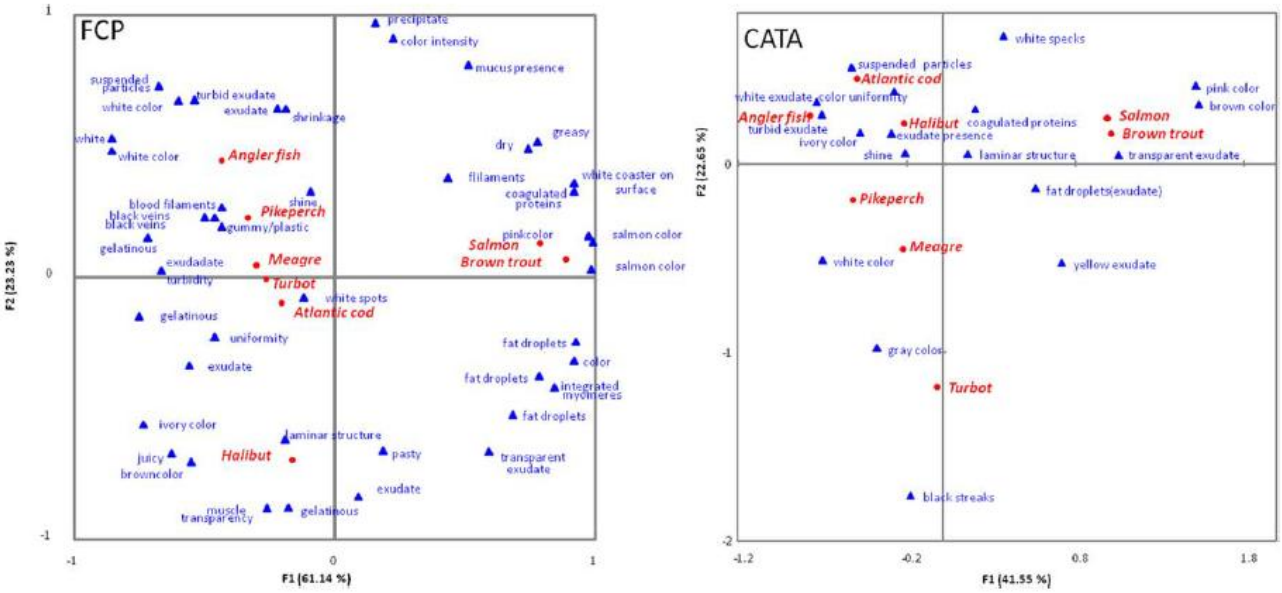

FIG. 1. APPEARANCE SELECTED ATTRIBUTES FOR EIGHT FISH SPECIES FROM GENERALIZED PROCRUSTES ANALYSIS (GPA) PERFORMED ON FREE CHOICE PROFILING (FCP) AND CORRESPONDENCE ANALYSIS PERFORMED ON CHECK-ALL-THAT-APPLY (CATA)

its fatty/oily character, properties shared with the Brown trout as well, which might explain why they were located together in the FCP map (both species had more similarities than differences) and separated in the CATA map (the earthy/mold descriptor was the main distinctive character between both species). Halibut and Atlantic cod present "ammoniac" as a common descriptor in CATA; however, in FCP, Atlantic cod was less influenced by this attribute and was placed consequently apart from halibut. Again, these differences can be explained by methodological issues because fish samples can have similar frequencies of elicitation for some descriptors (i.e., a similar position on the CATA map) and at the same time different intensity (i.e., different positions on the FCP map). Qualitative methods (CATA) seem to provide less information and discriminant abilities than quantitative data (FCP). CATA produces counts (frequencies)

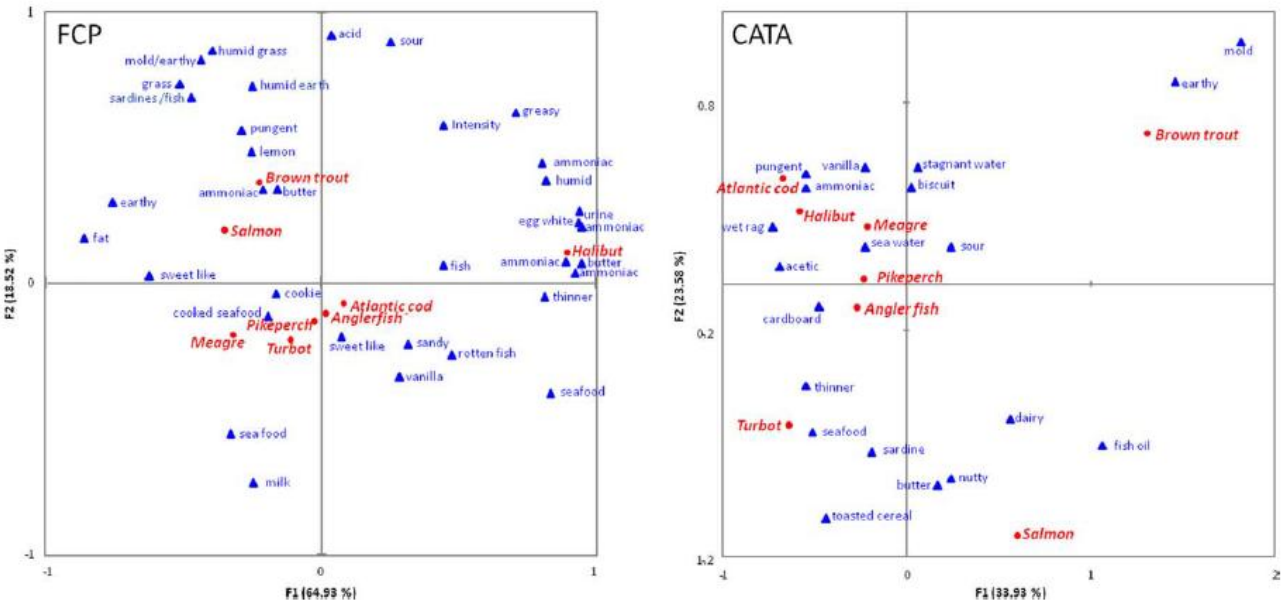

FIG. 2. ODOR SELECTED ATTRIBUTES FOR EIGHT FISH SPECIES FROM GENERALIZED PROCRUSTES ANALYSIS (GPA) PERFORMED ON FREE CHOICE PROFILING (FCP) AND CORRESPONDENCE ANALYSIS PERFORMED ON CHECK-ALL-THAT-APPLY (CATA)

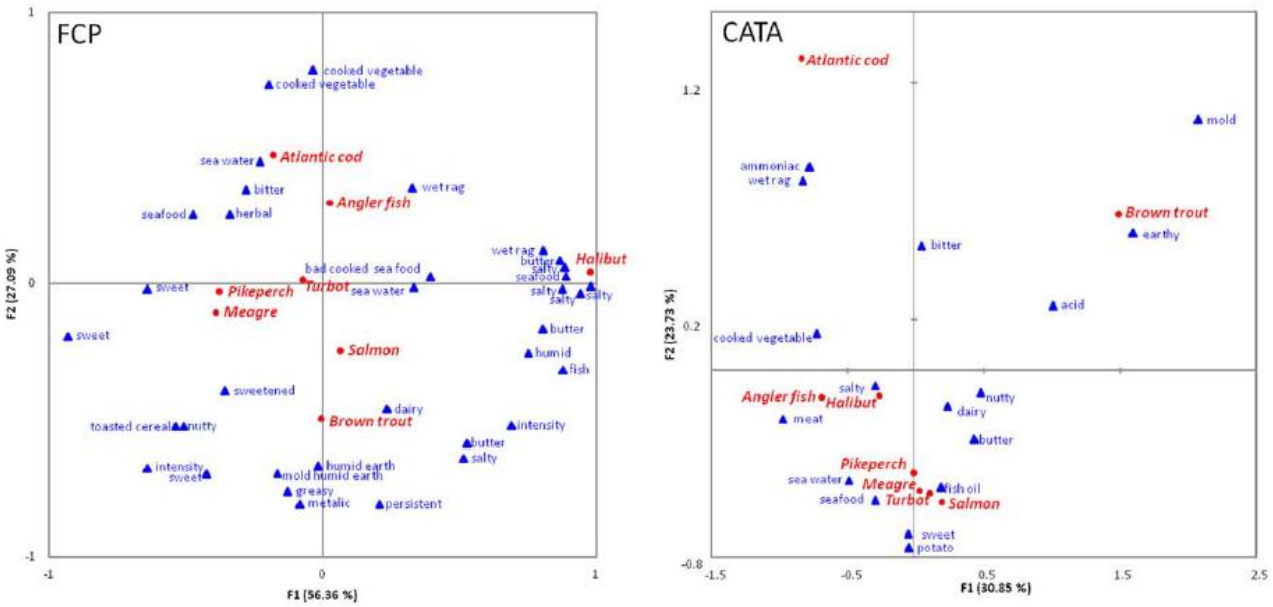

FIG. 3. FLAVOR SELECTED ATTRIBUTES FOR EIGHT FISH SPECIES FROM GENERALIZED PROCRUSTES ANALYSIS (GPA) PERFORMED ON FREE CHOICE PROFILING (FCP) AND CORRESPONDENCE ANALYSIS PERFORMED ON CHECK-ALL-THAT-APPLY (CATA)

instead of scoring or intensities (Dooley *et al.* 2010) and as stated by Valentin *et al.* (2012), nonparametric data has a tendency to have less power than parametric data (FCP). In any case, "ammoniac" was described as the main halibut descriptor for odor in both methods. Finally, turbot was described as having a "seafood odor" in both cases.

Flavor attributes are shown in Fig. 3. Atlantic cod and Brown trout were among the most different species both in CATA and in FCP. Again, halibut was well differentiated with FCP procedures and not with the CATA method in agreement with the statistical peculiarities of each method, as previously mentioned. Brown trout was characterized by "earthy mold" and "humid earth" flavors, as was observed in odor attributes. However, descriptors used for Atlantic cod were different in the two methods ("ammoniac" and "wet rag" odors were reported in the CATA method and

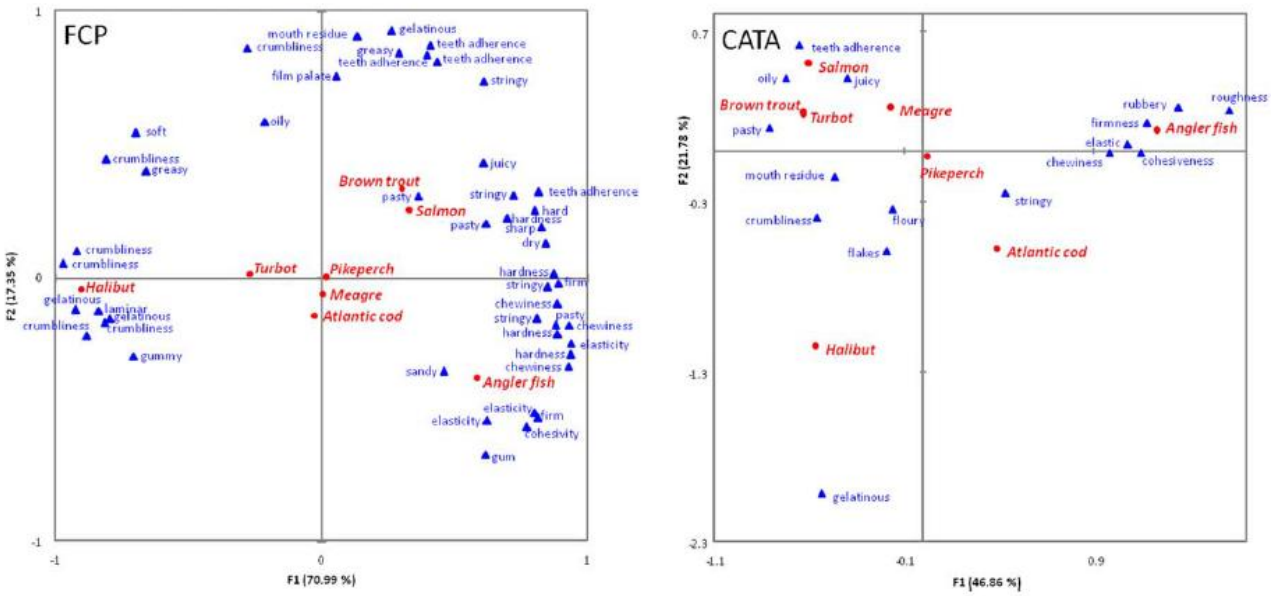

FIG. 4. TEXTURE SELECTED ATTRIBUTES FOR EIGHT FISH SPECIES FROM GENERALIZED PROCRUSTES ANALYSIS (GPA) PERFORMED ON FREE CHOICE PROFILING (FCP) AND CORRESPONDENCE ANALYSIS PERFORMED ON CHECK-ALL-THAT-APPLY (CATA)

TABLE 5. DISCRIMINANT ABILITY OF CHECK-ALL-THAT-APPLY (CATA) AND FREE CHOICE PROFILING (FCP) METHOD

Sensory modality	FCP‡	Discriminant analysis†	CATA‡	Discriminant analysis†	RV coefficient*
Appearance	8.042	100%	6.926	98.61%	0.765**
Odor	6.589	85.94%	6.478	95.83%	0.588 ns
Flavor	5.762	90.63%	7.410	100%	0.707***
Texture	7.790	100%	9.171	100%	0.602 ns
Average	7.046	94.14%	7.496	98.61%	

* Ns, no significant ($P > 0.05$); ** $P \leq 0.01$; *** $P \leq 0.001$.
† Percentage of correctly classified fish samples in their corresponding species (confusion matrix).
‡ F values of ANOVA.

"seafood" and "cooked vegetable" odors were reported in the FCP method). Lastly, halibut was mainly described as "salty."

Figure 4 shows the sensory profile for textural attributes. Halibut, brown trout, salmon and angler fish were all well differentiated in both methods. Halibut was described as "gelatinous" and "crumbly."

Even though these figures (Figs. 1–4) provide a good descriptive overview of the main attributes associated to each sample and allow speculating about the respective discriminant ability of each method, they do not provide strong enough arguments to draw conclusions. Table 5 shows the discriminant power of the two methods for each sensory modality based on two different statistical approaches (ANOVA and Discriminant analysis) as well as the closeness between CATA and FCP data calculated by means of the RV coefficient. According to the F value, FCP had higher discriminant ability for appearance and odor, while CATA had higher values for flavor and texture. However, the F value does not allow knowing whether all the species were clearly differentiated among each other or simply one of them differed to a great extent from the rest. This information can be obtained from the discriminant analysis. The percentage of samples correctly classified in their respective species (confusion matrix) by means of the discriminant function was similar for Texture descriptors (100%). However, CATA showed higher discriminant ability than FCP for Odor and Flavor modalities. In average, CATA had higher discriminant scores than FCP for both the F value and the percentage of fish samples correctly classified. These conclusions can also be inferred from Fig. 5, where at first impression CATA seems to discriminate better between fish species than FCP. However, some species such as meagre, pikeperch or turbot were poorly differentiated by CATA compared to FCP data. Based on all these results it seems difficult to conclude which method performs better regarding the discriminant power.

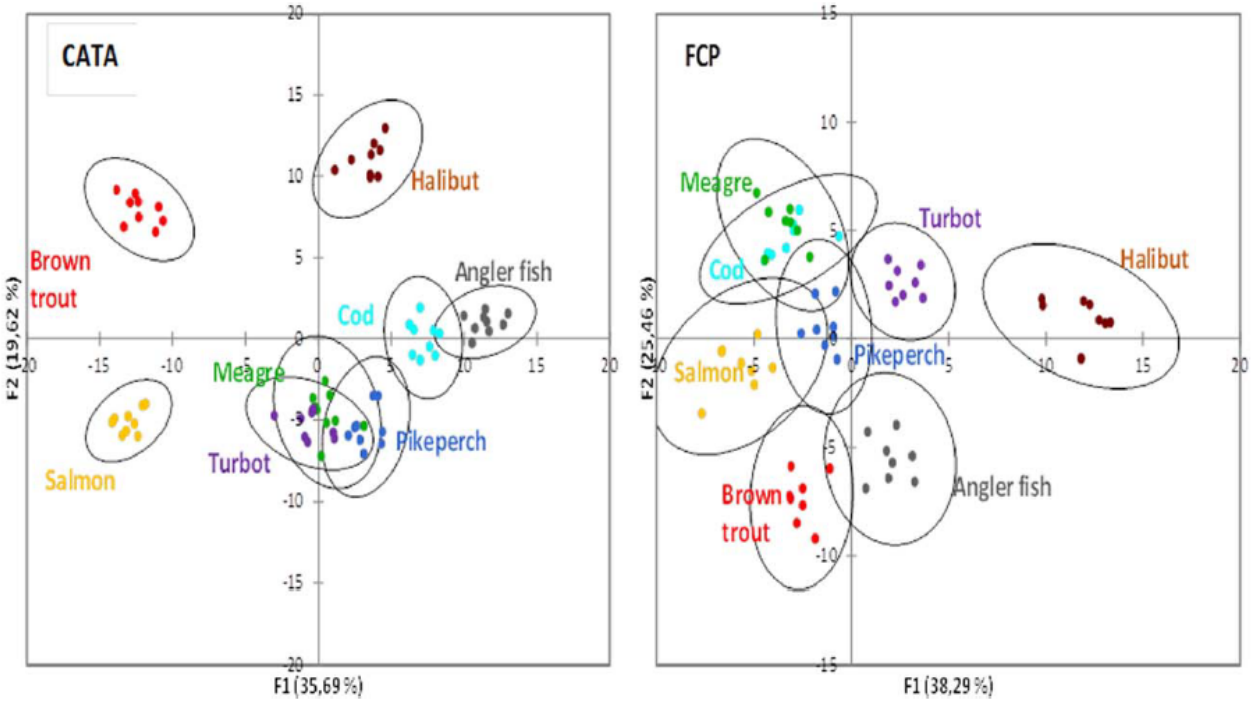

FIG. 5. LOCATION OF THE SAMPLES IN THE FIRST TWO DIMENSIONS OF THE DISCRIMINANT ANALYSIS PERFORMED FOR THE FREE CHOICE PROFILING AND CHECK-ALL-THAT-APPLY DATA. CONFIDENCE ELLIPSES WERE COMPUTED AT 5% OF ERROR

In any case, it is worth to mention that although CATA simply measures the frequencies of elicited attributes and FCP measures not only their presence or absence but also the magnitude of the differences in their intensity, both techniques exhibited, at least, similar discriminant ability. Statistical test based on quantitative data (GPA) make use of more information than those focusing on frequencies or binary data (correspondence analysis) because real numbers provide more precise information than categories alone. Consequently, parametric data tend to be more discriminating or powerful than nonparametric data (O'Mahony 1986) contrary to what was observed in this study. In the same vein, Kim *et al.* (2013) did not find higher discrimination between products when comparing GPA (parametric data) vs. Correspondence analysis (frequencies profile) with consumers.

The use of trained assessors for descriptive attribute elicitation, as described in this article, might increase the quality of a descriptive profile by avoiding useless terms and, especially in the case of CATA, ensuring that the most relevant descriptors are included. This fact is especially important when explaining consumers' preferences by means of sensory data because small changes in the descriptive profile could lead to important changes when drawing conclusions about preference patterns (Gou *et al.* 1998). In addition, both techniques can provide valuable information when selecting the most appropriate descriptors to retain for a final descriptive profile. Descriptors can be checked for their discriminant ability without having to train the assessors specifically for them and without having to develop standards (references) before knowing whether they would be discriminant or not.

Generally speaking and based on the results obtained in the present paper, CATA performed better than FCP in terms of the descriptive ability and slightly better regarding the discriminant capacity. According to the RV coefficients, both methods provided similar product location in the multidimensional space. This coefficient was significantly different from zero for all the sensory modalities except for odor and texture (Table 5). However, noticeable differences were observed in product description (Figs. 1–4). These differences could be explained by the type of data obtained in the different methods previously discussed in this article (absence/presence in CATA vs. scoring in FCP) or by the nature of the mental process involved in both methods.

One the main limitation of the present study is the lack of a descriptive profile performed with a consensual method to compare with both CATA and FCP. This consensual profile would allow the assessment of the real improvement derived from these two techniques. In addition, the use of different number of fish species in both methods might have had a contextual influence on the results shown. In any case, this contextual effect cannot be estimated in this study and could have been partially blocked by the high training and descriptive experience of the assessors involved.

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Sensory characterization, physico-chemical properties and somatic yields of five emerging fish species

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Sensory references

ABSTRACT

Aquaculture plays an important role in supplying the fresh fish. However its production is dominated by only few long-established species that in turn limit the variety of available products in the market. Therefore, new fish species need to be properly introduced to create a diversification in the current market. In order to achieve this goal, it is important to know, understand and characterize their quality features so they can be addressed to local and global markets. Sensory, compositional, instrumental texture parameters and somatic properties of five emerging fish species, namely wreckfish, greater amberjack, grey mullet, meagre, and pikeperch, were examined for characterization purposes. Sensory references were specifically developed for the training of the assessors, both from a qualitative and quantitative perspective. Twenty two sensory descriptors were used for describing the samples. Several differences were observed among the measured parameters. Somatic measures revealed the filleting yield to be the most important of them. Regarding the compositional parameters, fat content was among the most relevant discriminating aspect between species, while hardness was among the most differentiating ones when dealing with texture. Greater amberjack was described with sour flavor, pikeperch was associated to an earthy flavor and grey mullet was characterized by bitter flavor. Sensory firmness was clearly distinctive for wreckfish, while meagre related to juicy texture. The analysis of the relationship between all parameters provided important correlations, especially those related to texture parameters, fat content, laminar structure and teeth adherence. The species in this study exhibited a wide range of physicochemical and sensory characteristics that show their potential for being further exploited when designing new products.

1. Introduction

Aquaculture plays an important role in the fish supply of the European market. Europe is the fifth largest producer worldwide, providing about 3.2% of global fish production. However, aquaculture is still far from reaching its full potential development, since only 20% of the total fish production is of aquaculture origin (Europa, 2013). This fact can be attributed to the production costs, the competition for space (inland and coastal) with other activities, as well as to the less positive image of farmed fish when compared with wild-caught counterparts among consumers (Claret, Guerrero, Gartzia, Garcia-Quiroga, & Ginés, 2016; Claret et al., 2014). The relative low market share of aquaculture can also be a direct consequence of the poor variety of aquaculture products in the market, and in particular because of the lack of processed aquaculture foodstuffs (Failler, 2007; FAO, 2012). It is important to remark that product variety has been identified as a relevant factor in order to stimulate consumers' purchase (Lähteenmäki & Arvola, 2001), thus avoiding boredom and satisfying individual curiosity. European aquaculture production is dominated by only few long-established species such as Atlantic salmon (*Salmo salar*), rainbow trout (*Oncorhynchus mykiss*) common carp (*Cyprinus carpio*), European sea bass (*Dicentrarchus labrax*) and gilthead sea bream (*Sparus aurata*) (EATIP, 2012), that in turn limits the number of aquaculture products available in the market. Increasing global consumption of aquaculture fish constitutes a great challenge and opportunity for the EU aquaculture industry. Therefore, the demand for European aquaculture products

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Table 1
Origin, season, sample (N), feed and size information of the selected fish species.

Species	Season	N	Origin – farming conditions	Feed	Fish size
Greater amberjack (*Seriola dumerili*)	Winter	8	Farm (Argosaronikos S.A.) – Attiki, C. Greece - floating sea cages	Frozen fish	15–20 kg
Pikeperch (*Sander lucioperca*)	Summer	10	Farm France –sweet water intensive farming	Commercial extruded feed	1–2 kg
Grey mullet (*Mugil cephalus*)	Winter	10	Wild fish. Bay of Cadiz – earthen ponds with sea water	Natural feeding	500 g–1 kg
Meagre (*Argyrosomus regius*)	Winter	10	Farm (Andromeda Group), Burriana, Spain – floating sea cages	Commercial extruded feed	1.5–2 kg
Wreckfish (*Polyprion americanus*)	Winter	5	Wild specimens: 2 caught in FAO 34.1.2 ATLANTIC N by the Canary Islands fishermen and 3 caught in Azores by Galicia's fisheries	Natural feeding	Two specimens of 25–30 kg* Three specimens of 2–3 kg

* These high weight value specimens were kept to include the range of commercial sizes available in the market.

needs to be further developed. A possible way to satisfy this request could be rearing new emerging species that would provide a higher variety within the EU market.

In order to successfully introduce new species, it is important to characterize their quality features so they can be properly addressed to local and global markets. This characterization often includes somatometric and edible parts' compositional parameters, which could be advantageous tools for product design. Sensory characteristics are also important determinants of food quality and drivers for consumer acceptance and food choice (Siret & Issanchou, 2000); they can also provide valuable information in order to select the most appropriate market for each species and their respective products. Defining and measuring the sensory attributes that characterize fish, seems to be necessary for product development in order to satisfy consumer expectations. The better the knowledge about accurate descriptors that best define fish, the less time needed for its product development (Carpenter, Lyon, & Hasdell, 2000). Moreover, in the case of fish, taste has proven to be the strongest motive of consumption intention (Verbeke & Vackier, 2005).

In order to cover the entire European fish culture domain and to stimulate different aquaculture categories, five species were selected in the present study based on both their biological and economical potential: meagre (*Argyrosomus regius*) and greater amberjack (*Seriola dumerili*) for marine warm-water cage culture, wreckfish (*Polyprion americanus*) for warm- and cool-water marine cage culture, grey mullet (*Mugil cephalus*) for warm-water pond, extensive and integrated culture, and pikeperch (*Sanders lucioperca*) for freshwater intensive culture using Recirculation Aquaculture Systems (RAS). These species, when farmed with sustainable methods, could help the development of high added-value products and represent an important driver for the growth of the of EU aquaculture market.

Several preliminary studies have been already performed over these selected species. Regarding greater amberjack, proximate and fatty acid composition of wild and reared fish (O'Neill, Le Roux, & Hoffman, 2015; Rodríguez-Barreto et al., 2012; Shioya, Takemura, Ishizuka, & Yamaguchi, 2012; Zupa et al., 2017) and some somatometric evaluations and lipid analysis (Rodríguez-Barreto et al., 2012) have been carried out. Respective data on pikeperch are scarce. Pikeperch quality has been assessed focusing on the freshness of wild fish (Özyurt et al., 2007). Some information is also available regarding the quality of farmed fish (Zakęś, Szczepkowski, Jankowska, Kowalska, & Demska-Zakęś, 2012), while Jankowska, Zakes, Zmijewski, and Szczepkowski (2003) compared wild and cultivated pikeperch by analyzing, color, compositional parameters and fatty acid profiles. Meagre has received much more attention in aspects of composition and sensory quality and relevant studies have been recently published (Grigorakis, Alexi, Vasilaki, Giogios, & Fountoulaki, 2016). Giogios, Grigorakis, and Kalogeropoulos (2013) measured somatometric parameters, volatile compounds and fatty acids between two groups of meagre of different size. Overall acceptability was also assessed in order to validate the existence of organoleptic differences as well. In addition, Hernández et al. (2009), estimated the shelf-life of commercial-sized meagre fillets held in ice storage. Sporadic data exist on fat composition (reviewed by Grigorakis et al., 2016) and post-mortem quality changes (Bahmani et al., 2011; Cayhan & Selli, 2011; El-Sabaiy, Metwalli, & Khalil, 1987) of grey mullet. Very few studies have been published regarding wreckfish characteristics. Roncarati, Cappuccinelli, Stocchi, and Melotti (2014) analyzed the proximate composition and fatty acid profile of meat in a wreckfish population from the Mediterranean Sea.

In any case, it is important to highlight that none of the studies found in the scientific literature about these five species focused in their complete sensory quality description, nor the relationship between their different characteristics. Therefore, the aim of this study is to characterize these five fish species based on their somatometric features, compositional, instrumental texture and sensory properties as well as to outline the existing relationship between these quality parameters.

2. Materials and methods

2.1. Experimental fish

Specimens of meagre, greater amberjack, and pikeperch used in the present study were of aquaculture origin whereas wreckfish and grey mullet were caught from the wild (unavailability of reared specimens because of the existence of important bottlenecks for its incorporation into the aquaculture industry) by commercial fishing vessels using long line or fishing nets, respectively (Table 1).

The greater amberjack was slaughtered by bleeding after cutting gill arches, while the meagre and pikeperch were ice-slaughtered according to custom commercial EFSA-approved method (European Food Safety Authority, 2009). Fish were subsequently packed with flaked ice into polystyrene boxes until the somatometric analysis was performed within the first 24 h.

2.2. Somatometric measurements

After reception, total weight and body length were measured in all sampled individuals. Fish from each species were gutted and body weight, visceral, gonad and liver weights were measured as well. Samples were subsequently filleted and fillets were also weighed. The following somatometric indexes were calculated individually:

Condition index (CI) = [100 × (body weight/body length)]

Dressing yield (DY) = [100 × (gutted body weight/body weight)]

Filleting yield (FY) = [100 × (fillet weight/body weight)],

Hepatosomatic index (HSI) = [100 × (liver weight/body weight)],

Gonadosomatic index (GSI) = [100 × (gonad weight/body weight)]

Viscerosomatic index (VSI) = [100 × (total viscera weight/body weight)].

2.3. Proximate composition

Protein, moisture and ash contents were determined according to standard AOAC (2005) methods. Moisture was calculated gravimetrically after complete drying of fish tissue in an oven at 110 °C overnight, and total inorganic content (ash %) through combustion of organic matter in a muffle furnace for 24 h at 450 °C. Total protein content was determined by the Kjeldahl method and calculated as % Nitrogen × 6.25. Total lipid (TL) was extracted by sample homogenization in chloroform/methanol (2:1, v/v) according to the method of Folch, Lees, and Stanley (1957). The organic solvent was evaporated under a stream of nitrogen and the lipid content was determined gravimetrically (Christie, 1982). All these analyses were performed on three animals from each species.

2.4. Instrumental texture analysis

The right fillets from five animals from each species (pikeperch, meagre, greater amberjack, grey mullet and wreckfish) were used for the instrumental texture analysis. Two different tests were carried out: a non-destructive compression test (compression rate 30%) with a spherical probe (18.4 mm diameter) and a Texture Profile Analysis (TPA, compression rate 75%) (Bourne, 1978) with a cylindrical probe (25 mm diameter). All the tests were performed with a TA-HD plus Texture Analyzer (Stable Micro System, Surrey, England) at a constant speed of 1 mm/s. The non-destructive test (spherical probe) was performed both in the same raw and cooked samples (20 min at 115 °C) in three different parts along the fillet, whereas the TPA was only carried out in cooked samples (because its destructive nature) in two different fillet locations along the whole fillet. Mean values of measurements of each test per animal were retained for statistical analysis. Left fillets from the same animals were vacuum packed and frozen at − 20 °C for sensory analysis.

2.5. Sensory analysis

2.5.1. Panelists and procedure

A panel of eight assessors (with previous experience in sensory analysis of different foods) was chosen in order to select the attributes that best described the fish species and characterize their sensory properties. A total of 21 descriptors (4 for odor modality, 6 for appearance, 5 for flavor and 6 for texture) were selected for the final descriptive profile of these five fish species (Table 2). Descriptors were chosen by means of Check-All-That-Apply (CATA) on a 49 list of attributes from a previous work (Lazo, Claret, & Guerrero, 2016) in one tasting session. In addition to these 21 attributes, sour was also included as a relevant descriptor associated with greater amberjack, since it was clearly identified by all the panelists, so a final list of 22 descriptors was used. To validate the discriminant ability of the selected descriptors between the fish species, assessors also quantified the selected attributes in two sessions. All the descriptors were discriminant among species and were consequently retained for sensory training.

2.5.2. Sensory training

Once the final list of descriptors was settled, reference scales were developed for each of the selected sensory descriptors in order to facilitate the training of the panelist. This procedure was used to help assessors to identify what constitutes high and low amounts of each attribute (Lawless & Heymann, 2010). Appearance, flavor, odor and texture scales were developed using specific references. Fig. 1 (appearance descriptors) and Table 3 show the characteristics of the different reference scales developed for all attributes and their corresponding score obtained as a result of the consensus between all panelists during the training sessions. Sensory references are set by presenting an array of chemicals, ingredients, spices or products that cover the entire sensory spectrum to be described (Rainey, 1986). Along this process, panelists became familiarized with the different descriptors and their intensity scales in order to assess the samples in a more accurate form (Braghieri et al., 2012).

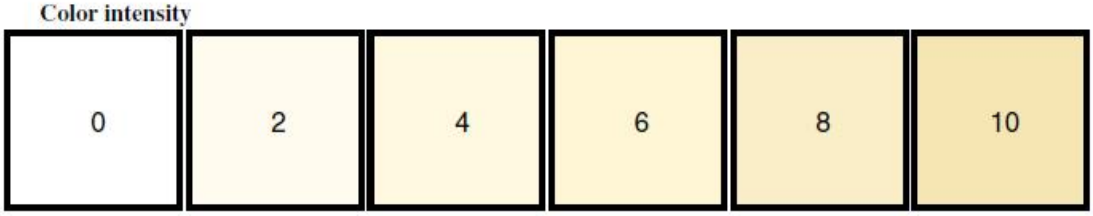
Table 2
Selected descriptors used for the final descriptive profile along with their description.

Attributes	Description
Appearance	
Color intensity	Color intensity from white to light brown inside the flesh of the fish
Color uniformity	Color homogeneity inside the flesh of the fish without black veins or spots
Exudate quantity	Quantity of liquid released after cooking the sample
Fat droplets	Fat released in fish exudate in the form of oil droplets
Laminar structure	Visual distinction of muscular structures when removing the skin of the fish
Turbidity of exudate	Suspended particles in exudate that block transparency
Odor	
Butter	Intensity of odor like butanedione
Earthy	Intensity of odor like humid earth
Sardine	Intensity of odor like fish oil
Sea food	Intensity of characteristic odor
Flavor	
Sour	Flavor like citric acid
Boiled vegetable	Flavor like cooked vegetable
Butter	Flavor intensity like butanedione
Bitter	Flavor like quinine
Earthy	Flavor like humid earth
Sea food	Flavor like seafood
Texture	
Chewiness	Number of chews before swallowing
Crumbliness	Degree of fish disintegration in the first bite
Firmness	Force required to deform the fillet between the tongue and palate
Juiciness	Liquid released when chewing the fish sample
Pastiness	Degree in which fish turns in to a paste after chewing
Teeth adherence	Degree in which fish sticks between molars

2.5.3. Assessment of fish samples

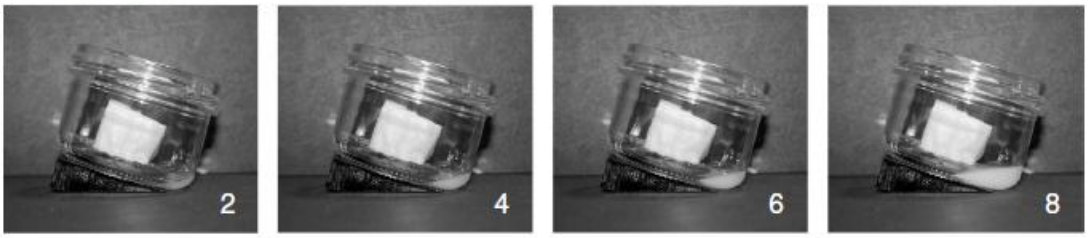
Once panelists were familiarized and trained with the sensory descriptors, quantitative analysis of the fish samples was carried out. Fish fillets had been previously stored, vacuum packed in double aluminum foil bags and frozen at − 20 °C for a maximum of one month period except pikeperch that was stored for 5 months (being acquired during summer season due to its limited availability). Samples were thawed the night before analysis by placing them in the refrigerator (4 °C). Left fillets from the same five animals selected for the instrumental texture analysis were used and cut in pieces of 2 × 2 cm. In all cases, samples were cooked in a convection oven at 115 °C for 20 min (HR 100%) in individual transparent glass jars (Model B-250, Juvasa, Spain) in order to make samples easy to visualize. Jar lids were used throughout preparation and until final assessment to preserve the samples' odor. Immediately after cooking, jars were placed inside a portable electrical heating chamber (Solac, Model 212, 220–240 V) set at 60 °C to keep them warm until being tasted. All five species were evaluated five times in five different sessions (five animals per species). In each session, the order of sample presentation and the first order and carry-over effects were blocked (Macfie, Bratchell, Greenhoff, & Vallis, 1989). Sensory evaluation was performed in a test room designed according to ISO guidelines (ISO 8589:2007). Each panelist assessed the samples placed inside the portable electrical heating chamber so temperature would be maintained. Samples were assessed by means of a semi-structured 10 cm-lineal scale anchored in the two extremes (0 = no presence of

Color intensity

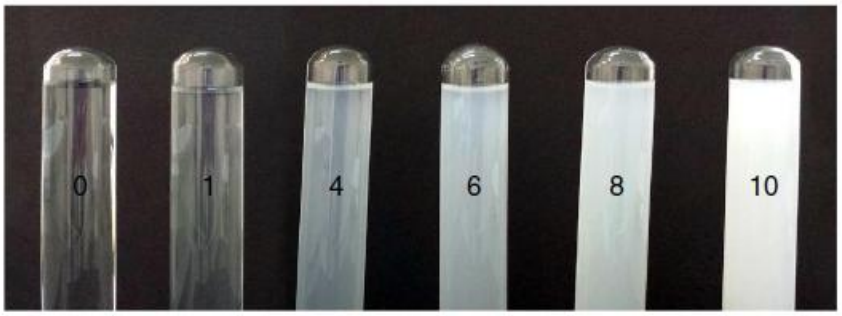


Color uniformity

Exudate quantity



Exudate`s turbidity



Fat droplets

Laminar structure

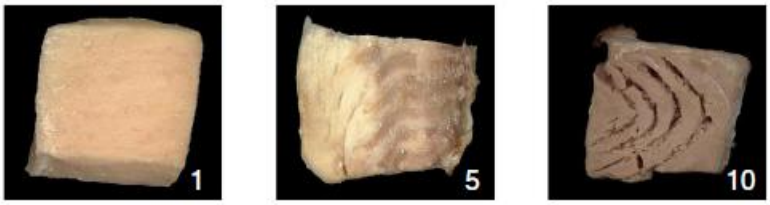


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Fig. 1. Appearance reference scales developed for sensory training.

Table 3
Odor, flavor and texture reference scales used for training in the sensory panel.

Sensory modality	Descriptor	Product used	% of product used	Part of the scale	Score
Odor	Butter	Melted butter (CADI Cat, Spain)	0%	Low	0–1
			4%	Medium	5
			6%	High	10
	Earthy	Geosmine solution 280 ng in 50 ml (AROXA Let. United Kingdom)	28%	Low	2
			33%	Medium	5
			41%	High	8
	Sardine	Omega cod capsules (nuaDHA1000) Vizcaya Spain)	5%	Low	2
			10%	Medium	5
			20%	High	10
	Sea food	Velvet crab (*Necora puber*)	25%	Low	2
			40%	Medium	5
			75%	High	10
Flavor	Sour	Citric acid solution 1 g:70 ml (ACS Panreac Cat Spain)	0%	Low	0–1
			10%	Medium	5
			20%	High	10
	Boiled vegetable	50% potato (*Solanum tuberosum*) 50% green beans (*Phaseolus vulgaris*)	60%	Low	2
			65%	Medium	5
			75%	High	9
	Butter	Melted butter (CADI Cat. Spain)	0%	Low	0–1
			4%	Medium	5
			10%	High	10
	Bitter	Proteolytic enzyme solution 1:1 (Delvolase DSM Delft, The Netherlands)	0%	Low	0
			5%	Medium	5
			10%	High	10
	Earthy	Geosmine solution 280 ng in 50 ml (AROXA United Kingdom)	23%	Low	2
			28%	Medium	5
			33%	High	9
	Seafood	Velvet crab (*Necora puber*)	15%	Low	2
			40%	Medium	5
			50%	High	10

Sensory modality	Descriptor	Reference used	Cooking time	Part of the scale	Score
Texture	Chewiness	Halibut	20 min	Low	1
		Seabream	20 min	Medium	5
		Tuna	60 min	High	10
	Crumbliness	Tuna	65 min	Low	0
		Seabream	20 min	Medium	5
		Halibut	20 min	High	10
	Firmness	Halibut	20 min	Low	1
		Seabream	20 min	Medium	6
		Tuna	65 min	High	10
	Juiciness	Tuna	75 min[a]	Low	0
		Salmon	15 min	Medium	6
		Halibut	20 min	High	10
	Pastiness	Halibut	20 min	Low	0
		Seabream	20 min	Medium	5
		Fish paste with proteolytic enzyme	20 min[b]	High	10
	Teeth adherence	Halibut	20 min	Low	1
		Seabream	20 min	Medium	5
		Salmon	20 min	High	8

[a] Cooked without lid to increase dryness.
[b] 10 g of fish paste with proteolytic enzyme (Delvolase DSM) solution during 20 min with additional 10 g of fish paste.

the descriptor, 10 = high intensity), to score all the selected descriptors. The scoring scale was based on the intensities defined during the training process. All panelists had water to drink as palate cleanser to drink between samples.

2.6. Statistical analysis

To analyze and visualize the CATA data, frequencies of each term were considered for each species. Only those descriptors being cited eight or more times (taking into account all assessors and the five fish species), 21 in total, were retained. The validity of these 21 descriptors together with sour attribute (added because of its presence in greater amberjack) was checked by means of a two way ANOVA (fish species and tasting session as fixed factors) for each assessor (made over the data set obtained from the two replicates performed before specifically training the panelist). All the descriptors were discriminant among species for each assessor and consequently all of them were retained for the final descriptive profile.

Descriptive data of the different animals were submitted to a one- (somatometric and compositional data), two- (instrumental texture) or three- (sensory profile) way ANOVA, including as fixed factors the fish species in all cases, the anatomic zone used of each fillet for the instrumental texture analysis, and the assessor and the tasting session for sensory data. A post-hoc Tukey HSD was computed for comparing the mean values of the different species.

A discriminant analysis was carried out in order to assess the ability of the non-destructive instrumental texture test to differentiate between species both in raw and cooked fish samples.

An additional Principal Component Analysis (PCA) was performed over the mean values of somatometric, compositional, instrumental texture and sensory data in order to examine the main relationship between all the information available. The Pearson moment correlation matrix was also retained from this analysis.

All statistical analyses were performed using XLSTAT 2017 software (Addinsoft, Paris, France).

3. Results and discussion

3.1. Somatometric analysis of the five fish species

Somatometric results of all five fish species are shown in Table 4. Wreckfish was the species with the highest CI, probably due to its generally plumper shape. In particular, wreckfish is a big species, individuals may reach a body length of 2 m, and weigh up to 100 kg, although on average individuals reach 45–55 cm body length (Roncarati et al., 2014). The CI is related to the body geometry of each species and can be indicative of the feeding condition of the fish when individuals of the same species are compared (Grigorakis, 2017). CI has been shown to increase in well-fed fish, e.g. in the intensive farming-originated fish in comparison with extensively farmed and wild fish (Flos, Reig, Oca, & Ginovart, 2002; Grigorakis, 2007; Martelli et al., 2013; Piccolo et al., 2008). Fish shape could act as an additional intrinsic cue affecting consumers' choices. In general, consumers have substantial difficulties in forming quality expectations, especially for fresh products for which little information about the product is normally provided. The formation of quality expectations in these cases is based on a few key cues, principally labeling (including price) and appearance (Font-i-Furnols & Guerrero, 2014).

Dressing yields for all species were quite similar, slightly exceeding 90% except for grey mullet who showed the lowest value. Dressing yield is relevant because it determines the yield when fish is sold as gutted, without further processing, which is a common way of commercialization in the EU for fresh and frozen fish (European Commission Fisheries, 2013).

The highest filleting yields were observed for greater amberjack and for wreckfish, in both cases exceeding 49%. For pikeperch, grey mullet and meagre the filleting yield was found to be similar and slightly lower than 40%. Filleting yield in pikeperch was slightly lower than the

Table 4
Mean values and standard deviation (SD) of somatometric analysis of wreckfish (N = 5) greater amberjack (N = 8), grey mullet (N = 10), meagre (N = 10) and pikeperch (N = 10).

Somatometric parameter	Wreckfish		Greater amberjack		Grey mullet		Meagre		Pikeperch	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Total weight (g)	13,028.2^{a}	13,716.7	13,000.0^{a}	1629.2	748.9^{b}	154.29	1834.58^{b}	140.40	1096.64^{b}	217.25
Condition I (%)	2.48^{a}	0.26	1.50^{b}	0.07	1.09^{c}	0.06	0.86^{d}	0.05	0.71^{e}	0.13
Dressing yield (%)	91.06^{b}	1.64	94.71^{a}	1.39	87.77^{c}	2.12	91.12^{b}	0.62	93.45^{a}	1.26
Filleting yield (%)	50.62^{a}	6.87	49.64^{a}	2.58	36.19^{b}	3.00	38.40^{b}	2.36	36.19^{b}	4.42
Hepatosomatic I (%)	1.66^{a}	0.85	1.14^{ab}	0.26	1.45^{a}	0.22	1.16^{ab}	0.19	0.80^{b}	0.18
Gonadosomatic I (%)	0.29^{b}	0.39	0.77^{a}	0.28	0.45^{ab}	0.09	0.20^{b}	0.14	0.22^{b}	0.26
Viscerosomatic I (%)	8.47^{a}	1.70	2.84^{c}	0.33	10.31^{a}	2.08	5.74^{b}	0.44	5.72^{b}	1.30

Different letters in the same row indicate statistically significant differences ($p \leq 0.05$) between the mean values of each species.
I: Index.

values reported by Zakęś et al. (2012) (40% for females, 42% for males). This could be attributed to a lower fillet mass in the fish of the present study, as was also indicated by the lower observed condition index, since fish in both studies had similar weights. Grey mullet and greater amberjack's filleting yields were also lower than those reported in the literature (Ali, Shams, Imran, Khanom, & Sarower, 2013; Öksüz, 2012), although in this case, differences in fish weight existed. Meagre, on the other hand, showed similar yields to those provided by Grigorakis, Fountoulaki, Vasilaki, Mittakos, & Nathanailides, 2011. Regarding wreckfish not published data were found about filleting yields. Filleting yield is an important parameter, especially for species where filleting is among their usual processing, because it describes their actual edible part. In fact, filleting yield provides a good index of what percentage of the total fish body weight is available for consumption (Nathanailides et al., 2013). Filleting yield depends on several factors such as size, structural anatomy of the fish, sex, species and feeding conditions (Rodríguez, Fountoulaki, Grigorakis, Alexis, & Flos, 2010), and is frequently used as fish selection criterion in order to improve its value (Bosworth, Libely, & Notter, 1998; Cibert, Fermon, Vallod, & Meunier, 1999). Since species with higher filleting yield can give higher profit in a filleted form, greater amberjack and wreckfish should be regarded as the most advantageous species.

Hepatosomatic index (HSI) is associated with the liver energetic reserves and metabolic activity. An increase in the HSI in any given species is associated with elevated feed abundance. HSI is also related to fish health as there are several studies that relate the liver size to a well-developed animal with lower pollution ratings (Pait & Nelson, 2003; Sadekarpawar & Parikh, 2013). Wreckfish was the species with the highest HSI values. The technical significance of HSI is rather indirect, since liver is not within the edible parts of the fish, and therefore the higher the HSI the higher the losses.

The low gonadosomatic indexes (GSI) found for all species are a clear indication that they have not started maturing at the time when sampling occurred. For instance, GSI close or higher than 1.0 indicate meagre entering maturation process, even for male individuals (Schiavone, Zilli, Storelli, & Vilella, 2012). Maturation can largely affect the biochemical quality of muscle tissues, and thus of fish edible parts, since it often uses part of the muscle energy depots (Love, 1992). The viscerosomatic index of the greater amberjack was found significantly lower than those of all species, the meagre and pikeperch showed intermediate values, while the grey mullet and wreckfish exhibited the highest ones (Table 4). The viscerosomatic index largely represents the losses during fish gutting (Grigorakis, 2010).

3.2. Fillet proximate composition

The fillet proximate composition of the studied species is shown in Table 5. In general, fillet protein content of all fish species was quite similar, nearing a 20% of total fillet constituents in agreement with previous studies (Grigorakis, 2010; Grigorakis et al., 2011). Fillet protein has been generally believed to be stable in adult fish and not to be influenced by external parameters (Grigorakis, 2010; Love, 1992). However, there have been some cases where seasonal protein changes have been reported for wild fish populations (Gökçe, Taşbozan, Çelik, & Tabakoglu, 2004; Patrick Saoud, Batal, Ghanawi, & Lebbos, 2008). Reduction of muscle protein in adult fish has been mentioned in cases of mobilization under prolonged fasting (Love, 1992).

Greater amberjack fillets had the highest lipid content which explains its lower water content. The total lipid content for fat fish species affects the percentage of moisture, since fat and water normally constitute around 80% of the fillet (FAO, 1995; Stead & Leard, 2002). All the other species exhibited fillet fat of < 1%, which would categorize them into low-fat species (Huynh & Kitts, 2009). In fact, meagre and pikeperch have been described as lean species (Kowalska, Zakęś, Jankowska, & Demska-ZakĘŚ, 2011; Sinanoglou, Proestos, Lantzouraki, Calokerinos, & Miniadis-Meimaroglou, 2014). Grey mullet on the other hand was supposed to contain higher fat levels in the fillet, and is normally described as a medium to high fat species (Özogul, Özogul, Çiçek, Polat, & Kuley, 2009) as opposed to what was found in this study. Nevertheless, it must be taken into account that all species except pikeperch were obtained during the winter period when lipid depots are generally reduced, and especially in wild specimens like the grey mullet. This seasonal effect has been observed for both wild and farmed populations (Grigorakis, 2010). Lipid content along with fatty acids profile in fish flesh directly affects odor and flavor intensity (Rincón et al., 2016). Thus, sensory differences could be expected among species depending on the fat content since most of the volatile compounds in fish are derived from the oxidative breakdown of unsaturated fatty acids (Grigorakis, 2007; Sérot, Regost, & Arzel, 2002).

3.3. Instrumental texture analysis

Texture is an important variable of the fish flesh and is of increasing concern in the aquaculture industry (Bjørnevik, Karlsen, Johnston, & Kiessling, 2003), especially for those animals to be submitted to an industrial process. As observed in Table 6, wreckfish was the species with the highest area and lowest slope value for both raw and cooked samples, thus indicating its more pronounced elastic nature. These elastic properties may be influenced by the amount and strength of the collagen cross-links in the raw flesh (Li et al., 2005) and the thermal-induced structural changes (Castro et al., 2015; Dunajski, 1979).

Grey mullet was the fish species where most noticeable differences in the mechanical properties (Maximum force and Area) between raw and cooked samples were observed. It exhibited the highest maximum force and slope values for cooked samples, suggesting that it was the hardest of all five species when using a non-destructive compression method. Texture is strongly affected by protein and water content. Provided that there were no significant differences between protein and moisture content among all the species in this study (Table 5), one

Table 5
Mean values and standard deviation (SD) of fillet proximate composition of wreckfish (N = 3) greater amberjack (N = 3), grey mullet (N = 3), meagre (N = 3) and pikeperch (N = 3).

Proximate composition parameter	Wreckfish		Greater amberjack		Grey mullet		Meagre		Pikeperch	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Moisture (%)	78.35^{a}	0.53	69.46^{b}	2.74	76.53^{a}	1.07	77.17^{a}	0.29	76.58^{a}	1.07
Protein (%N)	19.27^{b}	0.30	22.21^{a}	1.58	21.37^{ab}	0.72	20.65^{ab}	0.20	21.80^{a}	0.72
Fat (%)	0.70^{b}	0.17	6.28^{a}	4.04	0.58^{b}	0.02	0.52^{b}	0.36	0.06^{b}	0.02
Ash (%)	1.15^{b}	0.05	1.44^{a}	0.13	1.27^{ab}	0.16	1.35^{ab}	0.01	1.30^{ab}	0.16

Different letters in the same row indicate statistically significant differences ($p \leq 0.05$) between the mean values of each species.

plausible explanation for these findings could be the protein type that may be present in this species. In this vein, Lin, Zeng, Zhu, and Song (2012) stated that the type of proteins (myofibrillar, sarcoplasmic, stromal) and their functional status tend to affect muscle hardness. Generally speaking, the thermal denaturation temperature of proteins is strongly related to their amino acid composition and protein structure. In consequence, the observed different behavior under low compression forces compared to the rest of the species might be explained by different denaturation processes when samples were cooked. It is important to remark, that these statements are merely possible hypothesis according to the literature review, since no actual measurements of protein denaturation took place in this study. Nevertheless, this issue should be addressed in further studies.

There was, however, a tendency for most species and retained parameters to exhibit higher mean values when samples were cooked. When heating, the collagen responsible for maintaining the structure of the fish fillet is gelatinized by thermal action (Castro et al., 2015), whereas the actomyosin complex (intracellular contractile proteins) changes from a soft gel to a firmer denatured complex, thus making fish samples harder (Dunajski, 1979). These changes explained the observed increase in various texture parameters, however, it is worth referring these results to a non-destructive compression. According to the discriminant analysis carried out and the results of the confusion matrix, texture variables were more discriminant between species in raw samples (data not shown). Therefore, the different fish samples were correctly classified in their respective species in 77.78% and 68.89% of the cases for raw and cooked samples respectively. According to Thorarinsdottir, Arason, Geirsdottir, Bogason, and Kristbergsson (2002); Badii and Howell (2002), each fish species has a different thermal denaturation point, which could suggest that the observed differences among species might be partially masked when samples were submitted to the same cooking procedure. Although, at 115 °C all samples should have reached the denaturation point, differences in protein and water content among species might have led to the formation of gels with a different strength (Sun & Holley, 2011).

Table 7 shows the results of the TPA performed over the cooked samples. Hardness was significantly higher for wreckfish, suggesting a stronger contractile protein complex in this species (Dunajski, 1979). Moreover, since wreckfish was also the species that released more exudate (water) among the species, it is likely that the tissue was dryer, hence resulting in an increased hardness. These animals also showed the highest cohesiveness. This particular textural property depends on the strength of protein binding (Christensen, 2012; Szczesniak, 1963), which indicates the existence of cross-links between collagen molecules. In addition, it has been demonstrated that pelagic fish like wreckfish, tend to have higher amount of sarcoplasmic proteins than other types of fishes. These proteins tend to contribute to the increasing of the cohesiveness in the fish tissue (Farouk, Wieliczko, Lim, Turnwald, & Macdonald, 2002). Resilience values (how well a product "fights to regain its original height" (Rosenthal, 2010) were also the highest for wreckfish. This parameter describes the ability of the muscle to recover from deformation and the offered resistance to this deformation. Resilience is affected by the elasticity of the muscular fibers and by the connective tissue (Veland & Torrissen, 1999). Consequently, wreckfish seems to have higher elastic character in its tissue, although no significant differences between species were observed for the springiness (elasticity). One plausible explanation could be related to the big size of the animal. Thicker fillets tend to present more elastic deformation (Ando, Toyohara, & Sakaguchi, 1992; Cheng, Sun, Han, & Zeng, 2014), indeed wreckfish was among the largest animal in this study. In addition to the highest mean value for hardness observed in this species, gumminess (hardness x cohesiveness) and chewiness (gumminess x springiness) were also significantly higher than in the remaining species accordingly.

Contrary to what was expected, adhesiveness values for greater amberjack were the highest among the species despite its higher fat content. Normally, fat presence around the muscle fibers acts as lubricant, since it can be released during the compression test reducing the stickiness between the compression plates and the sample (Carpenter, 1962). However, the internal released juice during fish compression could also contain other substances different from melt fat. These substances could be fiber proteins, such as elastin or fibronectin, which have both structural and adhesive functions, and solubilized collagen (Koolman & Heinz-Roehm, 2005) which could act as an organic glue increasing the adhesiveness of the sample. Greater amberjack was also the species with lower resilience and higher fracturability (lower force needed to fracture the sample). Since greater amberjack is a fat fish species, the existing intramuscular fat between myomeres

Table 6
Mean values and standard deviation (SD) of nondestructive instrumental texture parameters (spherical probe compression) for cooked (C) and raw (R) fish samples: wreckfish (N = 5), greater amberjack (N = 5), grey mullet (N = 5), meagre (N = 5), and pikeperch (N = 5).

Inst. texture parameters	Wreckfish		Greater amberjack		Grey mullet		Meagre		Pikeperch	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Area R (gf/s)	1029.16^{a}	437.09	965.35^{a}	177.28	382.29^{b}	220.54	620.09^{ab}	423.72	734.36^{ab}	499.61
Max. force R (gf)	368,02	122.03	383.88	78.48	365.19	180.64	332.21	190.96	394.43	235.62
Slope R (gf/mm)	64.35^{b}	29.39	67,65^{b}	14.94	166.73^{a}	74.85	80.90^{b}	40.20	98.56^{b}	53.99
Area C (gf/s)	1604.29^{a}	956.91	1147.35^{ab}	275.06	1043,07^{ab}	563.37	806.27^{b}	254.65	698.37^{b}	333.56
Max. force C (gf)	430.60^{ab}	178.80	383.88^{b}	74.74	607.73^{a}	247.80	376.17^{b}	54.22	315.17^{b}	93.89
Slope C (gf/mm)	65.99^{b}	26.69	69.39^{b}	12.32	192.83^{a}	86.93	92.87^{b}	15.90	73.49^{b}	20.08

Different letters in the same row indicate statistically significant differences ($p \leq 0.05$) between the mean values of each species.

Table 7
Mean values and standard deviation (SD) of texture profile analysis (TPA) parameters of cooked samples of wreckfish (N = 5), greater amberjack (N = 5), grey mullet (N = 5), meagre (N = 5), and pikeperch (N = 5).

TPA parameters	Wreckfish		Greater amberjack		Grey mullet		Meagre		Pikeperch	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Hardness (gf)	7032.00^{a}	3977.10	3985.74^{ab}	1181.17	3328.62^{b}	598.20	4402.66^{ab}	835.18	2251.51^{b}	246.97
Fracturability (gf)	2692.45^{a}	890.79	842.08^{b}	189.57	2120.97^{a}	808.28	2411.79^{a}	398.19	1552.62^{ab}	200.35
Cohesiveness	0.42^{a}	0.05	0.32^{ab}	0.09	0.27^{b}	0.08	0.33^{ab}	0.04	0.37^{ab}	0.04
Springiness	0.8	0.05	0.70	0.20	0.75	0.14	0.80	0.02	0.78	0.01
Adhesiveness (gf/s)	−164.10^{ab}	122.17	−204.83^{b}	148.66	−43.00^{a}	48.40	−14.34^{a}	7.21	−9.56^{a}	9.82
Resilience	0.08^{a}	0.02	0,03^{d}	0.01	0.04^{cd}	0.01	0.07^{ab}	0.01	0.05^{bc}	0.01
Gumminess (gf)	3119.95^{a}	1960.95	1354.29^{b}	711.63	926.25^{b}	373.47	1512.62^{ab}	443.12	837.86^{b}	144.00
Chewiness (gf)	2553.38^{a}	1633.85	1040.99^{b}	668.06	726.36^{b}	378.77	1222.76^{ab}	377.59	655.03^{b}	114.51

Different letters in the same row indicate statistically significant differences ($p \leq 0.05$) between the mean values of each species.

probably caused changes in the muscle firmness, resulting on a weakening of its cellular binding force (Thakur & Morioka, 2016).

It is worth mentioning that texture differences observed among the studied species were strongly affected by the instrumental method applied. According to Bouton and Harris (1972) compression values seem to be more influenced by the strength of the materials holding the muscular fibers together than by the strength of the muscular fibers themselves. Thus, depending on the level of the applied compression, i.e. the conducted test, the contribution of the muscular fibers or the surrounding collagen network to the final force values will vary (Ogawa et al., 2003). Spherical probe compressed the samples only at 30% of its height (non-destructive) and mainly measures the texture on the more external part of the fillet (Jonsson, Sigurgisladottir, Hafsteinsson, & Kristbergsson, 2001), while TPA compressed samples twice at 75% of its initial height involving the whole muscular structure (destructive measurement) (Rehbein & Oehlenschlager, 2009).

3.4. Sensory analysis

Results from quantitative analysis performed on the five fish species are shown in Table 8. Only those descriptors showing significant differences between species are discussed.

Wreckfish was distinguished for having the highest presence of exudate among the samples. The differences between species for this descriptor could be explained by specific biochemical mechanisms that control protein denaturation when cooking (Sotelo, Aubourg, Perez-Martin, & Gallardo, 1994; Sun et al., 2006) and also by the different content of connective tissue that these species might have (Batista, 1999). A higher content in connective tissue will favor the exudate release during cooking as a result of higher muscle contraction (Mc Gee, 1984). Wreckfish also presented the highest sensory firmness and chewiness in agreement with the instrumental texture parameters.

Greater amberjack was described as having laminar structure. This attribute is related to the separation of myomeres (muscle blocks attached to collagen septa) in the fish (Helfman, Collette, Facey, & Bowen, 2009). The myomeres structure connection (myocommata) in high fat fish species is based on collagen and the presence of adipocytes (Zhou, Ackman, & Morisson, 1995). According to Thakur and Morioka (2016) greater amberjacks lipids are deposited between its myomeres thus favoring the development of a laminar structure. Greater amberjack also showed sour flavor as a defining characteristic. No plausible explanation has been found on the literature to justify the presence of this sensory descriptor. In addition, greater amberjack also exhibited higher teeth adherence than the other species. As previously mentioned,

Table 8
Mean values and standard deviation (SD) of descriptors intensity for the five fish species obtained by quantitative sensory analysis of wreckfish (N = 5), greater amberjack (N = 5), grey mullet (N = 5), meagre (N = 5), and pikeperch (N = 5).

Descriptors	Wreckfish		Greater amberjack		Grey mullet		Meagre		Pikeperch	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
OButter	3.36^{a}	2.18	2.21^{b}	1.74	1.95^{b}	1.86	3.90^{a}	1.94	1.85^{b}	1.57
OSeafood	1.21^{ab}	1.26	1.12^{ab}	1.18	0.65^{b}	0.65	1.32^{a}	1.03	0.72^{ab}	1.06
OSardine	2.10^{a}	1.77	1.30^{ab}	1.75	2.20^{a}	2.01	1.53^{ab}	1.77	0.91^{b}	1.02
OEarthy	0.62^{c}	0.89	0.92^{bc}	1.50	1.78^{ab}	1.96	0.63^{c}	1.12	2.38^{a}	2.00
Color	4.57^{a}	1.62	3.65^{bc}	1.12	3.98^{ab}	1.91	3.10^{c}	1.22	2.03^{d}	0.90
Color uniformity	6.86^{bc}	2.12	8.10^{a}	1.62	6.68^{bc}	2.23	6.51^{c}	1.81	7.66^{ab}	1.52
Exudate	8.42^{a}	1.72	6.85^{b}	1.99	2.06^{d}	1.88	5.90^{bc}	2.32	4.81^{c}	1.73
Turbidity	6.66^{b}	2.81	1.36^{c}	1.29	1.83^{c}	1.74	6.17^{b}	2.29	7.97^{a}	2.17
Fat drops	6.08^{a}	2.76	5.28^{a}	2.47	0.87^{b}	1.15	5.71^{a}	2.62	0.98^{b}	1.09
Laminar structure	4.33^{b}	2.33	6.13^{a}	2.44	4.70^{b}	2.07	4.62^{b}	2.14	4.75^{b}	2.35
Sour	0.81^{b}	1.24	4.03^{a}	1.88	0.92^{b}	1.32	0.65^{b}	1.08	0.65^{b}	0.95
Bitter	1.68^{b}	1.63	1.91^{b}	2.40	3.10^{a}	2.36	1.70^{b}	1.83	1.51^{b}	1.30
Butter	1.87^{ab}	1.63	2.08^{a}	1.89	0.87^{c}	1.26	2.39^{a}	1.73	1.13^{bc}	1.10
Sea food	1.00^{ab}	1.01	0.98^{ab}	1.00	1.01^{ab}	1.05	1.30^{a}	1.47	0.48^{b}	0.69
Vegetables	2.51^{a}	1.91	1.37^{b}	1.87	2.0^{2ab}	1.27	2.26^{ab}	2.15	2.20^{ab}	1.62
Earthy	0.51^{c}	0.93	1.06^{bc}	2.05	1.64^{ab}	2.08	0.27^{c}	0.52	2.37^{a}	2.10
Firmness	6.66^{a}	1.49	5.96^{a}	1.68	5.88^{a}	1.76	4.85^{b}	1.31	4.36^{b}	1.40
Crumbliness	4.13^{d}	1.40	5.20^{c}	1.51	5.41^{bc}	1.75	6.15^{ab}	1.44	6.77^{a}	1.41
Juiciness	4.83^{bc}	1.65	5.50^{ab}	1.61	4.31^{c}	1.47	5.96^{a}	1.00	5.16^{ab}	1.12
Chewiness	6.38^{a}	1.25	5,83^{ab}	1.65	5.25^{b}	1.49	4.01^{c}	1.25	3.77^{c}	1.35
Pastiness	2.96^{ab}	1.99	3.80^{a}	2.38	2.65^{b}	2.09	3.85^{a}	2.46	3.88^{a}	2.35
Teeth adherence	3.66^{b}	1.98	6.83^{a}	1.15	3.82^{b}	2.06	3.82^{b}	1.78	2.95^{b}	2.00

Different letters in the same row indicate statistically significant differences ($p \leq 0.05$) between the mean values (descriptor's intensity) of each species.

adhesive proteins are likely to be released while chewing the fish, therefore clinginess is likely to be produced between molar teeth (Koolman & Heinz-Roehm, 2005).

Grey mullet was principally characterized for its bitter taste. According to Cayhan and Selli (2011), grey mullet has low antioxidant activity compared to other species, which possibly allows higher lipid oxidation producing short-chain volatile compounds such as aldehydes that also elicit characteristic bitter flavors (Eskin & Shaidii, 2013). (Z)-4-heptenal and E-2 Nonenal, are two aldehydes that have been found among the aroma components in grey mullet (Cayhan & Selli, 2011), and have been related to rancid and bitter taste in fish (Cha & Cadwallader, 1998).

Meagre showed among the highest values measured between species for butter odor and flavor attributes. According to Giogios et al. (2013) meagre volatiles have been characterized by the presence of different compounds including 2, 3-butanedione. This aldehyde is a natural product that contributes to the taste of butter (Peterson & Reineccius, 2003), therefore it is likely that this descriptor might be related to the presence of this compound.

Pikeperch was mainly characterized by "earthy" odor and flavor. These sensory attributes seem to be related with the fish origin and/or environment. Pikeperch is normally reared in freshwater recirculating tank systems. Tank systems often contain actinomycetes which could be responsible for muddy odor by producing compounds such as geosmine and 2-methylisoborneol usually associated to the earthy odor/flavor (Persson, 1980; Selli, Prost, & Serot, 2009).

3.5. Relationship between the parameters assessed

Fig. 2 shows the results of the PCA performed over the whole data set (including somatometric, composition, instrumental texture, and sensory parameters). The first two dimensions of the PCA explained 67.34% of the variance. The first component was positively influenced by instrumental texture (hardness, gumminess, chewiness and area) and parameters such as CI and HSI indexes. Area values for cooked samples were positively correlated with the CI of the animals (r = 0.98) and with hardness (instrumental texture) (r = 0.87). Sensory firmness was also located together to instrumental hardness, chewiness and gumminess.

The second principal component contained descriptors positively correlated to fat content (laminar structure (r = 0.95), teeth adherence (r = 0.98), GSI (r = 0.92) and sour taste (r = 0.99)). According to Venugopal and Shahidi (1996), lipid content is an important chemical basis for flesh texture forming, thus creating the laminar structure. Regarding the connection of GSI with the lipid content, Ando, Hatano, and Zama (1985) found that lipid stores are necessary when building up fish gonads, thus suggesting a relation between the fat presence and the GSI of the fish. In addition, high fat content in other fish species like salmon have been reported to have sourness as a descriptive characteristic in its profile (Cardinal et al., 2004), thus the free fatty acid content might have contributed to the presence of this descriptor in this study too, although further research would be needed to prove such hypothesis. According to Montreuil, Vliegenthart, and Schachter (1997), fatty fish species often have a high content of glycoproteins with adhesive properties, whose presence translates into higher force required to separate teeth after biting the fish samples (Maldo de Paula & Conti-Silva, 2014). Accordingly, teeth adherence descriptor might be related to fat content as well.

PC 3 and PC4 explained 32.66% of the variance. In PC3, a positive correlation between maximum force and slope values (r = 0.89) of cooked samples were observed. According to Casas, Martinez, Guillen, Pin, and Salmeron (2006), high values of slope could be regarded as an index of stiffness, therefore higher force should also be required when compressing the fish sample. In the case of grey mullet, samples were placed close to these properties in the plot, thus having the higher slope and maximum force values.

Seafood flavor was one of the most representative attributes in PC4. According to Josephson (1991), seafood flavor is strongly related to lipid-derived aroma compounds, which are produced by the enzymatic oxidation of the polyunsaturated fatty acids (arachidonic, eicosapentatenoic and docosahexaenoic fatty acids) present in fish (Reineccius, 1994).

In general, the agreement between instrumental and sensory data reported in the present paper seems to indicate the appropriateness and usefulness of the sensory references developed during the training process of the assessors. As Rainey (1986) stated, sensory references are the most convenient way to transform in objective and comparable those scores provided by a sensory panel. Accordingly and as stated by Muñoz and Civille (1998) a common criteria for scoring intensities should be established in order to have more uniform and calibrated panel ratings.

The species herein presented a wide range of physicochemical and

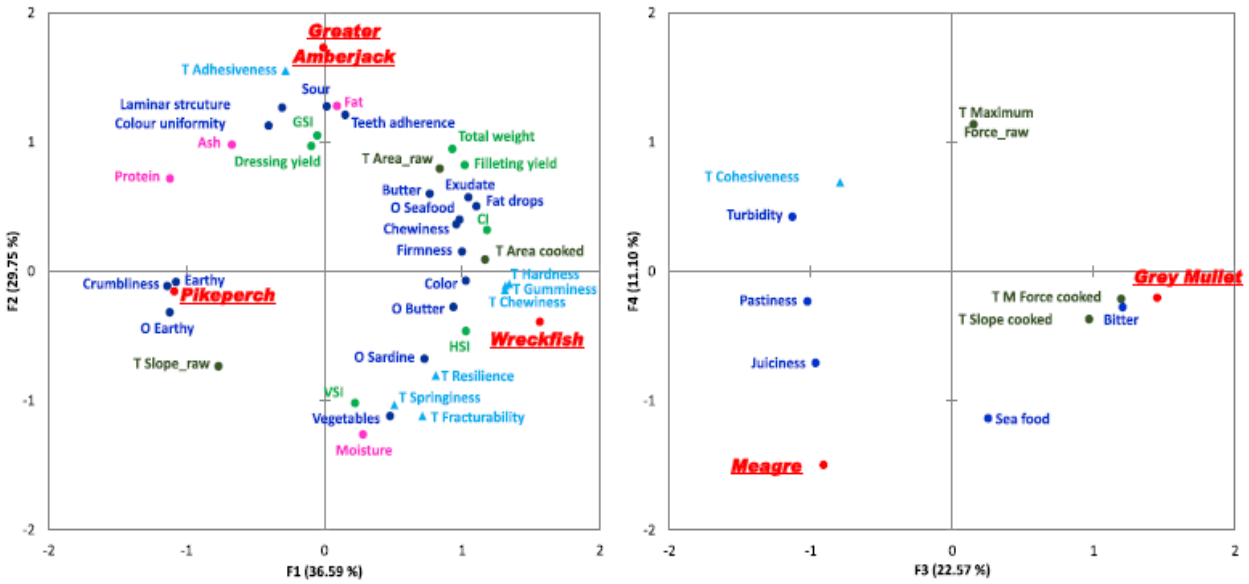

Fig. 2. Sensory somatometric, compositional and instrumental texture correlations of the five fish species. Only those attributes and samples being well projected on the graphs (sum of square cosines higher than 0.5) are shown.

sensory characteristics that show their potential for product development, thus increasing the variety of options for consumers and probably favoring the demand for farmed fish. The information reported in the present paper could be further exploited when designing new products by providing reliable guidelines about the most convenient applications and uses for each of the species under study. Species like pikeperch (characterized by "earthy" odor and flavor) or grey mullet (described with bitter flavor), could be used in products that come with dressing, spices or sauces that can mask their peculiar characteristics, probably undesirable for some consumers in some specific markets.

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4.3 Stage 3: Development of concepts and ideas for new products: Focus groups in five countries and idea screening.

This section describes the data collected from consumer focus groups in each of the five countries (Germany, UK, France, Italy and Spain), and the new product concepts that were created out of these focus groups. The obtained results are presented individually per country, in order to follow the differences among them.

4.3.1 Focus groups with consumers in Germany

Generally, respondents seemed to be more oriented toward convenience, practical products that they could prepare in a quick and easy manner. These products had to be appealing to families, working mothers and fathers that do not have a lot of time. Furthermore, respondents agreed that they would prefer to be able to have varying cooking choices for preparing the product. Respondents prefer wild-caught fish, but on the other hand they were environmentally conscious and aware of the overfishing practices. Importance of environment and sustainability are themes frequently mentioned, and respondents are quite aware of the major challenges of environmental sustainability and need to maintain the environment for every ones benefit. Thus, they would like to have an alternative to wild-caught fish and are open to the farmed fish species.

The pictures of fish products had quite an impact on the respondents, who were very concerned with visual appearance of the fish products and their packaging. Respondents emphasized that packaging should have attractive pictures, visible information of production, transport, and preparation methods. A supplementary leaflet with recipes would be perceived positively too. In addition, packaging should allow the product to be seen. Product appearance must be unaltered, as much as possible, like fish fillets with no additives, preferably without coating (*i.e.*, potatoes, bread crumbs) and extra sauces marinades. Nevertheless, respondents would like to have an option of an already prepared marinade, sauces, herbs or vegetables in a separate sachet that they could use if they want. Respondents were also very concerned that the taste of the new fish products could not measure their expectations. Overall, respondents prefer to have more unprocessed fish products due to health and nutrition concerns.

The most accepted creative product idea that was suggested and accepted by the respondents was the fish fillet in a cooking bag or on a plate that can be popped in the oven or on a grill. Sliding packaging with attractive pictures was suggested as an addition. The best solution was the one where both product and packaging could be visible with additional information on fish production and cooking methods. It should also be environmentally sustainable with recyclable material. This product was suggested to be deep frozen so that it could be prepared when needed.

4.3.2 Focus groups with consumers in United Kingdom

Respondents from UK were oriented towards innovative and food enjoyment, but on the other hand they were not over environmentally conscious and not too concerned about environmental sustainability. They were very open to the subject of new fish species and saw them as new possibilities in terms of cooking and having wider variety of fish products.

Respondents confronted with pictures of new fish products stressed the importance of appearance and presentation of the products, where they preferred products that were more visible. Packaging was also important for consumers from UK, but not as much as visual appearance and taste of the product. The best way to enjoy a good meal according to these respondents was through social settings where they aimed to impress others, like friends and clients with an easy made and colorful fish dish that of course could be varied. They mentioned to like to vary different fish products, by changing the fish species or using the same fish species but changing the dips, sauces and marinades. They seemed to be quite innovative and adventurous in terms of experimenting with fish products and combining them with other different ingredients. It was also significant for them the easiness to prepare the dish, accompanied by additional information on cooking and serving suggestions.

The new creative product idea that was considered most promising by these respondents, was to have a joint of fish as a product that could look like a piece of meat and be used as a healthier variant for special occasions, like a Sunday lunch. This product had to be appealing mostly to single consumers with busy and frenzied lifestyle that prefer already prepared fish products, or even fish products on the serving trays with additional serving suggestions so they do not waste time. Product must be visible with transparent packaging, where fish fillet can be seen entirely.

4.3.3 Focus groups with consumers in France

Respondents from France were quite adventurous and innovative in terms of food in general and fish products in particular. They were opened to new tastes and products. They were not afraid of the challenge of trying new fish products and new recipes, and more than that, they would actually love to experience new things. They preferred fish

from the sea (wild-caught) above farmed fish. However, they were environmentally conscious and painfully aware of the overfishing practices, and the importance of fish farms for fish consumption in the future. Hence, they would not mind eating fish products from farmed fish, if this fish is ethically treated in terms of rearing and feeding. Since they were environmentally conscious, they would like to have the information on the product packages related to production of the fish and its origin.

Respondents had quite divided opinions towards the pictures of new fish products. Overall they preferred more unaltered fish products, like back fish fillet and salmon fillet, rather than convenient fish products. Although, there were some respondents who liked convenience fish products and gourmet products that are readymade, pre-sliced and easy to prepare. Nevertheless, these respondents emphasized that they must be able to vary these products in terms of preparation and different trimmings like vegetables and sauces.

Furthermore, respondents preferred these products to be also accompanied by the 'chef's advices' and recipes of how these products could be made to be more enjoyable. Moreover, respondents considered fish as a ‘basic ingredient’ that should be processed as less as possible. Fish garnish was quite important to the respondents as they found that the fish flavor could be enhanced. Respondents also thought that the packing of the product should carry the image of the fish for easier association.

Regarding the new product ideas, respondents were more oriented towards fresh fish fillets and luxury products such as Carpaccio. Respondents considered that fish should not be altered as much, but instead be creatively presented or it should be accompanied by different sauces and spices. Respondents were very creative regarding the packaging and the information that should be printed in the product, like recipes and health-related messages. The best accepted idea among respondents, was a round box package with the form of a wheel and different sections for fish and accompanying products.

4.3.4 Focus groups with consumers in Italy

Italian respondents were more traditional and reserved regarding the new experiences in fish products and food products in general. Respondents preferred fish products that carry a label or a brand they could associate to a certain production method or specific

product characteristic (*i.e.*, taste). Attractive packaging and serving suggestions, shown as traditional recipes, were also seen as an additional value to the product. Even though, the traditional respondents were not afraid of a cooking challenge related to the fresh fish products. Respondents also pointed out the importance of the environmental sustainability and need for new ways of fish production. Regarding the pictures of new fish products, the respondents emphasized that the most important element would be the image of the product in the form of brand. More specifically, they would like to associate a product to a well-known brand, see it in a nice packaging with additional information about the origin of the product. Origin and label of the product are very important to these respondents. Furthermore, they mentioned that they would like to have additional information regarding the cooking methods and recipes. They liked 'easy to cook' and readymade fish products, but did not care that much about convenience.

Italian respondents were also very traditional and conservative in creating new ideas for fish products. Most of the ideas were mainly related to traditional recipes, with visible packaging and information on the product's origin. The product idea that got more attention was a traditional recipe for a fish fillet with the bread crust that could be accompanied with vegetables and sauce.

4.3.5 Focus groups with consumers in Spain

Spanish respondents were positively oriented towards fish products. They were mostly concerned about the convenience of preparing the product, and the new experience and enjoyment that can come out of this practice. Spanish consumers think fresh fish products are always good but, they are not afraid to go and try the assortment of readymade fish meals. Thus, they liked convenience products such as cooked octopus, and were also considering products like snacks and fish burgers as a way of introducing the fish products to children. They were quite conscious when it came to the environment and sustainability of the aquaculture industry, pointing out that new fish species could help to solve some of the environmental issues related to overfishing.

When confronted with the new fish products, respondents found that the visual appearance of the product, packaging and information related to a preparation method should always be emphasized. More specifically, they were especially interested in the

cooking methods that could open new horizons and experiences in terms of taste and enjoyment. Spanish respondents pointed out that as a society, they should be moving on from eating meat in to eating more fish. Thus being this a healthier option since fish is the meat of the future. Thus, they agreed that farmed fish could be a good solution for decreasing meat consumption.

Spanish respondents had a few interesting ideas in the creative part. These ideas were mainly related to the packaging and presentation of the fish products. One of the interesting ideas was a golden tray package that could emphasize fish qualities. Afterwards, respondents thought it could be convenient and attractive to cut the fish into small cubes, to accomplish a better presentation of the fish product and to make it more convenient. Another interesting idea was related to the production of fish snacks or fish sticks in the shape of fish to make it more appealing for children. Respondents also mentioned an idea that could also be valuable: producing fish in a liquid or mashed form for the elderly consumers and vegetarians, so they can make soups or drink fish.

4.3.6 Summary of elicited ideas in Focus groups

The general categories involving all ideas created can be found in Table 4. Most of the participants created product ideas related to fresh fish, however, they also had specific interest on packaging, accompaniments or arrangement (as opposed to frozen and readymade fish dishes. The majority of ideas had in common the need of the product “to be seen”, emphasizing transparent and see-through packaging. Furthermore, participants emphasized that the new products have to have something more than simple convenience, and be practical and useful in preparation due to the general lack of time, knowledge and skills of the typical consumer. Participants were certain that new products that offer more convenience in preparation, proper accompaniments and arrangement with additional preparation suggestions and recipes would be more likely to influence consumer perceptions and choice of these products positively. (i.e. ‘Fish slices. Totally clean, without bones and pre-sliced in a plastic package) with a plastic tray, so you can put it in the microwave or oven. Easy opening system with cooking instructions and easy recipe, 5 min preparation. Thus, the final choice of concepts chosen for new fish products are in table 5.

Table 4. Categories identified in the created product ideas

Category	Examples of elicited words	Overall % Frequency of mention*
Transparent packaging	Transparent package, clear packaging, cardboard pack with transparent section, packaging can be cardboard with the window that you can see the product, glass jar	87% 26 of 30
Convenience in preparation	Convenience in cooking, different ways to cook, easy, quick, ready to eat, easy to prepare, readymade	73% 21 of 30
Accompaniments	Sauces, marinades, vegetables, potatoes, herbs, olive-oil, cheese	60% 18 of 30
Arrangement	Fillet, pre-sliced, in cubes, little dices, medallions, shape of fish, whole piece, clean-no-bones	47% 14 of 30
Preparation suggestions and recipes	Preparation suggestions, preparation mode, recipes, instructions for additional serving methods and for cooking	47% 14 of 30
Healthy	Healthy, pure, natural	40% 12 of 30
Innovative	Innovative product, original, unique, new, surprise, out of ordinary, magic	40% 12 of 30
Purchase point	Supermarket, fish market, fishmonger, retail shop, must be available	40% 12 of 30
Fresh	Fresh, freshness, fresh fish at all times	37% 11 of 30
Affordable price	Affordable price, razonable price	37% 11 of 30
Sensory experience	Taste, tasty, pleasure in one bite, smells, delicious, flavors, first class Enjoyment	33% 10 of 30
Fish species	Salmon, swordfish, tuna, bass, cod, marlin, loup de mer	30% 9 of 30
Frozen	Frozen, deep-frozen, chilled	27% 8 of 30
Information	Information about the product such as origin, sustainability, labels, quality controlling, manufacturing and origin of the products, ingredients	27% 8 of 30
For family and friends	For whole family, satisfy everyone at the table, to share with friends, for parties	23% 7 of 30
Quality	Quality, high-quality, best-quality, top-range	20% 6 of 30

*Percentage of sub groups per focus group (6 per country) using this category out of a total of 30 subgroups

Table 5. Overall summary for new product ideas developed in the focus groups in the five selected countries

Country	Product	Packaging	Additional Information	Purchase point	Comments associated
Germany	-Frozen fillet -Fillet with herbs	Visible product Vacuum packed Ready for cooking Evironmentally conscious With pictures	Recipes Labels - fish origin Health claims on nutrition and quality	Specialized markets	Enjoyment Appearance Nutrition Health Convenient Environment Traditional Taste Quality-Price
UK	-Fresh fillets + different seasonings	Barbeque tray Microwavable Appealing in fancy trays	Recipes Quality Nutrition facts	supermarket	Environmentally friendly Innovative Health Taste Appearance Preparation
France	-Carpaccio with chilli -Fish roast -Cured fish	Round box transparent plastic Cardboard with transparent lid	Health message Nutrition	supermarket	Ready made Convenient Environment friendly Health Innovative Social occasion
Italy	-Frozen fish in oil -Steamed fillets -Bread crusted fillet	Visible Glass jar	Origin Quality Brand	supermarket	Tradition Environmentally conscious Convenient Ready made Healthy Good impression
Spain	-Tartar -Small cubes for soup -Liquid drink -Burgers -Fish sticks -Fillets	Individual Transparent Vacuumed Microwavable Tetra brick Bottle Golden tray	Cooking instructions Nutritional Quality	Supermarket Fish market	Tasty Healthy Variety Ready made Ready to eat Easy to cook

According to the obtained results in the five countries, the categories identified in the created ideas, could be drivers of consumer preferences and useful when marketing new aquaculture products across the selected European countries (Banovic et al., 2016).

Convenience in preparation seemed to be an overall necessity towards the aquaculture products. Consequently, convenience should be considered as an essential characteristic to develop new aquaculture products, in terms of their easiness to adjust to different cooking possibilities. In the same vein, Brunsø et al, (2009) and Olsen et al. (2007), also found that convenience in cooking is an important factor that influences consumer`s choice behavior and thus their perception towards farmed fish. In addition, it has been stated that consumers seek for convenience due to a time constrain when cooking or preparing their meals, therefore, the easier the product cooking the higher chances for them to acquire these products.

The requirement to have product accompaniments, arrangements as well as preparation suggestions and recipes for the new aquaculture products was also a general statement. This could also be related to the need of having easily transformed products, or to combine them with other food products in order to be more accepted by consumers. Additionally, previous studies have shown that accompaniments with serving and cooking suggestions have an important impact on consumer seafood choice and fish consumption (Leek, Maddock, & Foxall, 2000; Mueller Loose, Peschel, & Grebitus, 2012).

Transparent packaging or materials that allow the product visibility were also a common interest for the consumers. According to Wedel & Pieters (2012), product packaging has a strong impact on the process of consumer´s decision making and choice. Thus, the transparency in packaging could be an important feature to be used in the aquaculture products.

Environmental consciousness was another important characteristic for aquaculture products. This can only be accomplished, if growing and catching techniques of aquaculture fish species are performed ethically. Products from aquaculture could be seen as optimal because they promote perseverance of wild fish resources (Thurstan & Roberts, 2014). According to Laroche, Bergeron, & Barbaro-Forleo, 2001, consumers are willing to pay more for environmentally friendly products, therefore, it could be

suggested that aquaculture products with environmental claims would be more likely to be accepted by consumers.

Healthy lifestyle is another worth considering factor that could contribute to higher aquaculture product acceptance. A typical target consumer of new aquaculture products would be a person very much concerned with their health and well-being. This could be further traced to natural, unprocessed or minimally processed products, specifically the perceived absence of industrially processed fish, where health-giving properties would be a sign of a good aquaculture practice (Banovic et al, 2016).

The creative part of the focus groups resulted in interesting and possible solutions for the new fish products. Nine concepts were built from these sessions to be used as a basis for the new product development of fish products. These concepts have been listed below in table 6.

Table 6 Final choice of creative concepts for new fish products

Country	Description
Germany Concept 1	Frozen fish fillet that is seasoned or marinated either traditional, Italian, Provence or Asian. The product is in a sliding, transparent vacuum packed bag made of recyclable material, with clear pictures of the unfrozen product on the cardboard sleeve.
UK Concept 2	Fresh fish back fillet that in tray or bag that can be prepared in an oven or barbecue. This fish is accompanied with dips, sauces and dressings The packaging is a transparent bag or a tray where fish is laid and covered with transparent plastic.
Spain Concept 3	Fresh ready to eat meal with fish fillet with different cheese and fine herbs. The fish is seasoned. This product is pre-cooked and can be prepared in the microwave in 5 minutes. The packaging is individual with transparent opening and a lid on the top so product can be smelled.
Spain Concept 4	Fish sausages and fish hamburgers. The main advantage of this product is that the product has no bones. The seasoning is very mild and therefore this product is suitable for children. The packaging is transparent and vacuum packed or comes in a plastic tray with transparent top plastic.

Italy Concept 5	Bread crusted crispy frozen fish product, with a topping of vegetables and sauce made by a traditional recipe. This fish product is medium seasoned and easy to prepare in the oven or the microwave in the original packaging. The packaging is a tray with a transparent lid where image of the ready dish is presented.
France Concept 6	Fresh fish Carpaccio that can be used as starter, for a hot meal or as sandwich filling. This Carpaccio will be seasoned with ginger and chili and presented resembling fish scales. The packaging is a plate that looks like a round box with compartments and transparent wheel on the top that you can turn to reach different sections.
France Concept 7	Cured fish like Botarga sliced in medallions. Botarga is a Mediterranean delicacy of salted, cured roe fish, typically from grey mullet or tuna. The packaging is a tray with the transparent film on the top and product can be served in the same tray.
Spain Concept 8	Liquid fish to make soups or a drink. Liquid fish for soups is in mashed form. These products are without additives and thus highly suitable for vegetarian people. The packaging for soups is tetra Brik, while liquid fish for drinking is in a plastic bottle.
Italy Concept 9	Cooked starters made in different shapes that can be used to incorporate in salads or canapes. The packaging is a transparent glass jar so the content is visible.

Note. All products are produced environmentally sustainable (containing ASC hallmark). Labeled as a premium product; the country of origin is EU.

4.3.7 Experts opinions of the created concepts

Expert`s opinions were retrieved for each created concept among the five selected countries. Each location assessed the general concept attractiveness and viability. These results can be observed in Table 7.

Table 7. Overall summary of expert opinions on the new product ideas for the selected fish species.

Concept	Level of attraction	Innovative	Price €/kg	Best Species	Distribution	Feasa-bility
1. Frozen fish fillet	Good	Not new	3-5	All	Supermarket	ok
2. Fresh back fillet	Convenient packaging	Not new	15-18		Supermarket	ok
3. Ready to eat meal with fish	Good	Medium	10-12	All	Supermarket	ok
4. Fish sausage and fish burger	Good for kids	Not new But convenient	10-15	All	Convenient store and catering	ok
5. Bread crusted crispy fish	Good	Medium	5-10	Meagre	Supermarket	ok
6. Carpaccio	Good	New	7-20	Greater Amberjack	Selected markets	ok
7. Cured fish	Good	New special	8-25	G. mullet	Delicatessen market	ok
8. Liquid fish	Good	Medium	3-10	All	Supermarket	ok
9. Cooked starters	Convenient	Medium	7-10	All	Selected markets	ok

In general all the developed concepts were well accepted and assessed by the experts, thus they were all taken in to account for the creation of more ideas out of each concept.

4.3.8 Creation of ideas

A combination of the market perceptions (results of focus groups with consumers and experts opinions), the use of other existing products (in the fish or meat market), and general consumer needs and opinions for fish, was used to generate a pool of ideas about potential products. Thus a total of 43 ideas were developed out of the nine previous concepts (Table 6). To follow up from which concept each idea was developed the order is presented as follows.

Concept 1: Frozen fish fillet that is seasoned or marinated

Idea 1: Frozen fish fillets with different recipes

Frozen fish fillets divided in double portions; each packaging includes three or four 2-person portions from the same or different fish species packaged separately. The product is included in transparent vacuum packed bags (one for each 2-persons' portion) made of recyclable material where fish fillets are laid; each bag can be divided easily from the other; each 2-portion bag has a different recipe from the others within the same package; a picture of the prepared dish is included on each 2-portion bag. The aim is to make it more attractive to traditional consumer that likes to be involved in cooking and to allow a longer shelf life.

Idea 13: Frozen fish fillet that is seasoned or marinated

Frozen fish filet that is seasoned or marinated either traditional, Italian, Provence or Asian. The product is in a sliding packaging, transparent vacuum-packed bag made of recyclable material, with clear pictures of the unfrozen product on the cardboard sleeve.

Idea 15: Whole deep frozen fish

Whole deep frozen fish, cleaned and easy to prepare in the transparent and clear recyclable packaging. Cooking suggestions on the package. Product message: Delicious slow food'; 'Pure and natural, straight and portionable, to satisfy different needs.

Idea 16: Frozen whole fish filled with spices and with organic vegetables

Frozen or fresh whole fish filled with spices and with organic vegetables containing no artificial aromas. Transparent, well-sealed and sliding recyclable packaging.

Idea 18. Frozen fish fillet with potatoes and vegetables

Frozen fish fillet with potatoes and vegetables ready to cook in the oven. Deluxe sliding packaging with visible product and instructions on preparation method.

Idea 19: Deep frozen white fish fillet in the transparent packaging with additional information

Deep frozen white fish fillet in the transparent packaging with additional information and suggestions on product serving and preparation. The product is environmentally sustainable (containing ASC label). It is labelled as a premium product; the country of origin is EU.

Idea 22: Frozen fish and seafood salad

Frozen fish and seafood salad in the tray packaging.

Idea 25: Frozen back fish fillet in transparent packaging and accompanying marinades

Frozen back fish fillet visually appealing with transparent packaging and accompanying marinades and serving suggestions on the package.

Concept 2: Fresh fish back fillet for roast with dips, sauces and dressings

Idea 14: Fresh fish fillet with herbs and spices

Fresh fish fillet covered with herbs and spices in the transparent packaging. Different fillet size in the packaging conveying the product message through images and voice:

Idea 17: Fresh whole fish filled with spices and with organic vegetables

Fresh whole fish filled with spices and with organic vegetables containing no artificial aromas. Transparent, well-sealed and sliding recyclable packaging.

Idea 20: Fresh back fish fillet

Fresh back fish fillet that looks like a roast in tray or bag that can be prepared in an oven or barbecue. This fish is accompanied with dips, sauces and dressings. The packaging is transparent bag or a tray where fish is laid and covered with transparent plastic.

Idea 21: Fresh fish fillet with different ‘healthy’ seasoning and marinades

Fresh fish fillet with different ‘healthy’ seasoning and marinades separately packed that consumer can choose and vary depending on the occasion. This product is sold with recommendation for the appropriate vegetables and wine to accompany the dish.

Idea 29: Fresh fish fillet medallions with garnish and sauce, separately packed

Fresh fish fillet sliced in the forms of medallions complemented with garnish and sauce, separately packed. Product is packed in vacuum plastic package with the plastic tray that can be easily open and used in the microwave. Package contains information on ω-3 fatty acids and cooking instructions.

Idea 31: Whole fresh fish with information how to be prepared

Whole fresh fish with information how to be prepared. Co-creation of a product with the consumer. Product can be sold in the fresh fish department or vacuum packed.

Idea 34: Fresh fish steak for grilling in the pan

Fresh fish steak for grilling in the pan. Transparent packaging.

Idea 37: Fresh fish fillet in a simple package

Fresh fish fillet in a simple package that transmits lightness and freshness of the product.

Idea 40: Fresh fish fillet sliced presented in the shape imitating of fish scales

Fresh fish fillet sliced with slices presented in the shape of fish imitating scales, reflecting freshness and luxury. Product is packed in a tray with the sauces on the side in the separate compartment and transparent lid.

Idea 42: Fresh fish roast

Fresh fish roast presented as a ‘meat roast’ in the tray with the transparent lid that could be used in the oven. Package comes with different recipes from the fishmonger.

Idea 43: Fresh fish fillet that comes with 3-day plan

Fresh fish fillet that comes with 3-day plan of the meals in the transparent packaging and placed on the tray. Recipes for warm and cold dishes come from the famous chefs with the picture of the final product on the package.

Concept 3: Fresh ready to eat meal with fish fillet

Idea 3: Ready to eat meal: fish soup

Fresh ready to eat fish soup made according to a traditional recipe; soup is accompanied by pieces of steam cooked fish provided separately within package. The product does not include additives. It can be heated easily on stove or microwave. The soup (which contains broth) is provided in plastic cup which is sealed using modified atmosphere packaging (MAP). The fish pieces are provided on a separate transparent accompaniment (modified atmosphere/ vacuum packed), to allow product visibility, and placed over the soup cup; the packaging has the picture of the ready to eat meal on it.

Idea 4: Ready to eat meal: salad with fish

Fresh ready to eat salad, which includes fish as well as an accompanying sauce; fish and sauce are separately packed and included within the original package. The fish included is either a smoked fillet (provided in slices), or vinegar-cooked, or alternatively bottarga; thus, the dish can be eaten cold. The packaging (MAP) is composed by bowl where the salad is placed. The fish pieces and the sauce are provided in separate transparent accompanying packages incorporated with the original bowl package. A transparent lid exists on the top to allow product visibility and the packaging has the picture of the ready meal on it.

Idea 5: Ready to eat meal: fish risotto

Risotto with vegetables accompanied by fish sauce with whole fish pieces. The pieces included in the sauce can be fish of different preparation methods such as cooked/ fried/steamed/ smoked, or pieces of bottarga that are not used as a separate product since they are not intact. The product does not include additives and can be heated easily on stove or microwave. The packaging (MAP) is composed by bowl where the risotto is placed. The sauce with fish pieces is provided in separate transparent accompaniment incorporated with the original bowl package. A transparent lid exists on the top to allow product visibility and the packaging has the picture of the ready meal on it.

Idea 8: Dried fish sticks with accompanying dip

Sticks that are made from dried fish, which are seasoned and are accompanied by a dip (vegetable dip etc.). The product is ready to eat and does not need any heating. The dried fish sticks are included in a long plastic cup; within the packaging in the upper part of the cup a compartment for the dip is included. MAP is used for the preservation of both dip and sticks; opened using a different seal.

Idea 26: Fresh ready to eat meal with fish fillet with different cheese and fine herbs

Fresh ready to eat meal with fish fillet with different cheese and fine herbs. The fish is seasoned. This product is pre-cooked and can be prepared in the microwave in 5 minutes. The packaging is individual with transparent opening and a lid on the top under which you can smell the product.

Idea 41: Readymade fish fillet / fish dices accompanied with cereals and vegetables

Ready-made fish fillet or fish dices that could be combined with original recipes and accompanied with cereals and vegetables. Package is a four cardboard tray - meal with transparent lid and with fork, bread and complete salad.

Concept 4: Sausage and hamburger (snack)

Idea 6: Fish burgers shaped as fish

Frozen fish burgers shaped as fish. The burgers are ready to cook and prepared with a mild seasoning and can be incorporated in a sandwich or prepared as a part of a meal. Among the advantages of this product is the absence of bones and the attractive shape for children. The product is placed in a transparent vacuum-packed bag or in a plastic tray with transparent plastic on the top. Information on fish for educative purposes (children) and playful gifts (e.g. sticker) are included in the packaging.

Idea 7: Fish balls

Frozen fish balls which are ready to cook and can be prepared in various ways (frying/oven/ etc.). The product is already seasoned, has no bones and can be used as a part of a meal. The product is included in a transparent vacuum-packed bag or in a plastic tray with transparent plastic on the top. Recipes for dishes containing the fish balls are included in the packaging.

Idea 23: Varied meal with fish fillet, burgers sausages

Fresh fish fillet with fish burgers and sausages in the microwavable package, as a varied meal. Product message: ‘To eat with partner, but also to share with friends.’

Idea 27: Fish sausages and fish hamburgers

Fish sausages and fish hamburgers. The main advantage of this product is that the product has no bones. The seasoning is very mild and therefore this product is therefore suitable for children. The packaging is transparent vacuum packed or in a plastic tray with transparent plastic on the top.

Concept 5: Bread crusted crispy frozen fish

Idea: Bread crusted crispy frozen fish product with a topping of vegetables and sauce made by the traditional recipe. This fish product is medium seasoned and easy to prepare in the oven or the microwave in the original packaging. The packaging is a tray with transparent lid where image of the ready dish is presented.

Concept 6: Fresh raw carpaccio

Idea 24: Fresh fish Carpaccio

Fresh fish Carpaccio ready to eat on a fancy (posh) tray with transparent lid and with dips, sauces and salad accompanying the product.

Idea 38: Fresh fish spicy carpaccio

Carpaccio will be seasoned with ginger and chilli and presented as scales of the fish. The packaging is a plate that looks like a round box with the compartments and transparent wheel on the top that you can turn to rich different sections.

Idea 30: Ready-made fish tartar with additional soy sauce

Ready-made fish tartar with additional soy sauce for cold serving. Packaging is the golden tray that reflects the colors and physical appearance of the product and that could also be used for serving. Package contains information how the product was made.

Concept 7: Botarga and cured products

Idea 39: Bottarga sliced as medallions

Bottarga is a Mediterranean delicacy of salted, cured fish roe, typically from grey mullet or tuna. The product is similar to the softer cured mullet roe, karasumi from Japan and East Asia. The packaging is a tray with the transparent film on the top and product can be served in the same tray.

Concept 8: Liquid fish for soups

Idea 10: Fish broth in cubes

Frozen fish broth cubes to be used in cooking, in order to enhance food flavor. The packaging resembles a plastic ice cube tray where the frozen broth is divided. On the packaging there are suggestions on the number of cubes needed for preparing specific food portions.

Idea 11: Fish powder/seasoning

Fish powder created by freeze-dried fish, which can be used instead of a broth or as seasoning in various dishes. The product can be only fish powder or be a mix with spices and/ or powder of freeze-dried vegetables to enhance the seasoning. The packaging resembles the ones used for selling spices.

Idea 12: Fish sauces

Fresh-chilled fish sauces prepared with different traditional recipes. The product can be prepared in a microwave or stove. The product is vacuum packed in small plastic bags with easy opening when it is sold in individual portions, or in big package with a twist lid (to facilitate the extraction of the product) when sold for larger portions. On the package, recommended uses for the product are written.

Idea 28: Liquid fish to make soups or drink

Liquid fish to make soups or drink. Liquid fish for soups is in mashed form. These products are without additives and thus highly suitable vegetarian people. The packaging for soups is tetra Brick, while liquid fish for drinking is in a plastic bottle.

Concept 9: Cooked starters to incorporate in dishes

Idea 2: Thin smoked fillets

Fresh thin smoked fillets from the same (or different) fish species, which can be used as a starter or incorporated within a sandwich/salad. The packaging is a plastic tray where the fillets are laid covered with a transparent plastic, which allows visibility of the fillets and vacuum packed or Modified Atmosphere (MAP) is used for shelf life prolongation. Ideas concerning the different uses of the fillets are included on the product's sleeve. This idea tries to assimilate classic smoked fillet products with the need of consumer for convenience.

Idea 9: Fish pate/spreads

Fish pate/ spreads prepared using different recipes. Can be used as starter or incorporated in a sandwich. The product placed in a tube to facilitate use and extraction of amount of product needed, as well as prolong shelf life (only outer part of the product will come in contact with air in each use). This idea was an attempt to create added value and to utilize raw materials that are usually leftovers of fish process.

Idea 33: Readymade fish fillets in olive oil

Ready-made fish fillets stored in olive oil with visible glass packaging.

Idea 35: Steamed fish fillets

Steamed fish fillets stored in the glass jar and seasoned with herbs.

Idea 36: Ready-made larger pieces of fish without bones

Ready-made larger pieces of fish without bones packaged in the jar or a can that could be used on pasta.

4.3.8.1 Quantitative screening of ideas

All ideas were scored after the experts rated all the 19 qualitative criteria (point 3.2.2.1, with 1-7 points). The mean values obtained from all the experts were computed as a final score for each one of them. These scores ranged from 1 to a maximum points of 133 (19*7). Based on these scores, ranking positions were established, these corresponded to the total score on each product concept. The ideas achieving higher scores were positioned on the top ranks, while the opposite applied for product concepts with lower total scoring. The ideas, which acquired the same total scoring, shared the same ranking position (Table 8).

Table 8 Final ranking of product concepts; first column presents the ranking position of each concept, second column the total score (sum of scores on all 19 criteria) given by experts, and the last column the number and name of idea.

Ranking	Total score	Number and name of Idea
1	105.78	21. Fresh fish fillet with different 'healthy' seasoning and marinades
1	105.78	14. Fresh fish fillet with herbs and spices
2	104.61	40. Fresh fish fillet sliced presented in the shape imitating of fish scales
3	104.31	29. Fresh fish fillet medallions with garnish and sauce
4	103.38	30. Ready-made fish tartar with additional soy sauce
5	103.16	20. Fresh back fish fillet
6	103.10	24. Fresh fish Carpaccio
7	102.80	38. Fresh fish Carpaccio 2
8	102.66	42. Fresh fish roast
9	102.31	43. Fresh fish fillet that comes with 3-day plan
10	102.15	01. Frozen fish fillets with different recipes
10	**102.15**	**02. Thin smoked fillets**
11	101.93	25. Frozen back fish fillet in transparent packaging and accompanying marinades

Ranking	Total score	Idea
12	101.68	19. Deep frozen white fish fillet in the transparent packaging with additional information
13	101.36	39. Bottarga sliced as medallions
14	**100.73**	**06. Fish burgers shaped as fish**
15	**100.66**	**04. Ready to eat meal: salad with fish**
16	100.60	13. Frozen fish filet that is seasoned or marinated
17	100.35	18. Frozen fish fillet with potatoes and vegetables
18	99.98	15. Whole deep frozen fish
19	**99.91**	**09. Fish spreads / pate**
20	99.15	17. Fresh whole fish filled with spices and with organic vegetables
21	98.18	27. Fish sausages and fish hamburgers
22	97.70	07. Fish balls
23	97.45	22. Frozen fish and seafood salad
24	97.33	28. Liquid fish to make soups or drink
25	**97.10**	**33. Ready-made fish fillets in olive oil**
26	96.85	05. Ready to eat meal: fish risotto
27	96.78	31. Whole fresh fish with information how to be prepared
28	96.55	08. Dried fish sticks with accompanying dip
29	96.45	41. Ready-made fish fillet / fish dices accompanied with cereals and vegetables.
30	96.28	35. Steamed fish fillets
31	96.21	11. Fish powder
32	95.70	10. Fish broth in cubes
33	**95.50**	**34. Fresh fish steak for grilling in the pan**
34	95.30	03. Ready to eat meal: fish soup
35	95.20	12. Fish sauces
36	94.71	37. Fresh fish fillet in a simple package
37	94.65	36. Ready-made larger pieces of fish without bones
38	93.21	16. Frozen whole fish filled with spices and with organic vegetables

Ranking	Total score	Idea
39	92.06	32. Bread crusted crispy frozen fish product with a topping
40	88.40	23. Varied meal with fish fillet, burgers sausages
41	84.73	26. Fresh ready to eat meal with fish fillet with different cheese and fine herbs

According to the ranking positions shown in Table 8, most of the fresh fillet products were the highest rated ideas being in the first 10 positions when assessing the 19 different criteria. Therefore it could be said that fish in a fresh fillet format is one of the main important cues to consider for the new product development. In order to have an overall view of the criteria related to each of the developed ideas a Principal Component Analysis was performed (Fig. 12)

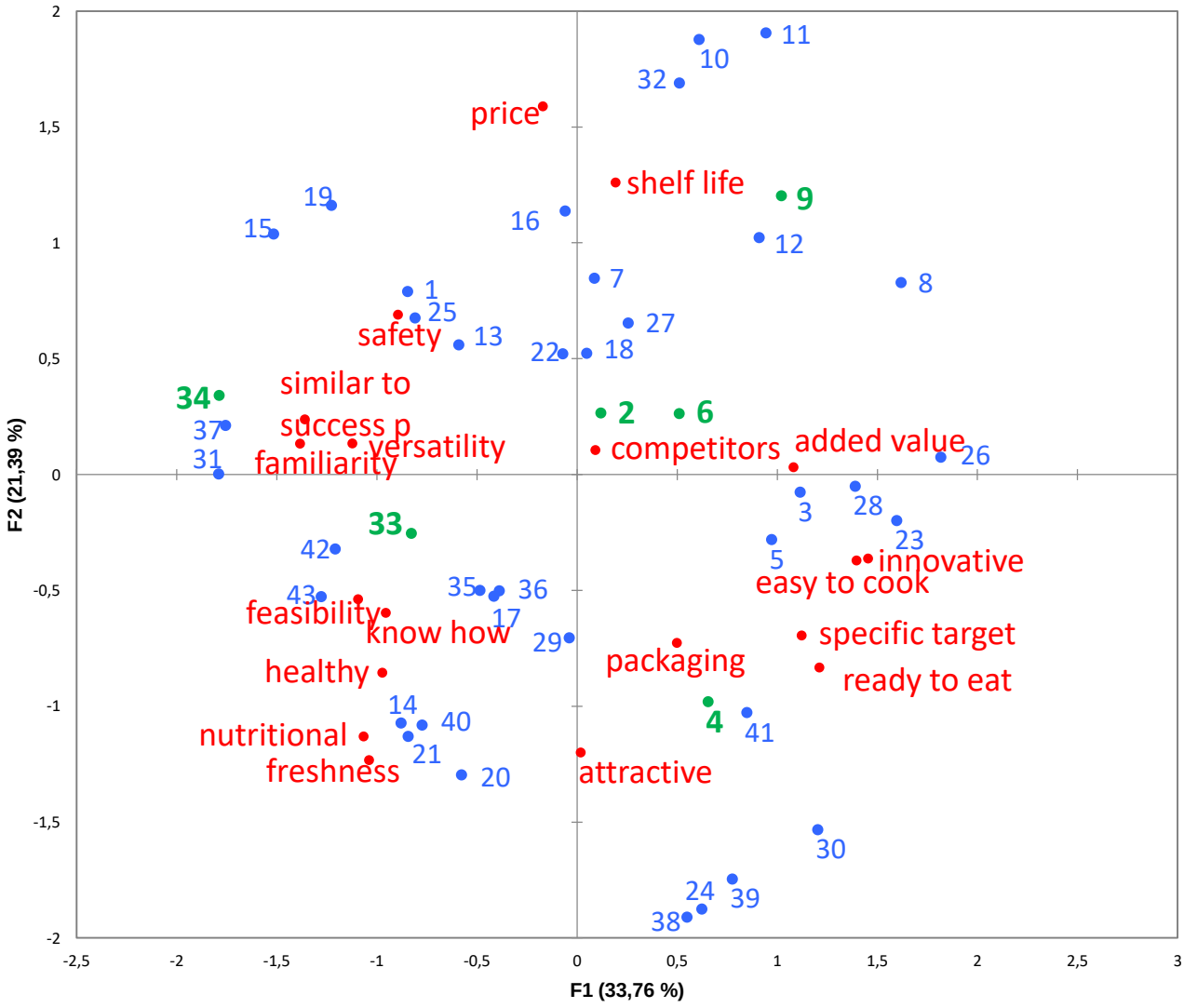

Fig. 12 PCA of the assessed criteria related to the developed ideas

Fresh products were associated with healthy, nutrition and feasible characteristics, whereas frozen products were associated with safety. Products like pate, breast crusted crispy frozen fish, fish powder or fish broth in cubes were perceived as products that could have extended shelf life probably due to the processing level these require. Tartar, carpaccio and bottarga were seen as attractive features probably due to the delicatessen type of product these represent.

4.3.8.2 Technical feasibility

The species physicochemical properties were also taken in to account to be incorporated in the product ideas, so suggestions for development would be more appropriate. General properties per species are summarized in Table 9.

Table 9. Summary of technical characteristics of the selected species

Species	Growth rate	Fillet Size	Yield	Firmness	Fat content	Flavor
Grey mullet	Slow	300-500g	Low	High	Medium/high	Bitter
Meagre	Fast	1-2kg	Medium	Medium	Low	Mild
Greater amberjack	Fast	3-5kg	High	Medium	High	Sour
Wreckfish	Fast	>8kg	High	High	Low	Neutral
Pikeperch	Medium	1-2kg	Medium	Low	Low	Earthy

4.4 Stage 4: New product development (physical prototypes)

4.4.1 Market selection

The ideas selected for the product development were grouped in three sectors that can address the main existing markets: mass market products, segmented market products and added value products (Stimson & Joy, 2000). Thus an addressed criteria could be used for the product prototypes.

a) Mass market products

Mass market (undifferentiated market) can sell the same products to a big group of consumers with widely varied backgrounds. These products can be delivered through several distribution channels and are oriented to the widest variety of consumer segments. Similarities are that they can constitute a regular daily meal; price and versatile characteristics allow their frequent use. There are no bottlenecks in their production. These mass market products included ideas in concepts: 1 (Frozen fish fillets), 2 (fresh fish fillets) and 3 (ready to eat meals).

b) **Products targeted to specific market segments**

These products are designed for specific consumer´s needs. Delicacies/high end products, best if delivered to the consumers through specific distribution channels such as specialty stores or delicatessens. The price range is elevated due to their nature, and are oriented mainly to consumer prototypes such as hedonic and variety seeking consumers (Linnemann et al., 1999). Competitive advantages include innovative nature, convenience and versatility in use. There are no obvious bottlenecks in their production. Ideas from concept 9 were included in this sector.

c) Added-value products

Added value applies to homogeneous products that are enhanced with a few differences from those existing of a competitor (USDA, 2017). These can be delivered through several distribution routes. These products often have a tendency to offer convenience or health distinction and can have high nutritional value, thus they can be addressed to health conscious consumers. Added value products may not by themselves increase significantly fish consumption, however, they should be incorporated in the production parallel to other products. Ideas from concepts: 4 (hamburger and sausages) and 9 (cooked starters) were included in this sector.

A total of twelve prototypes were developed using four fish species, excluding wreckfish due to unavailability when elaborating the products. This section will only describe the six products that were selected for the final part of the study. These products were selected based on three levels of processing (Low, Medium and High) and each of the mentioned types of market was also represented.

4.4.2 Product prototypes

Two product prototypes were chosen per sector. For the mass market sector, ideas 34 Fresh fillets for grilling in the pan (grilled fillets) and Idea 4 Ready to eat salad with fish were selected. For the specific market segments, Idea 2 Smoked fillets and Idea 9 fish pâté were selected, since they can be used as gourmet additions or for canapes filling. Finally, for the added value products segment, Idea 6 fish burger shaped as fish, and Idea 33: fillets in olive oil were chosen, considering the nutritional advantages they can offer.

4.4.2.1 Fresh fish fillet for grilling in the pan (grilled fillets)

Description of the product concept

Fresh fish steak for grilling in the pan. Ingredient Greater amberjack fillets (Fig. 13).

Reasons for its selection

Even though this product was rated in the 34th position, it was chosen due to its similarity to successful products (as shown in Fig. X), since it is a product for grilling and thus versatile for preparation styles.

Greater amberjack is a fast grower and thus suggested for this idea. This is a very suitable species to be used for raw preparation products (fresh fillets) due to its high fillet fat contents, good filleting yields and distinct sensory characteristics such as sour flavor and color uniformity Publication 2. These particular traits make it very interesting for grilling.

Microbiological and sensory shelf life assessment

The shelf life assessment was performed through microbiological and sensory analysis. Microorganisms like: *Salmonella, Listeria spp., Listeria monocytogenes, Shigella* and mesophilic bacteria were determined for these samples. According to the results shown in table 10, the product had good microbiological qualities from the first day and until 5 days of storage.

Table 10. Shelf life assessment of fresh greater amberjack steak for grilling in the pan: microbial counts over the shelf life assessment period (7 days)[1].

	Day 0 Log (CFU/g)	Day 2 Log (CFU/g)	Day 5 Log (CFU/g)	Day 7 Log (CFU/g)
Mesophilic bacteria	<1.00*	2.30	3.10	3.80
Enterobacteriaceae	1.50	2.00	2.30	3.00
E.coli	<1.00*	<1.00*	<1.00*	<1.00*
Psycrophilic bacteria	<1.00*	<1.00*	<1.00*	<1.00*
Salmonella	A	A	A	A
Listeria monocytogenes	A	A	A	A
Listeria spp.	A	A	A	A
Shigella	A	A	A	A

[1]Samples were stored at 4ºC for one third of the corresponding estimated period (day 0, day 2, day 5) and the remaining period stored at an abused temperature of 8ºC (day 7).

Fish is often considered to be a difficult culinary object due to the fact that it is easily spoiled, prone to oxidation and it may develop off-flavors due to wrong handling or incorrect storage. Thus, it is very important to preserve its freshness and the high nutritional value therefore, it is necessary to keep the product on temperature slightly above 0ºC from harvest till processing or consumption (Sampels, 2015b). Cooling should start as soon as possible after killing the fish. Ice

flakes are normally used in the farms and more recently, ice slurry is also in use. This water-ice system reaches temperatures below zero faster and provides to the fish additional protection against oxidation.

In order to determine the sensory shelf life, initial characteristics and changes in the quality of fresh greater amberjack steak were evaluated at different storage points (day 0, day 2, day 5 and day 7), same as in the microbial assessment. As shown in Table 11, various attributes like odour and appearance decayed after 7 days of storage, thus modifying the sensory properties of the product.

Table 11. Sensory evaluation of the characteristic attributes likely to change during the storage of the greater amberjack steak for grilling in the pan [1]

Quality parameter	Attributes and score	Day 0	Day 2	Day 5	Day 7
Appearance	0: totally homogeneous	0	0	0	**1**
	1: appearance of some grey/oxidized areas				
	2: totally heterogeneous				
Fluid retention capacity	0: no exudate	0	1	1	**2**
	1: intermediate				
	2: intense exudate				
Odour	0: fresh	0	0	1	**2**
	1: mold				
	2: rotten taint				
Texture	0: firm and not slimy	0	0	0	**1**
	1: a little soft and slimy				
	2: very soft and slimy				
Temperature	0: 0ºC < T < 4ºC	0	0	0	**1**
	1: 4ºC < T < 8ºC				
	2: T > 8ºC				
Brightness	0: glossy	0	0	0	**1**
	1: intermediate				
	2: matt				

[1]Samples were stored at 4ºC for one third of the corresponding estimated period (day 0, day 2, day 5) and the remaining period stored at an abused temperature of 8ºC (day 7). The attributes and scores reached at the end of the storage period are highlighted in bold.

Consumer handling/cooking specifications

Greater amberjack fillets should be prepared as soon as possible since the product has a very limited shelf life. Once package is open, fish should be placed on a pan with olive oil. Grilling time will depend on the thickness of the fillet and personal taste. Some recommendations indicate that fish can be cooked to preference or pink in the middle since microorganisms are located in the outer part of the fish but not inside. Nevertheless, it is advisable to grill enough time so the whole fillet is cooked.

Product packaging and retail market prototype

Packaging system: vacuum packaging
Packaging equipment: vacuum packaging machine, EDESA VAC-40DT
Design: individually packed portion in bag sealed by thermo sealing.
Packaging material: 90 µm polyamide/polyethylene bag (Orved, Italy)
Size: 30 mm x 20 mm
Recyclable: yes

By following the instructions the physical prototype should be illustrated as shown in Fig. 13.

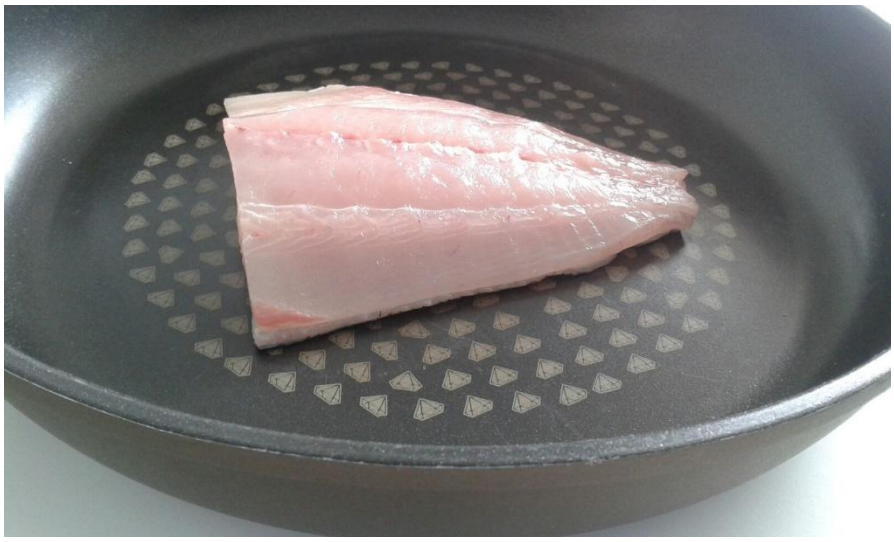

Fig. 13. Greater amberjack fresh fillet ready for grilling in the pan

Vacuum package helps to extend shelf life of any fresh perishable product like fish by 3 to 5 times is normal refrigerated life. Fresh Fish increases shelf life from 1-2 days to 1

week. The advantage of using vacuum package with fish, is that this can be prepared in advance without loss of freshness (FDA, 2001).

4.4.2.2 Ready to eat meal: salad with fish

Description of the product concept

Fresh ready to eat salad that includes fish as well as an accompanying sauce; fish (vinegar cooked) and sauce are separately packed and included within the original package.

Ingredients:

- Mixed vegetables "mesclun" (75 g): the proposed mix consists of romaine lettuce, endive lettuce, lamb's lettuce and radicchio in similar ratios.
- Cherry tomatoes (35 g).
- Vinegar-cooked meagre (45g): meagre fillets, cider vinegar, water.
- Croutons (10 g): crunchy bread cubes made of wheat flour, vegetable oils (sunflower and palm), yeast, salt and malt wheat.
- Mustard vinaigrette (35 g): Dijon mustard (water, mustard seeds, alcohol vinegar, salt, citric acid, potassium metabisulfite), oregano, honey, olive oil, lemon (juice and zest), black pepper.

Reasons for its selection and existence of similar products in the market

Now a days, the tendency of western civilization moves towards a faster lifestyle increasing the need for convenience in meal preparation (Costa, Schoolmeester, Dekker, & Jongen, 2007). Therefore, the creation of Ready to Eat Meals, are much in demand today by different sectors of society such as: students, working women, families on the go and practically anyone who needs a quick alternative to eat (Gupta & Dudeja, 2017). In this sense, a ready to eat salad with fish seemed to be a good choice to develop since it fits with these demands having a healthy addition which is fish presence.

Meagre was found to have appropriate sensory attributes (Second publication) making it an interesting candidate for the salad. In fact, meagre fish is used in the elaboration of dishes such as Peruvian Ceviche in which it is marinated in a sour sauce (lemon juice)

and served at room temperature. Therefore, a vinegar-cooked presentation seemed to be a suitable alternative for this product. In addition, the muscle fat of farmed meagre is low (0.73-2.93%) (Giogios et al., 2013; Poli et al., 2003), making it more appropriate to be cooked in vinegar. Thus, different concentrations of pure acetic acid and vinegars were studied. First relatively high concentrations of acetic acid were used according to the literature (Ozden, 2005; Szymczak, M 2011). However, it was necessary to adjust and reduce the concentration of the acid given the fact that the assayed concentrations conferred a strong sour taste even after marinating at 2 and 3% concentrations overnight. In addition, vinegars from wine, cider and rice were also studied. Cider vinegar was chosen for having a smoother flavor and being more available than rice vinegar, which also conferred a mild flavor. After that, the concentration and period of marinating was adjusted to reach a pH below 4.4 to avoid microbial growth, in particular Listeria monocytogenes, during its storage at refrigeration temperatures (Table 12). A mustard vinaigrette containing honey was found to combine with the fish as it reduces the tangy flavor of the salad.

Table 12. Effect of different concentrations of cider vinegar on the pH of meagre after different times of marinating at 4 °C[1]

Vinegar	Initial pH	pH 30 min	pH 60 min	pH 120 min	pH 180 min
30%	6.64	6.45	5.72	5.2	5.1
40%	6.64	6.24	5.52	5.16	4.90
50%	6.64	5.99	5.10	5.06	4.87
60%	6.64	5.79	4.75	4.54	4.45
70%	6.64	5.34	4.56	4.35	**4.2**

[1] Meagre was cut in cubes of approximately 1.5 cm and marinated at 1:1 weight ratio with the different vinegar solutions containing 1% Na Cl. The pH was measured in well-drained samples, which were homogenized in 10 volumes of distilled water.

Microbiological and sensory shelf life assessment:

The vegetable mix and croutons were not considered for these analysis. The shelf life of croutons should be given by the provider and it should be longer than that given to the rest of the ingredients. However, in this case it should be considered that they can become rancid or loose crunchiness with time. The product should be used before these

detrimental effects may occur. With respect to the salad, it needs to be processed in the facilities of conventional producers of this type of products in order to ensure product's safety and standard shelf life, which is up to 8 days. The shelf life assessment of the vinegar-cooked meagre fish and the mustard vinaigrette was carried out according to the given recommendations (EURL, 2014; European Commission). These ingredients were stored at 4 °C for the first 2 days and at an abuse temperature of 8 °C till the end of the period (8 days). Results are shown in Table 13.

Table 13. Shelf life assessment of the vinegar-cooked meagre and the mustard vinaigrette of the "*salad with fish*" prototype: microbial counts over the shelf life assessment period (8 days). [1]

		Day 1 Log (ufc/g)	Day 5 Log (ufc/g)	Day 8 Log (ufc/g)
Vinegar-cooked meagre	Lactic acid bacteria	<1.00*	<1.00*	<1.00*
	Mesophilic bacteria	1.10	1.45	0.86
	Enterobacteriaceae	<1.00*	<1.00*	<1.00*
	E.coli	<1.00*	<1.00*	<1.00*
	Psycrophilic bacteria	<2.00*	<2.00*	<2.00*
	Salmonella	A	A	A
	Listeria monocytogenes	A	A	A
Mustard vinaigrette	Mesophilic bacteria	4.06	4.22	4.33
	Enterobacteriaceae	<1.00*	<1.00*	<1.00*
	Salmonella	A	A	A
	Listeria monocytogenes	A	A	A

[1] Samples were stored at 4 °C during the two first days and the rest of the estimated period were stored at an abuse temperature of 8 °C. Results are averages of 5 different samples. The presence of *Listeria* and *Salmonella* is determined in 25 g of sample and the rest in 10 g. Letter "A" stands for absence and the asterisk indicates that is below the limit of detection. For more information see material and methods section.

In order to determine the shelf life, initial characteristics and changes in the quality of vinegar-cooked fish and the mustard vinaigrette were evaluated at different storage points (day 1, day 5 and day 8) as in the microbial assessment (two thirds of the storage period at abuse temperature). As shown in Table 14, various attributes are expected to decay in these food components according to the literature (Kilinc, 2009; M. Szymczak, Szymczak, Koronkiewicz, Felisiak, & Bednarek, 2013). Few minor changes were observed throughout the storage period. In consequence, the limit of this product is, as expected, determined by the vegetables that may present various defects such as limpness after 8-9 days of storage.

Table 14. Sensory evaluation of the characteristic attributes which may change during the storage of the vinegar-cooked fish and vinaigrette components of the "*salad with fish*" idea[1]

Quality parameter by components		Attributes and score
Appearance	Fish colour	**0: totally homogeneous** 1: appearance of some grey/oxidized areas 2: totally heterogeneous
	Seasoning colour	0: light yellow green **1: intermediate** 2: darkish yellow brown
Odour	Fish	**0: fresh** 1: mold 2: rotten taint
	Seasoning	0: balanced sweet, acid and fresh herbs **1: decrease of odour intensity** 2: unbalanced and appearance of off-flavours
Flavour	Fish	**0: fresh** 1: mold 2: rotten taint
	Seasoning	0: balanced sweet, acid and fresh herbs **1: decrease of flavour intensity** 2: unbalanced and appearance of off-flavours
Texture	Fish	**0: firm and not slimy** 1: a little soft and slimy 2: very soft and slimy

[1] Samples were stored at 4 °C during the two first days and the rest of the estimated period were stored at an abuse temperature of 8 °C. The attributes and scores reached at the end of the storage period are highlighted in bold.

Overall, microbiological and sensory results indicated that the shelf life of the vinegar-cooked meagre and mustard vinaigrette are longer than the expected shelf life of the green vegetables “mesclun” that determine the limiting factor of this product idea.

Consumer handling/cooking specifications:

The product needs to be stored under refrigeration until its consumption but it can be removed from the fridge few minutes before if desired. The product can be consumed after mixing all the ingredients in the same tray or alternatively serve it in a plate.

Product packaging and retail market prototype:

Packaging system:	modified atmosphere packaging (MAP: 7% O_2, 8% CO_2, 85% N_2).
Packaging equipment:	MAP heat sealing machine, C26S COMPAC Srl. (Canavaccio, Italy)
Design:	the vegetable mixture is packed in a transparent tray. Vinegar-cooked fish, mustard vinaigrette and croutons are individually packed in plastic sachets and included in the tray. A plastic fork is also included in the tray.
Packaging Materials:	tray: amorphous polyethylene terephthalate (A-PET), GB 85 GT, COMPAC srl. Sealing film: PET/ PET-AF with antifog properties, B260TAPBX, COMPAC srl. Sachets: PA/PE film
Size:	tray: 190 x 137 x 85 mm (1500 ml). Sachets: 100 x 130 mm
Recyclable:	yes

By following the instructions the physical prototype should be illustrated as shown in Fig. 14.

Fig. 14 Physical prototype of the "*salad with fish*" packaged in MAP

The application of modified atmosphere retail packaging, in which food does not contact with oxygen, is an effective method of food preservation that inhibits microbial growth (Cyprian et al., 2013). The storage life of chilled products, such as white fish, like meagre can be extended by packing them in a modified atmosphere (FAO, 2001).

4.4.2.3 Thin smoked fillets

Description of the product concept

Fresh thin smoked fillets, which can be used as a starter or incorporated within a sandwich/salad. Ingredients: for the preparation of this prototype, thin smoked grey mullet fillets skin-on have been used. Hot smoking with dry salting and addition of sugar was the procedure followed for the preparation of the product.

Reason for idea selection and existence of similar products in the market

This fish product occupies 10th position in the ranked ideas, in addition in the European market similar presentations of smoked fish products were found, so this idea is not unfamiliar with the existing market. Thin smoked fillets can utilize any of the fish species as raw materials. In general, fish of larger sizes, having higher yields are expected to be more profitable. It is also important to consider that transforming raw fish species into a high quality product without compromising its nutritional value can

be significantly influenced by the type of processing, the chosen parameters and by the kind of preparation (Sampels, 2015). Therefore, since light smoking also produces a sense of dehydration, higher muscle fat could possibly give more desirable sensory characteristics to these products. Thus, greater amberjack and grey mullet offer an advantage since they could combine higher fat contents (good sensory result in smoking) with good yields.

Nowadays there is a new generation of chefs trying to implement the consumption of grey mullet due to the association of this species with pond culture in areas with high natural value, that have culture practices in accordance with the surrounding ecosystem. Thus, Grey mullet was selected to make this product. It is commonly sold whole in a size range from 300g up to 2 kg. The bigger specimens are usually used to elaborate the product known as bottarga, which is roe salted and dried. Grey mullet fillet flesh has a pinkish coloration and variable lipid content (up to 12.6 %) (El-sebaiy, Metwalli, & Khalil, 1987), which makes it a suitable product for smoking. Smoking is one of the most traditional, almost ancient method to preserve fish. Most probably it dates back to the times after the possibility of cooking over a fire was discovered (Sampels, 2015). Smoking is not only used as preservation method but is also a way to create new products with special organoleptic characteristics. Most of the smoked products presented in the markets are from salmon (due to its fat content); however other fish species can be also used such as herring, eels, trout, mackerel and gilthead seabream (Arvanitoyannis & Kotsanopoulos, 2012). The phenolic compounds of the smoke have antioxidant effects due to their ring structure with conjugated double bonds, which are able to build stable radicals. Smoking has also a drying effect and increases the inhibition of bacterial growth. The dried surface of smoked fish is a barrier against microbes. Moreover, smoking includes salting and drying processes, which improve the preserving effect and the sensory attributes as well. Salting is used because most bacteria, fungi and other potentially pathogenic organisms cannot survive in a highly salty environment, due to the osmotic pressure that salt creates (Sampels, 2015). In addition, Martinez et al. (2012), evaluated an alternative to traditional smoking. They found that dry salting with addition of sugar before immersion in a liquid smoke flavoring resulted in a product with lower oxidation, lower hardness and elasticity values and therefore a higher quality product compared to liquid

smoked fillets that were only brine salted without sugar. Hot smoking results in a ready-made product with longer shelf life compared to cold smoking.

Microbiological and sensory shelf life assessment:

For the shelf life assessment the product was stored at 4ºC. **Table 15** shows the microbial stability of the smoked grey mullet fillets throughout the storage period.

Table 15. Shelf life assessment of the smoked grey mullet fillets: microbial counts over the shelf life assessment period[1].

	Day 1 Log (CFU/g)	Day 21 Log (CFU/g)	Day 31 Log (CFU/g)
Mesophilic bacteria	<1.00*	<1.00*	3,62
Enterobacteriaceae	<1.00*	<1.00*	<1.00*
E.coli	<1.00*	<1.00*	<1.00*
Psycrophilic bacteria	<1.00*	<1.00*	<1.00*
Salmonella	A	A	A
Listeria monocytogenes	A	A	A
Listeria spp.	A	A	A
Shigella	A	A	A

[1]Samples were stored at 4ºC during 31 days. Results are averages of 3 replicate samples. The presence of microorganisms is determined in 25 g of sample. Letter "A" stands for absence and the asterisk indicates that is below the limit of detection. For more information see material and methods section.

The microorganisms *Salmonella, Listeria spp*., *Listeria monocytogenes* and *Shigella* were not detected in any sample tested. The mesophilic bacteria had significantly higher counts at day 31 compared to the beginning of the shelf life assessment. In consequence, the limit of this product is less than 31 days of storage.

With respect to sensory attributes, changes in the quality parameters of the smoked grey mullet fillets were evaluated during the same storage sampling points (day 1, day 21 and

day 31) as during the microbial assessment. Table 16 shows the different attributes that are expected to decay in this product according to the literature (Betts et al., 2004; Man & Jones, 1994; Robertson, 2009). According to the results, 31 days can be considered as the limit of acceptability for this product.

Table 16. Sensory evaluation of grey mullet fillet attributes which may change during storage[1]

Quality parameter	Attributes and score	Day 1	Day 21	Day 31
Appearance	0: totally homogeneous	0	1	**1**
	1: appearance of some grey/oxidized areas			
	2: totally heterogeneous			
Odour	0: fresh	0	1	**2**
	1: mold			
	2: rotten taint			
Flavour	0: fresh	0	1	**1**
	1: mold			
	2: rotten taint			
Texture	0: firm and not slimy	2	2	**2**
	1: a little soft and slimy			
	2: very soft and slimy			

[1]Samples were stored at 4ºC during 31 days. Results are averages of 3 replicate samples. The attributes and scores reached at the end of the storage period are highlighted in bold.

Consumer handling/cooking specifications:

Smoked fish fillets are recommended to be kept in the refrigerator until consumption. The product can be consumed directly on a toast or as part of a salad or even as main course of a meal served with smashed potatoes or boiled rice

Product packaging and retail market prototype:

Packaging system: vacuum

Packaging equipment: vacuum packaging machine, EDESA VAC-40DT

Design: vacuum bag sealed by thermo sealing, including the desired number of portions.

Packaging material: 90 µm polyamide/polyethylene bag (Orved, Italy)

Size: 30 mm x 20 mm

Recyclable: yes

By following the instructions the physical prototype should be illustrated as shown in Fig. 15.

Fig. 15. Prototype of smoked grey mullet fillets, vacuum packed ready for consumption

4.4.2.4 Fish burgers shaped as fish

Description of the product concept:

Frozen fish burgers shaped as fish. The burgers are ready to cook and prepared with a mild seasoning and can be incorporated in a sandwich or prepared as a part of a meal.

Ingredients used: Meagre fish meat, emmental shredded cheese, salt and black olives and stabilizer (ferrous gluconate)

Reasons to choose idea:

Fish is a food rich in valuable nutrients but it is scarcely appreciated by children (Donaldini, dumi & Porreta, 2013), partly due to a low familiarity within their food choices (Mitterer-Daltoé et al., 2017) and partly because spines are an obstacle for its consumption. However, it has been noticed that fish could become more attractive to children through industrialized products such as nuggets, meatballs and hamburgers (Latorres et al., 2016; Mitterer-Daltoé, Latorres, Treptow et al., 2013). In addition Zampollo et al. (2012), suggested that children prefer having foods served as figure on their plate. Thus the shaped fish burger seemed like a good idea to fit these criteria.

Meagre was considered a very interesting fish species for this product idea for various reasons. Firstly, meagre has a higher proportion of discarded muscle when filleting, which can be used for that purpose. Secondly, due to its low fat content it is particularly indicated for frozen products. Finally, it presents low chewiness values and thus it may be indicated for children, which would, in their majority, prefer less "chewy" fish.

Fish burgers, can be made from all of the studied species, nevertheless, meagre was chosen for this idea due to its high growth rate. Since the product is aimed for children it is best that only leftover fillet parts (not tails, heads etc.) and/or intact musculature pieces are used. This information could be included on the packaging/ marketing to increase the products perceived quality. Additionally, if products would be marketed as a frozen, low fat species like meager, are more compatible in aspects of lower lipid oxidation and higher preservation quality.

There were two important concerns in this product idea. The first one was to select a seasoning or mild ingredient suitable for children and, if possible, help to improve the intake of fish in children. Therefore, the addition of cheese was the suitable strategy for masking the fish flavor of this product and somehow resemble to conventional cheeseburgers. The second concern was, the integrity of the sample, especially the fish tail, when cooking. In addition, it was found that the texture of the product was soft and easy to disaggregate. Taking these aspects into consideration, two strategies were assessed: the formation of calcium-alginate gels and transglutaminase crosslinking. The first one provided a slimy texture when eating whereas the second one formed a fish burger with a hard texture, which was decided to be more appropriate. After that, different proportions of cheese and microbial transglutaminase enzyme were assessed to adjust the formulation of the final product. It should be mentioned that transglutaminase is a processing aid and as such it is not necessary to declare it as ingredient.

<u>Microbiological and sensory shelf life assessment:</u>

Histamine was determined because of its health effects and as indicator of spoilage and microbial growth before freezing the product. Prototype histamine levels (9 ± 0.3

mg/kg) are far below the limits reported in the EU regulation 2073/2005 (EU, 2005). The shelf life of this product has to be similar to other related products that have been processed and under the same storage conditions and, in consequence, expected to be of 9 months or higher (Gimenez, Gomez-Guillen, Perez-Mateos, Montero, & Marquez-Ruiz, 2011; Man & Jones, 1994).

After production, the product was characterized and its quality loss was evaluated by assessing those sensory attributes that are expected to decay in this product as shown in Table 17. Note that the evaluation of cooked fish burgers was only carried out after 2 months of storage since there was no more time to conduct the shelf life study for extended periods. Results showed that there is no limiting factor for the sensory characteristics of burgers at this storage time.

Table 17. Characteristic attributes of the "*fish burger shaped as fish*" product concept[1]

Attribute	Scores
Overall appearance and colour	**0 relatively homogeneous colour/ fish shaped** 1 not homogeneous 2 very inhomogeneous/black spots/broken apart
Odour	**0 notes of fish and cheese** 1 mild fish and cheese notes 2 cheesy/fishy/rancid
Flavour	**0 notes of fish and cheese** 1 mild fish and cheese notes 2 cheesy/fishy/rancid
Texture	**0 relatively hard / not breaking in small pieces** 1 not hard/ beaks into pieces 2 breaks in small pieces/soft/chewy

[1] The attributes and scores reached after 2 months of frozen storage at -20 °C are highlighted in bold.

To conclude, based on previous experiments and the existing literature (Erickson & Hung, 1997) the shelf life of this product is expected to be as much as or higher than 9 months when stored at -20 °C. However, further studies should be considered to determine the shelf life of this product idea.

Consumer handling/cooking specifications

Fish burger is recommended to be thawed in the refrigerator before its use. Once the product is thawed it may be fried on the pan with a little bit of oil on it. It is recommend to not overcook it. It can be served accompanied by mashed potatoes, vegetables, etc. or in hamburger bread.

Product packaging and retail market prototype:

Packaging system: vacuum skin packaging

Packaging equipment: thermo sealing machine, SMART 500, ULMA Packaging, S. Coop (Oñati, Spain)

Packaging Materials: tray: EOST 1523-30, CRYOVAC (Sealed Air; Charlotte, USA). Sealing film: 150 µm thick, VST 0280

Size: tray: 147 (width) x 132 mm (length) x 30 mm (height)

Recyclable: yes

By following the instructions the physical prototype should be illustrated as shown in Fig. 16.

Figure 16. Physical prototype of the "*fish burgers shaped as fish*" product concept.

4.4.2.5 Fish spreads / pate

Description of the product concept

Fish pate / spreads prepared using different recipes. Can be used as starter or incorporated in a sandwich.

Ingredients:100 g of cooked pikeperch (64.00%), 55 g of emulsion (35.20%), 1 g of salt (0.64%), 0.15 g of garlic powder (0.10%), 0.1 g of cayenne pepper (0.06%).

Reasons for its selection and existence of similar products in the market

Pikeperch was the selected species for this product. It was sensory characterized with earthy flavor and odor, being a species that was suitable for more processing and combinations with ingredients. Thus it was more appropriate for a more processed product.

The rheological properties of the product are crucial for its intended application and success. Given that pikeperch is a lean fish, it was necessary to add a reasonable amount of lipids (as in pâté) to obtain the desired texture and spreadability. However, the emulsifying properties of fish proteins are limited and even so more when the product is submitted to a thermal treatment (Pasteurization or sterilization). Therefore, it was necessary to obtain a thermally stable emulsion in which the lipid phase is dispersed in a continuous matrix of proteins. Thus, different proteins with good emulsifying properties were considered and evaluated (e.g. caseinate and other milk, egg proteins).

Microbiological and sensory shelf life assessment

The shelf life assessment of the fish pate was carried out according to the given recommendations (EURL, 2014; European Commission). Pikeperch fish pate was stored at 4°C the first 10 days and at an abuse temperature of 8°C till the end of the period. Taking into account the results shown in Table 18, it seems possible to obtain similar products with a shelf life of about 1 month under refrigeration conditions.

Table 18. Shelf life assessment of the pate: microbial counts over the shelf life assessment period[1]

	Day 1 Log (ufc/g)	Day 7 Log (ufc/g)	Day 14 Log (ufc/g)	Day 20 Log (ufc/g)	Day 29 Log (ufc/g)
Lactic acid bacteria	<1.00*	<1.00*	<1.00*	<1.00*	<1.00*
Mesophilic bacteria	4.00	4.18	4.09	4.39	6.37
Enterobacteriaceae	<1.00*	<1.00*	<1.00*	<1.00*	<1.00*
Psycrophilic bacteria	3.51	3.30	3.47	3.61	6.30
Salmonella	A	A	A	A	A
Listeria monocytogenes	A	A	A	A	A

[1] Samples were stored at 4 °C during the 10 first days and the rest of the estimated period were stored at an abuse temperature of 8 °C. Results are averages of 5 different samples. The presence of *Listeria* and *Salmonella* is determined in 25 g of sample and the rest in 10 g. Letter "A" stands for absence and the asterisk indicates that is below the limit of detection. For more information see material and methods section.

It is estimated that after opening the product it should be consumed within the 3 following days. Therefore, it is necessary to conduct an appropriate shelf life assessment to properly determine the secondary shelf life (i.e. after opening of the product).

With respect to sensory attributes, changes in the quality changes of the fish pate were assessed at different storage periods as in the microbial assessment. Table 19 shows the different attributes that are expected to decay in this product according to the literature (Man & Jones, 1994; Robertson, 2009). The product was evaluated after 30 days of its production when aroma/flavour characteristics became unbalanced and a significant diminution of the fresh garlic intensity was observed. In consequence, this storage period can be considered as the limit of acceptability.

Table 19. Sensory evaluation of the characteristic attributes which may change during the storage of the "*fish pate*" idea

Quality parameter	Attributes and score
Appearance	**0 no exudates/glossy/homogeneous colour**
	1 initial appearance of exudates
	2 exudates/rust-coloured (grey-brownish)
Odour	0 fresh fish/fresh garlic aroma
	1 unbalanced/decrease of fresh garlic intensity
	2 rancid fish/rotten/off-odour
Flavour	0 fresh fish/intense garlic flavour
	1 unbalanced/decrease of fresh garlic intensity
	2 rancid/off-flavour
Texture	**0 spreadable/juicy**
	1 less spreadable but juicy
	2 difficult to spread/less juicy

[1] Samples were stored at 4 °C during the first 10 days and the rest of the estimated period were stored at an abuse temperature of 8 °C. The attributes and scores reached at the end of the storage period are highlighted in bold.

Consumer handling/cooking specifications

The product can be consumed directly from the fridge and served as appetizer or spread on sandwiches, toast, etc.

Product packaging and retail market prototype:

Packaging system: recommended to pasteurize followed by aseptic filling

Packaging equipment: in this case manually but can be automatized

Packaging Materials: white tube: Aluminium, Witte y Solá, S.A. White cap: high density polyethylene, Witte y Solá, S.A.

Size: 30 mm diameter, 160 mm height, 60 ml volume

Recyclable: yes

By following these instructions the prototype should be as shown in Fig. 17

Figure 17. Physical prototype of the "*fish spreads/pate*" with the product coming out of the tube.

The packaging of this product could allow its introduction in a selected gourmet market, since its format is appropriate for filling canapés and other snacks presentation. This tube package is not available for sterilization process, therefore, pasteurization was more suitable for preserving the product.

4.4.2.6 Ready-made fish fillets in olive oil

Description of the product concept:

Ready-made fish fillets stored in olive oil with visible glass packaging.

Ingredients: Grey mullet fillet, extra virgin olive oil all sterilized.

Reasons for its selection

The importance of a healthy diet and the close relationship between nutrition and psychophysical well-being can characterized some consumer's choices (Bimbo, Bonanno, & Viscecchia, 2016; Grunert, 2005; Urala & L€ahteenm€aki, 2004). In this sense, extra virgin olive oil provides healthy components that give the added value to this fish product, thus having the possibility to address it to a specific niche market. Thanks to these health properties, the perceived value of the product can be increased, at least for a specific group of consumers (Boncinelli, Contini, Romano, Scozzafava, & Casini, 2016; Casini, Contini, Marinelli, Romano, & Scozzafava, 2014).

Grey mullet was the species chosen for this product. Its characteristic bitter flavor and hard texture made it desirable for a combination with olive oil (Second publication). These features can be in line with the characteristic bitterness of some virgin olive oils and texture resemblance of tuna, which is the existing similar product in the market. Preservation of fish in olive oil is a very popular method of preserving fish for human consumption and provides a shelf life that can range from one to five years. Fish is usually processed (filleted), sealed in airtight container (glass container in this case) and heated for sterilization of the product. The use of olive oil as filling media has an important impact on the final quality of the product. A protective effect of extra virgin olive oil against lipid oxidation in canned tuna has been found (Naseri, Rezaei, Moieni, Hosseini, & Eskandari, 2011). Extra virgin olive oil is rich in tocopherols, which have a protective effect against lipid oxidation. A side effect of canning/bottling can be a change in the nutritional value of the fish, when canned/bottled with added oil (Sampels, 2015a).

Microbiological and sensory shelf life assessment

The shelf life assessment of the ready-made fish fillets in olive oil was carried out according to the given recommendations (EURL, 2014; European Commission). The product was stored at room temperature till the end of the study period (12 days). Results are shown in Table 20.

Table 20. Shelf life assessment of ready-made fish fillets in olive oil: microbial counts over the shelf life assessment period (12 days). [1]

	Day 0 Log (CFU/g)	Day 5 Log (CFU/g)	Day 12 Log (CFU/g)
Mesophilic bacteria	<1.00*	<1.00*	<1.00*
Enterobacteriaceae	<1.00*	<1.00*	<1.00*
E.coli	<1.00*	<1.00*	<1.00*
Psycrophilic bacteria	<1.00*	<1.00*	<1.00*
Salmonella	A	A	A
Listeria monocytogenes	A	A	A
Listeria spp.	A	A	A
Shigella	A	A	A

[1] Samples were stored at room temperature during 12 days. Results are averages of 3 different samples. The presence of *Listeria* and *Salmonella* is determined in 25 g of sample and the rest in 10 g. Letter "A" stands for absence and the asterisk indicates that is below the limit of detection. For more information see material and methods section.

In order to determine the shelf life, initial characteristics and changes in the quality of ready-made fish fillets in olive oil were evaluated at different storage points (day 1, day 5 and day 12). The analysis was carried out for only 12 days (Table 21), but the typical shelf life of this product ranges from one to five years (Sampels, 2015).

Table 21. Sensory evaluation of the characteristic attributes which may change during the storage of the ready-made fish fillets in olive oil[1]

Quality parameter	Attributes and score	Day 0	Day 5	Day 12
Appearance	0: totally homogeneous	0	0	**0**
	1: appearance of some grey/oxidized areas			
	2: totally heterogeneous			
Oil odour	0: fresh	1	1	**1**
	1: intermediate			
	2: intense			
Texture	0: firm and not slimy	1	1	**1**
	1: a little soft and slimy			
	2: very soft and slimy			
Brightness	0: glossy	0	0	**0**
	1: intermediate			
	2: matt			

[1] Samples were stored at room temperature during 12 days. The attributes and scores reached at the end of the storage period are highlighted in bold.

Consumer handling/cooking specifications:

No further cooking is needed for this product. It can be used directly in a salad or any other natural (no cooked) preparation.

Product packaging and retail market prototype

Packaging Materials: transparent glass jars with lid.

Size: 250 ml volume

Recyclable: yes

The product is packed in a transparent glass bottle, which allows seeing the piece of fish and the olive oil inside. The product message is a traditional product, premium quality.

By following the instructions the physical prototype should be illustrated as shown in Fig. 18.

Figure 18. Prototype of ready-made grey mullet fillet in olive oil.

Since this is an added value product it could be important to include health claims in the product package. These could deliver information about the quality of the olive oil. It is important to promote and deliver such claims to consumers to make them aware of the health benefits of olive oil, increasing their knowledge about it and thus their purchasing motives (Roselli et al., 2017).

4.5 Stage 5: Characterization of new products and evaluation of consumers perception

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Manuscript Number:

Title: Discriminant ability of Check All That Apply (CATA) technique performed with consumers and trained assessors compared to traditional Quantitative Analysis

Article Type: Research Article

Keywords: CATA, Trained assessors vs. consumers, Discriminant ability

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Abstract: Food products have been traditionally assessed using descriptive analyses with trained assessors, nevertheless, these methods have known to be time consuming. Consequently, several rapid methodologies for product characterization have been developed, being Check-All-That-Apply (CATA) one of these methods. This technique has been known to be quick, simple and easy to use when gathering sensory information about products, and has mainly been performed with consumers. However, it has been stated that trained assessors can be more reliable when it comes to describing their perception on products. Therefore, this study compares the discriminant ability of CATA performed with trained assessors and CATA performed with consumers, with a profiling traditional method that is the Quantitative Analysis. To accomplish this task, six fish products were used to assess the dissimilarities among these methodologies.
Important differences were observed when dealing with the use of attributes to describe the samples, especially in the texture descriptors. When comparing the samples configuration among methodologies, CATA performed with consumers seemed to resemble more to CATA performed with trained assessors than to the Quantitative Analysis. All three methodologies proved to have a good discriminant ability clearly separating all six samples. However, it is important to highlight that even though samples were clearly different, consumers had the highest variability among them compared to the trained assessors.

4.5.1 Discriminant ability of Check All That Applies (CATA) technique performed with consumers and trained assessors compared to traditional Quantitative Analysis. Publication 3.

Impact factor 3.19

Quartile 1.

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4.5.2 Evaluation of consumer`s perception

In this section, results are presented in order to observe the differences between the consumers expectations of the different developed products and the consumers acceptance when they actually taste the product in blind and informed conditions. Expectations, image/perception of the different concepts/ideas of product, acceptability of the selected products, overall liking, and purchase likelihood are shown below.

4.5.2.1 Overall expected acceptability

Table 22**,** shows the expected degree of liking of the six selected product ideas described previously in the five countries. Products with a lower degree of processing were those who generated higher expected acceptance. Similar results were obtained for the two segments of consumers that participated in this study, ("Involved traditional" and "Involved innovators"), therefore no separate results are shown.

Table 22. Overall expected acceptability per country*

Idea	Overall	DE	ES	FR	IT	UK
Grilled fillet	7.5^{a}	7.1^{a}	7.3^{a}	7.5^{a}	6.8^{a}	7.3^{a}
Smoked fillets	6.8^{bc}	6.5^{b}	7.0^{a}	7.0^{a}	5.9^{b}	6.2^{b}
Fish salad	6.7^{c}	6.2^{bc}	6.4^{ab}	7.4^{ab}	5.8^{b}	6.4^{bc}
Fillets in olive oil	6.6^{c}	6.1^{bc}	6.9^{bc}	7.2^{bc}	6.0^{b}	5.8^{bc}
Fish burger	6.2^{d}	6.0^{c}	6.5^{c}	6.9^{bc}	6.0^{b}	6.0^{c}
Pate	5.8^{e}	5.2^{d}	6.3^{c}	6.6^{c}	4.9^{c}	5.3^{d}

*written concept of product. a-e: Mean values with different superscripts in the same column differ significantly ($p<0.05$).

In addition all the 19 criteria were assessed on each product to observe the cues that also influenced the consumers expectations in each of the selected countries (Table 23).

Table 23. Effect of the different studied parameters on the expectations by country

Parameter	Effect on expectations					
	Overall	DE	ES	FR	IT	UK
Nutritious	+			+	+	
Healthy	+					
Feels good	+	+		+		
Convenient			+			-
Available	-			+		
Tastes good	+	+	+	+	+	+
No additives						
Natural						
Good value	-					-
Expensive	-					-
Hard to digest	-				-	
Familiar	+	+	+			
Traditional		+				
Env friendly	-			-		
Authentic						
High quality						
Helps locals		+				
Unsafe	-			-		-
*R^2	0.418	0.585	0.350	0.465	0.342	0.391

+: significant positive effect on expectations ($p<0.05$); -: significant negative effect on expectations ($p<0.05$); *: All the R2 values are significant ($p<0.0001$). Signs marked in green are those with the highest standardized regression coefficient, in orange the second highest and in red the third highest ones (in absolute value).

4.5.2.2 Blind tasting (sensory acceptability)

All the tasted products had scores higher than 5, thus indicating that none of them were clearly rejected in an overall sense (Table 24).

Table 24. Mean acceptability values for the different products per country in blind tasting

Product	Overall	DE	ES	FR	IT	UK
Grilled fillet	7.1^{a}	6.9^{a}	7.0^{a}	7.5^{a}	6.8^{a}	7.3^{a}
Fish burger	6.5^{b}	6.2^{ab}	6.9^{ab}	7.1^{abc}	6.4^{ab}	6.0^{bc}
Fillets in olive oil	6.3^{b}	6.0^{b}	6.7^{ab}	7.2^{abc}	6.0^{bc}	5.7^{bc}
Fish Salad	6.3^{b}	6.0^{b}	6.2^{b}	7.4^{ab}	5.5^{c}	6.4^{b}
Smoked fillets	6.2^{b}	6.3^{ab}	6.7^{ab}	6.7^{c}	5.6^{c}	5.9^{bc}
Pate	5.8^{c}	5.2^{c}	6.4^{ab}	6.6^{c}	5.3^{c}	5.3^{c}

a-c: Mean values with different superscripts in the same column differ significantly ($p<0.05$).

The product characterization of all products was also assessed through CATA analysis in order to observe not just the acceptability of the product but also the consumer´s overall perception of each product in the five countries (Fig. 19).

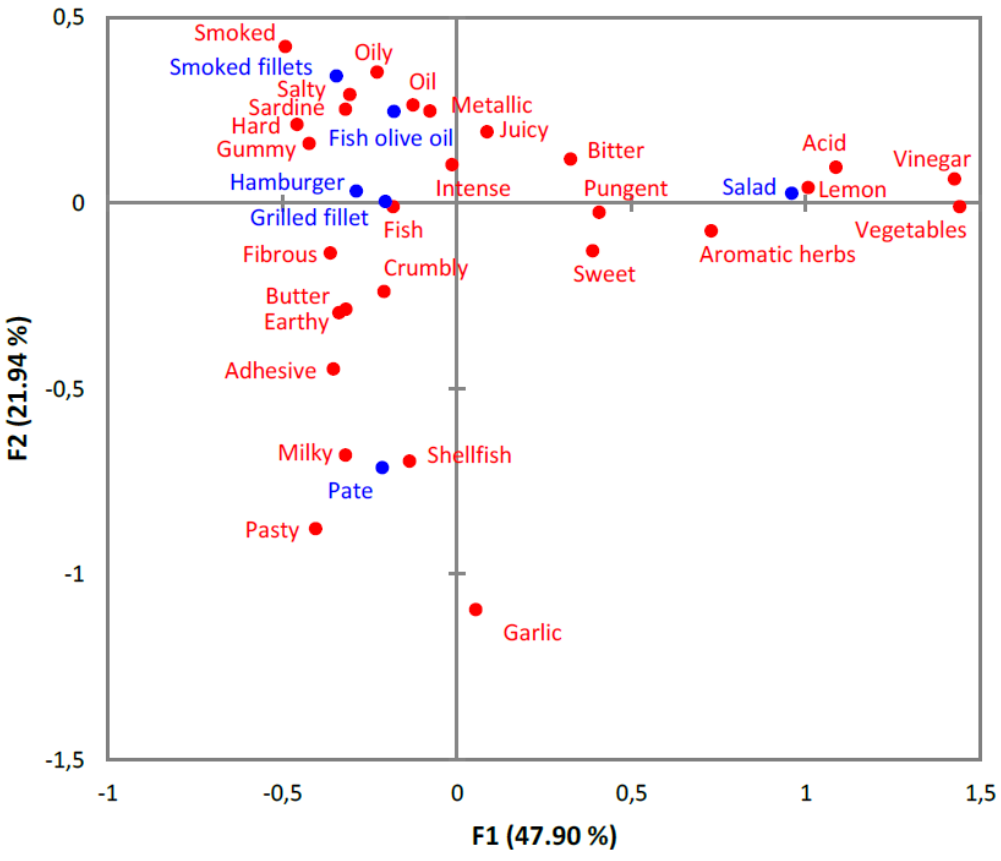

Figure 19. First two dimensions of the correspondence analysis performed over the consumers CATA data (n=510)

Consumers were also able, to properly describe in sensory terms the different products, especially the fish pate and salad, which were located alone in different places (Figure 19). The fish pate was characterized by its higher garlic and milky odor/flavor and by its pastiness. The fish salad was mainly described as acid/vinegar lemon as a result of the dressing sauce. The grilled fillet had the highest fish flavor while the hamburger was the hardest and gummy product. Obviously, the smoked fillet presented the highest values for the smoked flavor/odor and for the salty taste as a result of the elaboration process. Finally, as expected, the fish in olive oil were described as having oil flavor and oily texture and the highest sardine flavor/odor.

Table 24 showed that products with a lower degree of processing were those who generated higher scores and higher acceptability in the blind test. The recruitment procedure used in the present study (regular fish consumers) could explain the higher preference for those products having the genuine sensory properties of fish, without any interference. It seems reasonable to infer that products having a higher degree of processing would be more appropriate for consumers who do not like fish because of its taste, presence of bones, odor, etc. In these cases, the existence of different processed alternatives could be a good solution for those individuals looking for a more convenient and less “fishy” product.

4.5.2.3 Overall liking in the full informed condition

The overall liking was assessed after having tasted each sample and after having read the full written description of each product. The acceptability scores obtained in this case were similar to those obtained for the expectations and for the blind tasting. Again, the grilled fillet was the preferred product and the fish pate the less accepted (Table 25).

Table 25. Mean acceptability values for the different products per country with full information

Product	Overall acceptability	DE	ES	FR	IT	UK
Grilled fillet	7.1^{a}	7.0^{a}	7.3^{a}	7.5^{a}	6.8^{a}	7.1^{a}
Smoked fillets	6.5^{b}	6.5^{ab}	7.1^{ab}	6.9^{ab}	6.2^{ab}	6.1^{b}
Fillets in olive oil	6.4^{bc}	6.0^{bc}	7.0^{ab}	6.9^{ab}	6.0^{b}	5.8^{b}
Fish salad	6.3^{bc}	5.9^{bc}	6.4^{b}	7.5^{a}	5.5^{bc}	6.2^{ab}
Fish burger	6.2^{c}	5.7^{bc}	6.5^{b}	6.8^{ab}	6.0^{b}	5.7^{bc}
Pâté	5.6^{d}	5.2^{c}	6.5^{b}	6.5^{b}	4.9^{c}	4.8^{c}

a-d: Mean values in the same column with different superscripts in the same column differ significantly ($p<0.05$).

Similarly to what was observed in the blind tasting, some differences were detected depending on the country of origin of the participants. Anyhow, only one product, the fish pate, had negative acceptability scores (below 5 in the scale) in Italy and in UK.

In general, and in agreement to what was observed in the blind tasting, consumers belonging to the "Innovators" segment tended to score the samples higher than the "Traditional" segment. This difference was significant for the pooled data and for Spanish, German and Italian consumers. Anyhow, the interaction segment x product was always not significant ($p>0.05$) indicating a similar preference pattern in both segments.

4.5.2.4 Confirmation/disconfirmation of expectations

According to the four routes to psychologically that describe how disconfirmation created by expectations may influence product quality perception (assimilation, contrast, generalized negativity and assimilation-contrast) (Anderson 1973) and based on the obtained results, the participants in the present study behaved according to two routes: assimilation and contrast (Figure 20).

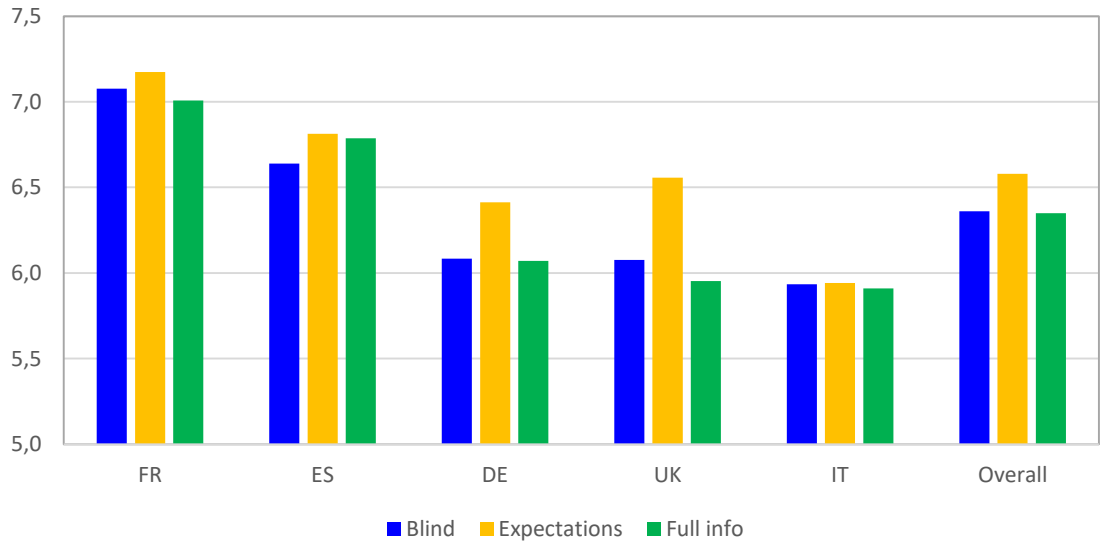

Figure 20. Mean acceptability for each country and all the samples in blind, expected and full informed conditions.

The only country where an assimilation effect was observed was in Spain, where the discrepancy between expectations and the product performance (i.e. blind tasting) was minimized (i.e. assimilated) by the consumer by shifting his/her perception closer to his/her expectation (i.e. full information). In the remaining countries and in the pooled data, a contrast effect was observed, especially in the UK. Contrast theory assumes that the consumer will magnify the disparity between the product received and the product expected. Nevertheless, in most cases the difference between the blind and the fully informed tasting was not significant ($p>0.05$). It is worth highlighting the lower values observed in Italy when compared to the other countries, especially for expectations. This difference might be due to an idiosyncratic use of the scoring scale, even though further information would be needed in order to confirm this hypothesis.

4.5.3 Purchase probability

Market researchers commonly use a mathematical technique called intent scale translations to convert a respondent's stated purchase intentions into actual purchase probabilities. To avoid this translation, in the present study the Juster's 11-Point Probability Scale was chosen as the option to make the assessment. The Juster scale in its many applications has been found to be superior as a predictive measure of future purchase behavior compared to other intentions scales. Table 26 shows the mean values

of this probability scales obtained for each product, both for the pooled data and for each county.

Table 26. Purchase probability for each product and country

Product	Overall	DE	ES	FR	IT	UK
Grilled fillet	6.6^{a}	6.7^{a}	6.4^{a}	7.4^{a}	5.9^{a}	6.7^{a}
Smoked fillets	5.6^{b}	5.9^{ab}	5.7^{ab}	6.1^{bc}	4.9^{ab}	5.2^{b}
Fillets in olive oil	5.4^{b}	5.3^{bc}	5.8^{ab}	6.2^{abc}	4.9^{ab}	4.6^{bc}
Salad	5.3^{b}	5.2^{bc}	4.9^{b}	7.2^{ab}	4.0^{bc}	5.3^{b}
Fish burger	5.1^{b}	4.8^{bc}	5.3^{ab}	6.2^{abc}	4.8^{b}	4.7^{bc}
Pate	4.3^{c}	4.1^{c}	4.8^{b}	5.6^{c}	3.4^{c}	3.4^{c}

a-c: Mean values with different superscripts in the same column differ significantly ($p<0.05$).

Taking into account that Juster scale is a 11-points scale (from 0 to 10), the probability values obtained ranged from 34% of purchase probability for the fish pate (in Italy and UK) to 74% for the grilled fillet (in France). The values reported in Table 26 showed a similar pattern with those obtained for the acceptability in the full informed condition.

It has been stated that general food choice motivations, such as health and convenience in preparation, can influence the purchase intention towards some products (Shan et al., 2017). Thus the observed preference for the grilled fillet could to be related to a health association due to less processing of the product.

4.5.4 Product image perception

Consumer acceptance of new food products, is complex and thus is influenced by several product- factors such as sensory characteristics, price, healthy ingredients and related claims, and also by consumer-related factors that derive from a social-psychological perspective (Lahteenmaki, 2013; Van der Zanden, Van Kleef, de Wijk, & Van Trijp, 2014). Therefore, product image information is critical when evaluating products.

In this study, 11 different adjectives were selected in order to assess how the different products tasted and described, were perceived by the participants. Figures 21, 22, 23, 24 and 25 show respectively the influence of these criteria on each product in each country (Germany, Spain, France, Italy and UK).

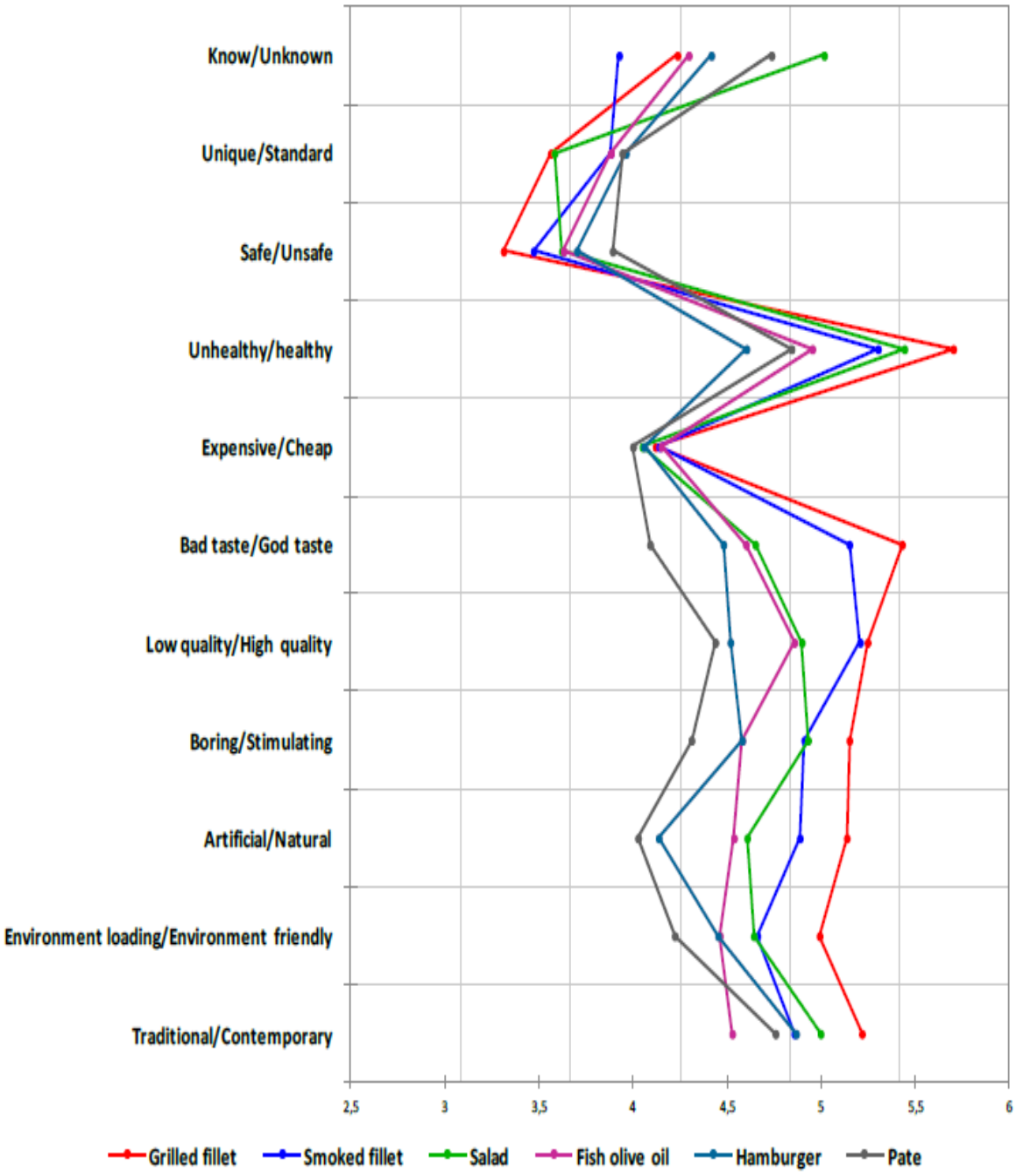

Figure 21 Differential semantic profile for participants in Germany

Figure 22 Differential semantic profile for participants in Spain

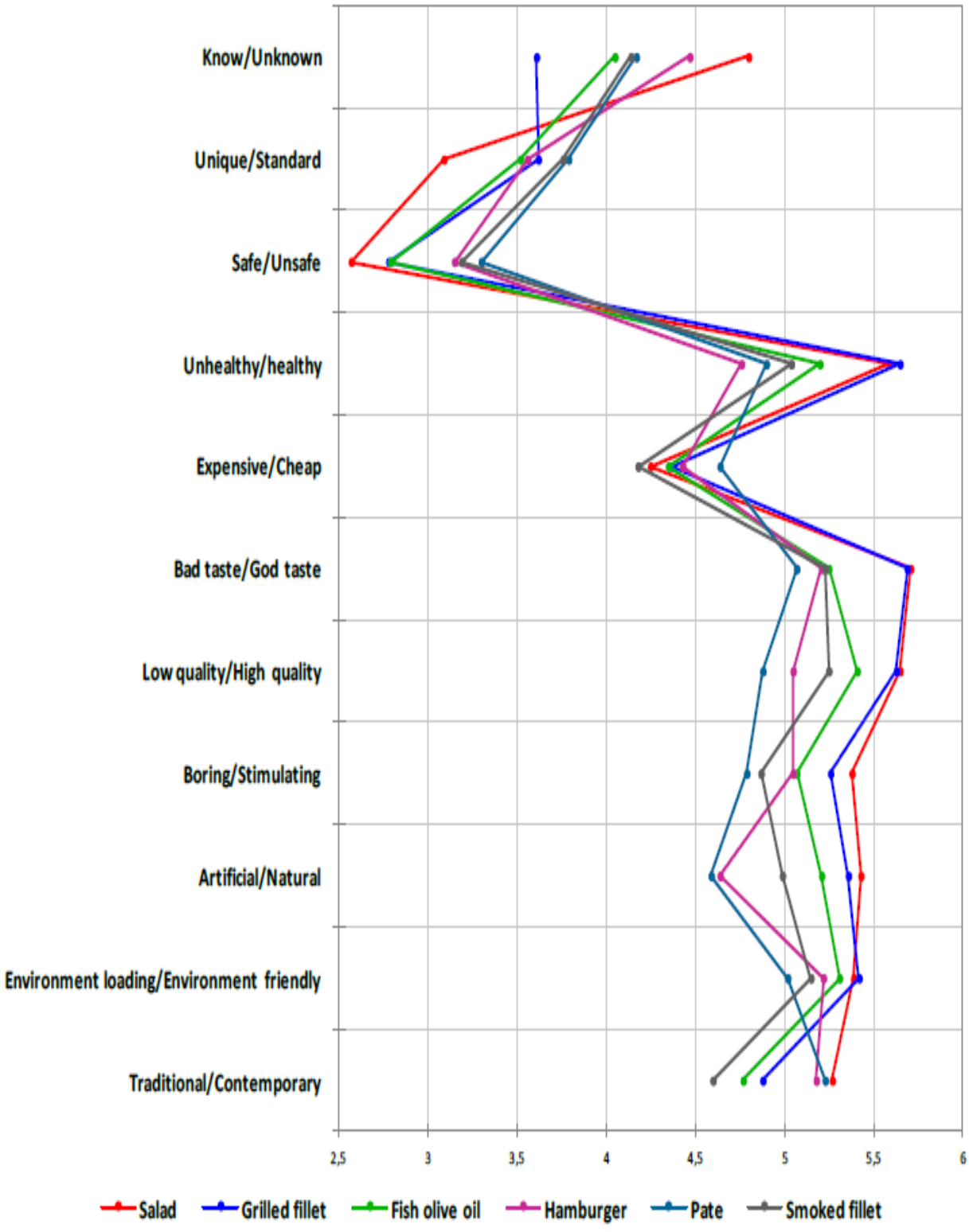

Figure 23 Differential semantic profile for participants in France

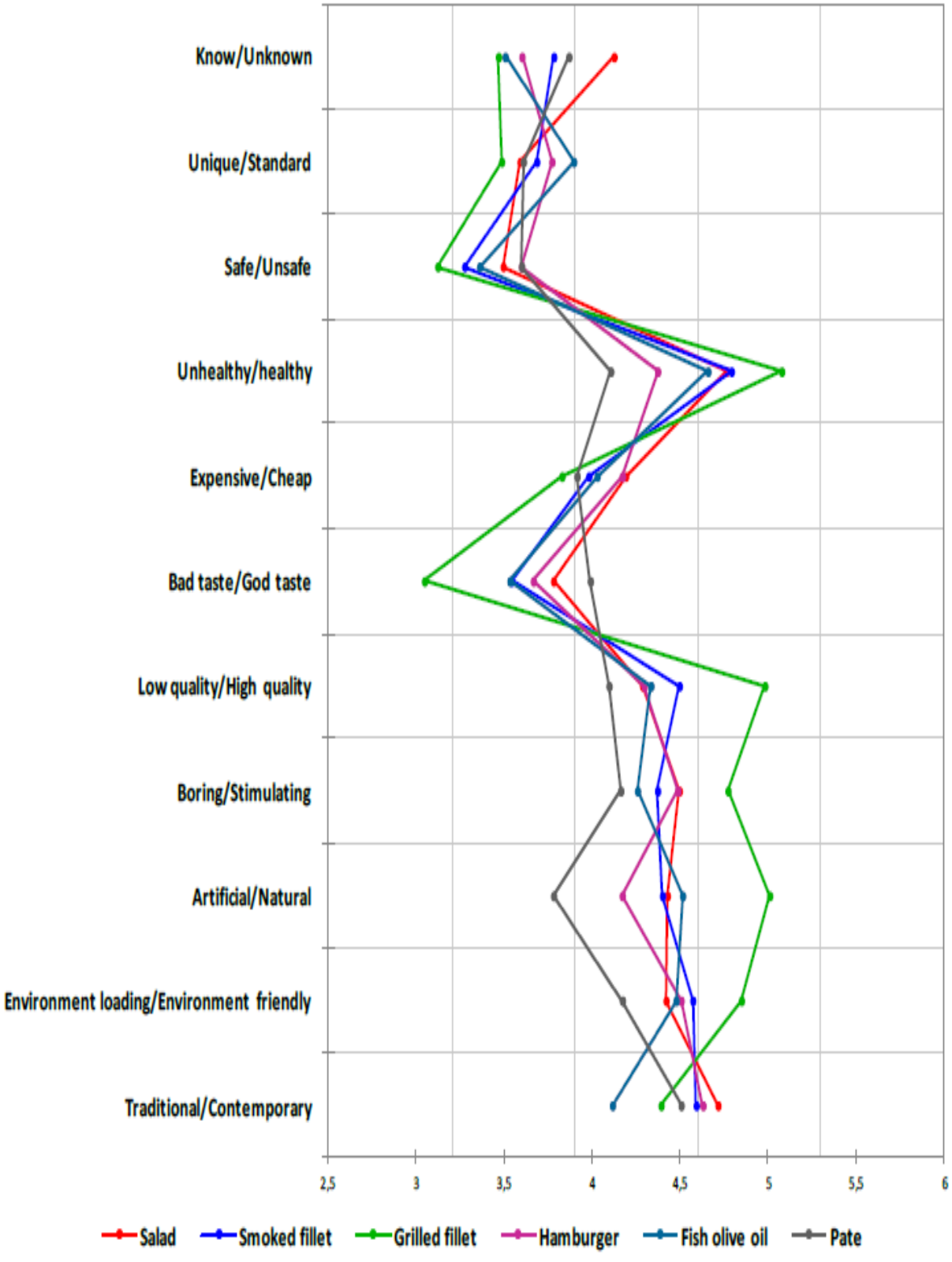

Figure 24 Differential semantic profile for participants in Italy

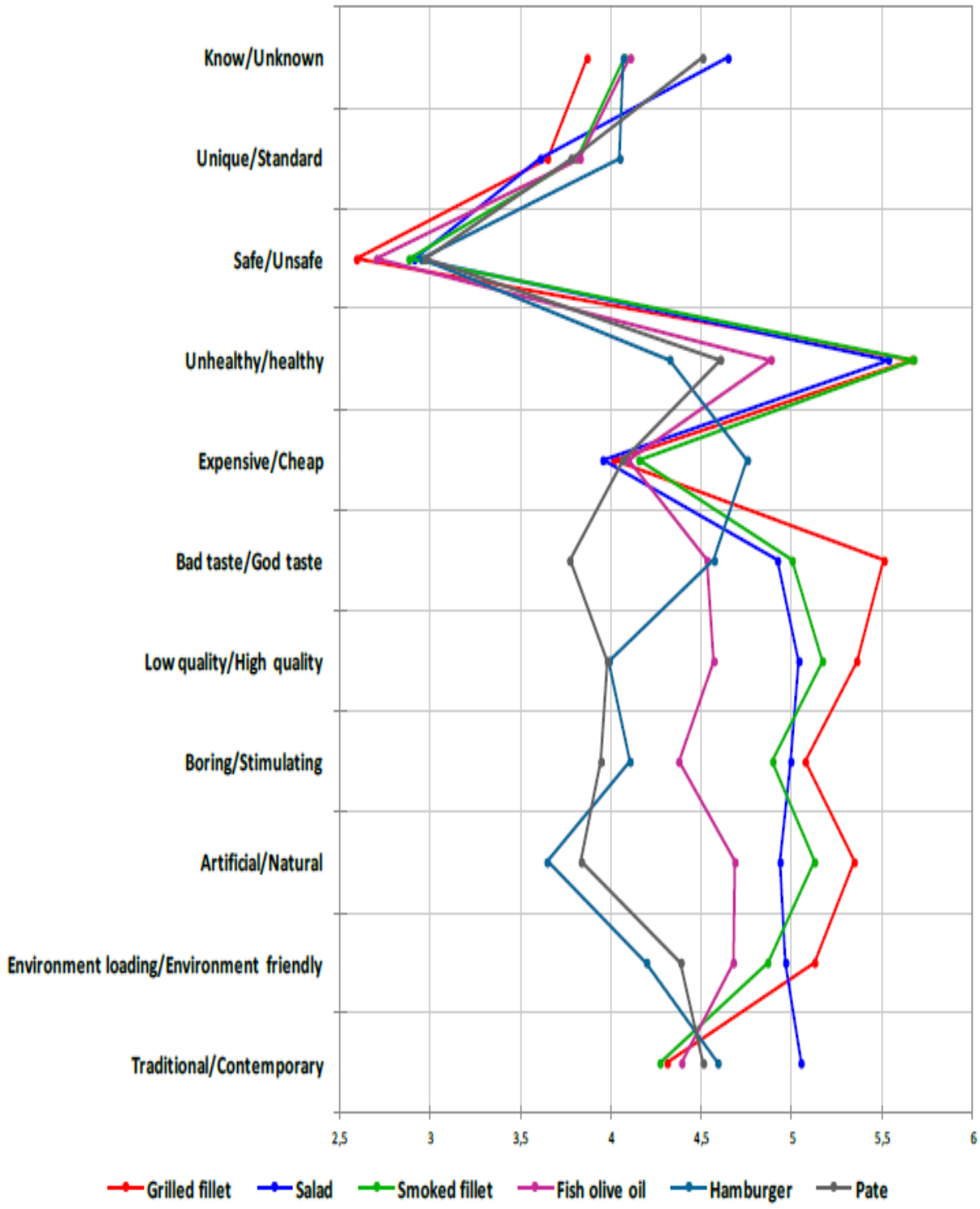

Figure 25 Differential semantic profile for participants in UK

Interestingly, the results provided by the differential semantic scales were those that showed higher discrepancies between countries. This finding seemed to indicate that even though the different products were perceived similarly in the different locations regarding the acceptability ratings (expected, blind and full informed), they were described in a clearly different way when dealing with the main intangible dimensions that might define them. These results however, deserve further and deeper analyses.

Generally speaking, the role of the country of origin of the participants was lower than expected, the variability being higher in some cases within countries than between countries. However, the image/perception of the different products other than the sensory properties, differed in an important way between countries, as well as their impact on the product acceptance and purchase probability. These results open a new framework of research aimed to understand the rationale behind the observed differences between countries and how they can be exploited to better design and commercialize the new products developed already.

5. OVERALL DISCUSSION

New product development involves as a part of its process to know all the properties that characterize the product as a whole. When a product is characterized there is a better knowledge of its properties possible optimization and potential drivers of acceptance. To accomplish this task, the use of descriptive analysis comes in handy and therefore, the correct use of attributes to describe the product. In this sense, CATA proved to be a useful methodology in this study, especially when using trained assessors to perform it. Different advantages were gained, first able, the generation of descriptive attributes (with trained assessors), ensured the quality of the descriptive profile, avoiding useless terms and thus reducing the risk of forgetting relevant attributes. Second able, the use of CATA with trained panelists helped to have the description of a product without the probability of having a consensus bias, a common problem with other traditional descriptive methods. In addition, a higher agreement between assessors when describing the different fish species (1st publication) and when characterizing the developed prototypes (3rd publication) was also obtained when performing CATA with trained assessors. The agreement among tasters translated in to a more uniform attribute and product description. It is also worth mentioning that since CATA tests data were analyzed through correspondence analysis, the main differences between samples and not their similarities were highlighted, since once again the accurate selection of attributes depended on choosing those that best defined the samples (Greenacre and Blasius 1994). A good discriminant ability was also observed with CATA performed with trained assessors both for the analyzed species and when describing the products.

When developing new aquaculture fish products there were two major aspects considered in this work: the characteristics of the raw materials that are being used to generate the product prototypes and the consumers ideas for new fish products. By analyzing the raw materials (the five selected fish species) is often possible to understand the advantages and disadvantages that these could have (physicochemical and sensory properties) for developing a product. In consequence, specific processing conditions can be addressed to produce a final product with the desired properties (Mc Clements 2000). The differences found in the five selected species showed their potential for addressed product development, which could favor the demand for farmed

fish. The physicochemical properties of foods (compositional, somatometric and instrumental texture) and sensory defining attributes, influence the perceived quality and behavior of products during their production, storage and consumption. Therefore in this study, it was important to define the fish species characteristics. The selected species in this work presented a wide range of physicochemical and sensory characteristics.

Considering the relevance of consumer behavior and the fact that it is the ultimate buyer who makes purchase decisions, the measure of consumer´s attitudes and perception about a product idea is of high importance. This allows turning a concept into a product as well as having feedback from their reactions to the product design and physical features. A product idea or concept can be developed from market and consumer research considering different aspects of the product. Usually, it is a combination of the company information with consumer or, in industrial marketing, customer discussion groups. Consequently, involving consumers in the process of creation of new food products has been identified as a key point for new product development (Banovic et al., 2016) therefore the use of focus groups technique was performed in this study.

The focus groups executed in the five selected countries in this work, showed several differences. In the case of Germany and UK, the frozen fish fillet and the fresh fish fillets respectively were the main elicited ideas, showing a more conservative tendency. According to Thurstan and Roberts (2014), UK fish demand is lower than the government recommendations, reaching only 64% of the suggested intake, suggesting they are not used to a high frequency of fish consumption. Nevertheless, consumers are aware of these facts and are therefore willing to increase their intake (Food Standards Agency, 2010). In the same vein, aquaculture in Germany is a rather small industry and when compared with other EU member countries its overall production is small, largely due to the relatively limited distribution of fresh fish. Most German supermarkets do not currently have a fresh fish department, which affects overall consumption levels (FAO 2005). Therefore, Germany is a major importer of fish and seafood, relying heavily on foreign suppliers to meet internal demand. In 2013, the main selling point of fish and seafood in Germany was the foodservice industry, being the most popular storage type with 132 products is frozen, followed closely by chilled with 131 products (Mintel Global New Products Database (GNPD) 2014). Its latest exports belong mostly within

the frozen fish category with environmental claims (Ecuomonitor International, 2013), thus explaining their proposal for frozen fillets. All of the above could explain their non- processed product ideas elicitation thus showing both countries are still fish growing markets. Accordingly, when it came to assess the fresh fillet idea in the developed prototype: grilled fillet (using Greater Amberjack), consumers in these same countries showed a higher preference for this product. These facts were also observed in their expectations scores before actually tasting the product (analyzing the product concept) and while actually tasting it. In general these consumers expectations before having any information about these two products and after having all the information about them, were concurrent with their initial suggested ideas, showing a congruent pattern.

In the case of Spain ready to eat meals and burgers were the main proposed ideas during their focus groups sessions, thus, a ready to eat salad with fish and fish burgers shaped as fish were the developed prototypes for these ideas. Spain is the European country with the highest monthly consumption of fish in households. 92% of Spaniards consume fish and aquaculture products on a monthly basis, thus showing a high potential as standard fish consumers (Bord Bia, 2017). In addition it has also been stated that 65% of Spanish, who buy fish/aquaculture products, often choose fresh produce products, which seemed to indicate that the fish salad could be a suitable prototype for the idea. Nevertheless, when evaluating the concept of the ready to eat salad with fish, the Spanish consumers showed low expectations when assessing the concept, thus presenting an incompatibility with the proposed ideas in the focus groups sessions carried out within the same country. In addition, when the product was tasted with and without information, the overall acceptability did not increase either. Therefore, it can be said that this concept was neither a concept match nor a well-accepted product by the Spanish consumers. This could also be explained by the fact that despite the consumer`s healthy perception of the product, they also perceived it as unknown and with not such good taste in comparison to the other products. This unfamiliarity seemed to be the reason of the lower acceptance of this product. On the other hand the fish burger shaped as fish idea was assessed differently. Even though, the initial expectations exhibited rather low acceptability scores, when the product was actually tasted its overall acceptability was positively increased, thus showing that this product could actually match the expectations of the initial proposal in the focus groups. This product was

perceived as healthy and with good taste thus explaining the reason why it was in their first two product choices. Fish burgers shaped as fish was also thought to meet a specific criteria: to improve children`s fish consumption. Shapes of fish products could be appealing to children consumers. When questions about why children don't eat more fish are raised, the price comes up as the first obstacle, followed by sensorial issues such as bones, and smell. This product is bones free, uses a white species with mild flavor and has good quality at a reasonable price. In order for families with children to increase their aquaculture fish consumption, this product could accomplish some of the general obstacles.

In France the proposed concepts during focus groups, involved cured products from grey mullet and marinated fish with a stronger spicy type flavor. High quality products seemed to be a common denominator with the French consumers. The closer prototype to fit in this criteria was grey mullet smoked fillets. In France, salmon is the second most sold species, and is bought in many different ways being the smoked one of the most popular of them. There is a very rich and differentiated offer of smoked salmon in supermarkets and for a long time, smoked salmon with pasta has been the main fish dish among French consumers (Seafood Study France, 2016). Being smoked flavor familiar to these consumers, it seem to be plausible to favor their acceptance of other smoked species different from salmon such as grey mullet. When assessing the French expectations of just the product idea it was perceived positively, afterwards when the product was blind tasted (no information) the acceptance scores slightly decreased. Nevertheless once these consumers were provided with the full information of the product the acceptance was positively increased. Therefore even though it was not their first choice among the six tested products it can be said it was well accepted. This acceptance was also related to a valued good taste and high quality of this product, which matches their preference in premium products previously mentioned in their focus groups sessions.

In the case of Italy, one of the main proposed ideas during the focus groups sessions, was cooked steamed fillets in a visible jar. Thus fillets in olive oil in a transparent glass jar was the developed prototype to match this criteria. Italy is the second largest olive oil producer in the European Union (EU) after Spain. Italy is also a leading olive oil consumer with approximately 11 liters per capita per year. More than 80 percent of the

consumption is extra virgin and household penetration of the olive oil is 90 percent, while the remainder goes to canning and cosmetics industries (USDA, 2017). Thus making this concept a very suitable idea for this country. When the Italian consumers were assessing the idea of this product (concept,) they selected it as their second choice of all the six tested products, all though not with high scores. Thus, it could be said that this concept had low corresponding with the initial proposal of the focus groups. When it came to actually taste the product without any information about it, a poor acceptability was obtained as well, in agreement with the low acceptability when evaluating the product in the full information condition. According to the analyzed parameters taste was the main obstacle in this product`s acceptability, despite the natural and healthy perception of the product and the allegedly habit of oil consumptions of the Italians.

Generally speaking, when it came to experimenting with fish products, respondents from France, Spain and UK seemed to be much more open towards aquaculture products, thus suggesting to combine them with different accompaniments, like vegetables, sauces, dips and marinades. They were quite open to new tastes and possibilities. On the other hand, respondents from Germany and Italy seemed to be more traditional when it came to new fish products. The one thing that respondents from all the countries agreed on was convenient fish product option. This convenience is related to the packaging, which could be used to have information in how to cook the product. The use of packaging in terms of more convenient for cooking and preparing the dish stood out in all countries. They all preferred a package that would allow physical product to be visible, and mentioned that the package should be colorful, possibly with the image of the fish species involved. Moreover, they all agreed that package should always be accompanied with possible recipes and suggestions for cooking. The presentation of the fish product was also considered as a very important cue.

When developing a product it is important to use a market driven method, in which segments are defined by asking consumers about the attributes that are important for them in a product. This market segmentation helps to identify the factors that affect the purchase decisions, thus grouping consumers according to presence or absence of these factors, dividing a population into groups with similar values and lifestyles. Having

specialized alternatives to smaller segments of the total market may capture enough segments of the market to defeat competitor`s strategy (Boone & Kurtz, 2015). Thus each one of the considerations of the consumers when assessing a product has major relevance. This explains why differences between countries occurred when evaluating their perceptions on the products properties such as healthy, high quality etc, showing what one population might like another would dislike. For instance smoked, salted, dehydrated or brine products do not seem to have much success in the Spanish market, (Bord Bia, 2017) thus explaining its lower acceptance in this country in comparison with other countries like France. In general, French consumers were the ones of all five countries who gave higher scores to all six tested products, which could be related to their habits of fish consumption. Nevertheless, even though countries like Spain and France are among the biggest consumers of farmed fish in Europe, there still are myths and poor opinions on aquaculture safety that need to be overcome. Therefore, to join consumers with fish farming, there is a great need for education to be spread to allow them to understand that farming is not only safe but also might just as well offer the quality guarantees they are seeking (Seafood Study France, 2016) which can be achieved through the introduction of these products in the market.

5.1 Limitations of the study

Even though the present study showed an overall acceptability towards the developed products there are still bottlenecks that need to be resolved, especially towards the different quality image of the aquaculture fish in comparison to wild fish. To overcome this situation, it would be necessary to change overall consumer perceptions and attitudes towards new aquaculture fish species and their products. In order to achieve this purpose, communication and diffusion efforts should be considered by the aquaculture industry to improve consumer´s perception on farmed fish products.

In this sense, since the developed products in this work came from not known fish species, these emerging species would need as a first step to be introduced and promoted before actually entering their derived products in the market. This procedure could have an influence in decreasing rejection from potential consumers.

In addition and in order to help products to succeed in the market, these should be differentiated from the vast existing competition. Thus, some marketing strategies should be implemented to make a successful launch. A possible suggestion could be to promote the fact that the species are cultured with sustainable methods and therefore, can lead to more environmentally friendly products.

Another remaining challenge is to create a specific demand for the European aquaculture products. In order to accomplish this, consumer needs should be fulfilled. One mode to satisfy these necessities is to make available convenient products in preparation, such as the ready to eat dishes, as it has been shown in the results of the focus groups in this study. Offering services that do not exist in the competing markets could provide an advantage of product choice by consumers.

5.2 Future research

Considering the obtained results of this thesis, the next phase would be to ensure a relationship between products and consumers.

As a first step, product mock ups should be developed and these should have a designed package that includes labels that could also function as valuable signals, such as quality certifications and health claims.

Subsequently, the developed mock ups should be used to identify the optimal extrinsic product quality profiles for targeted consumers. This could facilitate associations between the wanted characteristics of a product and the sector of consumers these products could be addressed to.

In addition written and broadcasted communication may be used as an incentive for consumers in order to test their influence on their buying intentions.

Furthermore, Small and Medium Enterprises should be involved in the process to manage the product design and develop a market approach. Products should be in fact developed at pilot scale and placed in actual supermarkets for testing consumers' reactions in situ, and thus purchase probability could also be measured.

6. CONCLUSIONS

According to the objectives of this work the following conclusions were obtained:

The sensory descriptors obtained with CATA method with trained assessors, were a platform for the further characterization of the fish species. This methodology generated reliable attributes with good discriminant ability for describing different species. Therefore, these can be used to assess different types of fish in order to make a consistent sensory profile.

Both sensory and physicochemical characterization were useful tools to understand the species properties. These characterizations along with the correlation of the different assessed parameters completed a detailed profile of each selected fish species. The acquired knowledge on each of the species showed their potential for future product development.

Focus groups showed that consumers were open towards new aquaculture fish products, they were quite environmentally conscious, and showed interest in farmed fish species. Packaging and product flexibility in preparation was a main concern in all 5 countries, showing this should be a part of the developing products. Therefore, is important to include these opinions and address the specific needs that the market is demanding when designing new fish products.

The technical feasibility of the species added to the experts evaluation on the generated ideas allowed to design the most appropriate products for each of the species.

Products characterization with trained assessors exhibited CATA method as a good alternative to the Quantitative Analysis, it can show a trust worthy profile and needs less time when assessing samples.

Products with a lower degree of processing were those who generated higher acceptability in the consumers expectations and higher probability for purchase intention. The recruitment procedure used in the present study (regular fish consumers) could explain the higher preference for those products having this genuine sensory properties of fish, without any interference. Nevertheless, the existence of different processed alternatives could be a good solution for those individuals looking for a more convenient and less “fishy” product.

The two segments of consumers previously identified ("Involved traditional" and "Involved innovators") had a low impact on the results obtained. The low effect of these two segments can be due to the relatively low novelty of the selected products. In fact, all of them exist already in the market, although using different fish species.

Even though the developed products were not able to reach the initial consumers expectations, most of them were positively accepted during the blind tasting. Therefore all six selected fish products assessed in this study seemed to have a specific place within the European market, even for the least appreciated product (e.g. fish pate).

The information provided in this study is an instrument to understand the way consumers perceive the different fish products and their characteristics. Therefore it is a useful tool for fish product producers and for possible launching strategies.

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