Valorization of recurrently discarded fish species in trawler fisheries in North-West Spain

M. Blanco² · F. Domínguez-Timón² · R. I. Pérez-Martín² · J. Fraguas² ·
P. Ramos-Ariza² · J. A. Vázquez² · A. J. Borderías¹ · H. M. Moreno¹

Revised: 1 August 2018 / Accepted: 7 August 2018 / Published online: 3 September 2018
© Association of Food Scientists & Technologists (India) 2018

Abstract The progressive elimination of fish discards established by the European Union Council in 2013 has stimulated the valorization of flesh from discarded high-quality species with good protein functional properties but which frequently have excessive fish-bones, fat, strange flavours, soft texture, etc. The present study therefore focuses on valorization of the extracted muscle (minced muscle), from several fish species frequently discarded in north-western Spanish fisheries (Atlantic Ocean): Blue whiting (*Micromesistius poutassou*), Mackerel (*Scomber scombrus*), Red scorpionfish (*Scorpaena scrofa*), Pouting (*Trisopterus luscus*) and Gurnard (*Trigla* spp.). Valorization of these discarded fish resources is a key objective for the survival of the fishery sector in this area. In this regard present study was planned to examine the behaviour of the mince during 6 months of frozen storage by means of physicochemical and sensory analyses, and to test consumer acceptance of three technologically different products (burgers, nuggets and structured fingers) prepared with fish mince from different species. Results indicated that protein aggregation started at the outset of frozen storage but progressed very slowly, with the exception of non-washed blue whiting and red scorpionfish minces. Moreover, during frozen storage lipid oxidation increased in all samples; the increase was with two objectives highest in

minced mackerel, a fatty fish, but no rancid flavour was detected. All mince samples presented acceptable physico-chemical properties and good sensory acceptability after 6 months of frozen storage. Acceptability of final products made with these minces was high in all cases. Burgers were more acceptable for consumers aged over 40 and fingers and nuggets more for younger people.

Keywords Landing obligation · Fish discards · Fish mince · Fish muscle valorization · Frozen storage

Introduction

In 2013 EU Regulation No 1380/2013 established as an objective the progressive elimination of fish discards by introducing the obligation to land (LO: landing obligation) all specimens of all species under TAC regulations (TAC: total allowance captures). When necessary, the new Common Fishery Policy also aims to make the best use of unwanted catches. There are three main reasons for discarding: (a) fish species of low commercial value, (b) fish under minimum conservation reference sizes and (c) non-quota fish species; however, most of those discarded specimens possess significant amounts of bioactive compounds besides good nutritional value, containing high quality proteins, fats or minerals among others (García-Moreno et al. 2013; Blanco et al. 2015; Vázquez et al. 2017). In this context, one of the most challenging aspects of the LO is therefore the need to develop different alternatives for valorization of those discarded species, which must now be kept on board, with the ultimate aim of maximizing the return on fishing captures, alleviating the costs imposed by the new regulation, and contributing to

✉ H. M. Moreno
hmoreno@ictan.csic.es

¹ Institute of Food Science Technology and Nutrition (ICTAN), Spanish National Research Council (CSIC), C/ José Antonio Nováis 10, 28040 Madrid, Spain

² Marine Research Institute (IIM), Spanish National Research Council (CSIC), C/ Eduardo Cabello 6, 36208 Vigo, Pontevedra, Spain

long-term environmental, economic and social sustainability.

Together with the most commercially valuable species captured by Galician fishing fleets (North-West of Spain) (hake, sole, monkfish, megrim, etc.), other non-target species are unintentionally caught and are mostly discarded (Ordóñez-Del Pazo et al. 2014; Blanco 2015). In view of the level of interest shown by fishermen and fish producer organizations, together with their known high nutritional value, the present study focuses on some habitually discarded species such as Blue whiting (*Micromesistius poutassou*), Mackerel (*Scomber scombrus*), Red scorpionfish (*Scorpaena scrofa*), Pouting (*Trisopterus luscus*) and Gurnard (*Trigla* spp.). Another key factor in selecting these species was their capture stability throughout the year.

The valorization of fish muscle proteins from high-quality discarded species has been studied, and these proteins are considered suitable for the preparation of different seafood products with enhanced added value in comparison to the traditional preparation of fish meals or fish oils (www.valdescar.com; Moreno et al. 2010a, b; Moreno et al. 2009). However, this is the first study analysing the preparation of different ready-to-cook products from muscle of the above mentioned species. For this purpose, fish muscle was first mechanically extracted, followed or not by fish mince washing depending on the types of products to be prepared; finally, natural additives (cryoprotectant and antioxidant) were added, and samples were frozen to produce a new raw material suitable for use in preparing different seafood products with different textures and flavours.

The aim of the present study was then to investigate frozen stability, up to 6 months at $-20\text{ }^{\circ}\text{C}$, of minces from those 5 fish species discarded in the Galician coastal trawler fishery, and also to obtain a consumer evaluation of three types of products, chosen as examples of different manufacturing procedures.

Materials and methods

Raw material

The selected fish species, Blue whiting (*Micromesistius poutassou*), Mackerel (*Scomber scombrus*), Red scorpionfish (*Scorpaena scrofa*), Pouting (*Trisopterus luscus*) and Gurnard (*Trigla* spp.), were captured by a commercial trawler during a 1-week trip, operating off the Northwest coast of the Iberian Peninsula (areas VIII_c and IX_a ICES) in September 2016. Immediately all the catch was on board, 100 kg of each selected species was separated from commercial ones and distributed in 12 kg iced boxes. Once in

port, all the fish was landed and transferred to the pilot plant where it was kept on ice until further processing.

Fish processing

Fish were gutted and headed by hand within 24 h of landing. Afterwards, fish meat was mechanically separated from bones and skin (Baader 694, Germany). Then the minced muscle from each species was divided into two batches. One was mixed with cryoprotectant (4% sorbitol, Panreac Química SLU) and antioxidant (400 ppm, Antiox 1 Tocopherol, Altaquímica, S.A.), placed in a freezer-tray and frozen in a plate freezer at $-20\text{ }^{\circ}\text{C}$. The other batch was washed with iced water (1:5 p/v) and slowly shaken for 10 min. Then, the fat was removed from the surface, and the mince was separated from the water using a rotary sieve. At this point the moisture content of the meat had increased from about 76–79 to 90–92%; it was therefore essential to remove the excess of water with a screw press (Baader 523, Germany) up to around 79–82% depending on the species (Table 1). Finally, a kneader was used to add the sorbitol and antioxidant to the mince. As in the unwashed batch, the mince was placed in a tray and frozen in a plate-freezer ($-20\text{ }^{\circ}\text{C}$). Frozen mince blocks (two for each species) were placed in plastic bags and stored in cold rooms at $-20\text{ }^{\circ}\text{C}$.

Physicochemical and sensory analyses of fish mince

Mince from the ten frozen blocks was subjected to physicochemical and sensory analyses and also used as raw material to prepare the final restructured products.

Proximate analyses and muscle yield

Ash, fat, crude protein and moisture contents of washed and unwashed mince from all species were determined in quadruplicate (AOAC 2000). Crude protein content was measured with a LECO FP-2000 Nitrogen Determinator (Leco Corporation, St Joseph, MI, USA). Muscle yield was determined as the percentage of muscle obtained from the headed and gutted fish.

SDS-PAGE in polyacrylamide/agarose gels: analysis of myosin cross-linking

Myosin heavy chain cross-linking was studied by observing the decrease in the MHC monomer and the increase in MHC polymer contents, separated on agarose/polyacrylamide gel (Konno and Imamura 2000). Fish mince was analysed at the beginning of the study and after 6 months of frozen storage ($-20\text{ }^{\circ}\text{C}$).

Table 1 Proximate analysis of fish minces (%) and muscle yield (%)

Samples	Fish mince proximate composition (%)				Muscle yield (%)
	Moisture	Ashes	Lipids	Proteins	
Blue whiting	76.40 ± 0.11	1.28 ± 0.09	1.25 ± 0.01	16.62 ± 0.12	57.84 ± 5.01
Blue whiting w	81.93 ± 0.05	0.51 ± 0.07	0.66 ± 0.03	13.18 ± 0.11	
Mackerel	66.50 ± 0.22	1.22 ± 0.09	4.28 ± 0.60	17.94 ± 0.26	50.25 ± 2.98
Mackerel w	75.25 ± 0.53	0.42 ± 0.08	3.18 ± 0.80	13.13 ± 0.04	
Red scorpionfish	74.44 ± 0.20	1.19 ± 0.04	1.78 ± 0.10	16.49 ± 0.16	51.24 ± 4.13
Red scorpionfish w	81.96 ± 0.15	0.41 ± 0.00	1.21 ± 0.00	11.16 ± 0.05	
Gurnard	74.32 ± 0.53	1.19 ± 0.02	1.49 ± 0.10	17.27 ± 0.14	40.72 ± 4.03
Gurnard w	82.51 ± 0.10	0.45 ± 0.04	0.36 ± 0.00	12.23 ± 0.06	
Pouting	75.30 ± 0.93	1.29 ± 0.09	1.00 ± 0.10	16.66 ± 0.07	34.64 ± 3.42
Pouting w	80.10 ± 0.28	0.51 ± 0.09	0.47 ± 0.01	14.96 ± 0.07	

w whashed muscle

Differential scanning calorimetry (DSC)

Thermal behaviour of the myosin from different fish minces was monitored using a differential scanning calorimeter (DSC Q1000, TA Instruments, New Castle, USA). The temperature (°C) and transition (ΔH -J/gdm-) enthalpies were determined for each fish mince at the beginning of the study and after 6 months of frozen storage.

Apparent viscosity (μ_{app})

The apparent viscosity, as indicative of protein functional quality, of all fish minces was determined according to Borderías et al. (1985) using a solution of muscle in a 5% NaCl solution (1:5 p/v). Measurements were carried out in triplicate at the beginning of the study and after 3 and 6 months of frozen storage. The results were expressed in centipoises (cP).

Cooking loss (CL)

Cooking loss was performed as described by Moreno et al. (2011). CL was expressed as percent of water released per 100 g of sample.

Lipids oxidation

Thiobarbituric acid reactive substances (TBARS) were determined at the beginning of the study and after 3 and 6 months of frozen storage, in order to evaluate lipid oxidation (Vyncke 1975). The results were expressed as mg of malonaldehyde equivalents per kg of sample (mg MDA/kg muscle).

Sensory analysis

Fish mince The appearance, taste and texture of the fish minces were analysed by 10 trained panellists in a standard sensory panel room using a non-structured 10-point scale. Samples were previously thawed, cut into portions 0.8 cm thick and grilled for 2 min before sensory analysis.

Consumer test: final restructured products The test consisted of 40 adult frequent seafood consumers. Consumers were asked to judge the general acceptability of the products by assigning scores on a 5-point scale to each product. The analysis was segmented according to sex and age.

Three different types of products were made with the fish mince. Depending on the final product, different minces were used to achieve the best physicochemical and sensory properties. Various formulations were tested (results not shown), but only the most appropriate are included in the results section. Test products were prepared as follows:

Burgers These were prepared using unwashed fish mince and washed Mackerel mince. The suggested formula was: mince (84.9%), Alaska Pollock Surimi grade KA (10%), modified starch (4%), salt (0.8%) and garlic powder (0.3%). The mince was gently blended in a blending machine with the rest of the components to preserve mince particle structure. The burgers were shaped in a manual burger machine. The burgers (~ 50 g) were frozen and stored at - 40 °C until use for the consumer evaluation test, when they were cooked on a grill.

Nuggets These were prepared using washed minces of Red scorpion, Blue whiting and Pouting (all lean species whose muscle has better gel-forming ability). The formula was: 80% mince, 15.2% surimi (97% surimi + 3% salt), 4% modified starch and 0.8% total dough. The surimi was homogenized in a vacuum cutter (Stephan UMC 5, Stephan

Machinery, Germany) at chilled temperature for 10 min with 3% salt. Then the rest of the ingredients were added and the whole homogenized for 5 min more. After gelation, cubiform portions of around 3 cm were battered and pre-fried at 180 °C for 20 s to fix the batter. The nuggets were then frozen at − 40 °C.

Structured fingers These were prepared to imitate the natural structure of fish muscle, which is organized in flakes (imitation of myotomes and myosepta) (CSIC 2007). Two formulae were required to make this product: for myotome (A): 85.2% mince, 10% surimi (97% surimi + 3% NaCl), 4% modified starch, 0.8% salt; and for myosepta (B): 11.62% sodium caseinate, 1.5% CaCO₃, 0.2% fish gelatin (Juncá S.A., Girona, Spain), 3% Microbial Transglutaminase Activa WM (Ajinomoto Co.; Tokyo, Japan) and 83.68% water. Slabs of around 1 cm were formed after homogenizing. A thin layer of formula (B) was spread on the formula (A) slabs. “Sandwiches” were formed from four slabs of formula (A) with the corresponding layers of formula (B) in between. Lastly, pieces 1 cm thick were transversally cut from the slabs. These portions (like broad fingers) were battered and pre-fried at 180 °C for 20 s, then frozen at − 40 °C.

Statistical analysis

One-way analysis of variance was carried out with the SPSS® computer programme (SPSS Inc., Chicago, IL, USA), and differences between pairs of means were evaluated by the Tukey test using a 95% confidence interval.

Results and discussion

Proximate analyses and muscle yield

Table 1 shows the proximate composition of the fish mince and the muscle yield after mechanical extraction. As observed, proximate composition profiles were very similar in all samples, the sole exception being mackerel, with a larger amount of lipids ($p < 0.05$) and not considered a lean species. The moisture content of washed mince was higher than unwashed. It was decided to maintain the water content between 74 and 82%, which is similar to the natural content of fish muscle.

In general, lipid content was lower in washed than in unwashed minces ($p < 0.05$). This result is consistent with the process considering that the loss of fat is a consequence of the washing process, as fat floats on the water and is removed with the washing water (Park et al. 2013). The protein fraction was proportionally lower in washed than in unwashed mince ($p < 0.05$). This result could be explained firstly by leaching-out of most of the soluble proteins

(lower molecular weight) during the washing step, and secondly due to the fact that the amount of water was greater in washed minces and so the percentage of protein was relatively smaller (Park et al. 2013).

Modification of protein structure during the process

SDS-PAGE in polyacrylamide/agarose gels: analysis of myosin cross-linking

As shown in the SDS-PAGE profile (Fig. 1), the MHC (Myosin high chain) band is denser in washed mince due to the fact that this fraction is proportionally greater with respect to the total protein. This could be due to the loss of other protein fractions of lower molecular weight (more soluble) in the washing step (Park et al. 2013). Washed mince showed more bands in the higher molecular weight area of electrophoretic gels (> 250 kDa), which could be molecules of polymerized or aggregated myosin (Núñez-Flores et al. 2018). This may also be related to the washing process, which could affect the protein muscle structure.

Comparison of the electrophoretic profiles of fish minces just after freezing (day 0) (a) and after 6 months of frozen storage (b) showed more bands with molecular weight over 250 kDa in the latter, indicating some polymerization or aggregation (Konno and Imamura 2000; Núñez-Flores et al. 2018). Also, after 6 months of frozen storage the MHC band appeared slightly denser than at day 0, indicating that native myosin had probably been slightly aggregated as a consequence of frozen storage.

Differential scanning calorimetry (DSC)

DSC analysis was used to determine preservation of the protein native structure. In general, the denaturation enthalpy was higher in washed samples than in unwashed ones (Table 2), indicating some aggregation due to the washing process, as also observed in the SDS-PAGE profile.

After 3 months of frozen storage, denaturation enthalpy tended to increase, most probably as a result of protein aggregation and/or polymerization during frozen storage (Schubring 2001). After 6 months of frozen storage the enthalpy had increased in most of the minces, though the increment between month 3 and 6 was smaller than the increment between months 1 and 3. This means that the aggregation started just at the beginning of the frozen storage period (Huidobro and Mohamed 1998). The enthalpy maxima recorded in these fish minces was similar to that found in good-quality Alaska Pollock surimi (Grade KA) (Núñez-Flores et al. 2018), meaning that the protein was not extensively denatured in any sample.

Fig. 1 SDS-PAGE profile of unwashed and washed fish minces. a) 0 days of frozen storage and b) 6 month of frozen storage

Table 2 Denaturation enthalpy (J/g dm) of fish minces

Samples	Month 0 ΔH (J/g)	Month 6 ΔH (J/g)
Blue whiting	0.19 ± 0.033^{a1}	0.3 ± 0.07^{a2}
Blue whiting w	0.49 ± 0.054^{b1}	0.39 ± 0.15^{b1}
Mackerel	0.05 ± 0.006^{a1}	0.29 ± 0.14^{a2}
Mackerel w	0.47 ± 0.012^{b1}	0.57 ± 0.14^{b1}
Red scorpionfish	0.38 ± 0.022^{a1}	0.45 ± 0.13^{a1}
Red scorpionfish w	0.63 ± 0.037^{b1}	0.36 ± 0.09^{a2}
Gurnard	0.20 ± 0.025^{a1}	0.54 ± 0.08^{a2}
Gurnard w	0.60 ± 0.056^{b1}	0.31 ± 0.03^{b2}
Pouting	0.78 ± 0.021^{a1}	0.61 ± 0.15^{b2}
Pouting w	0.58 ± 0.027^{b1}	0.67 ± 0.14^{a1}

Different letters mean significant differences among washed samples and unwashed samples. Different numbers means differences during the storage period ($p \leq 0.05$)

w washed muscle

Functional properties of minces

Cooking loss

Table 3 shows data from the cooking loss analysis. Cooking loss was significantly lower at the beginning (month 0) than after frozen storage (months 3 and 6). The increase was particularly evident after 3 months of frozen storage, after which it remained stable. During frozen storage myofibrillar proteins, mainly myosin, become aggregated, leading to changes in their structure. As a consequence, some water bound to the proteins is exuded, an effect which could be maximized by extreme temperatures (Damodaran and Paraf 1997). Also, cooking loss was

higher in washed than in unwashed minces. The washing process removes undesirable water-soluble materials, such as fats, inorganic salts and some proteins, and at the same time proteins bonded to water molecules (Park et al. 2013). These water molecules are weakly linked to proteins, which are easily lost during cooking.

Apparent viscosity (μ_{app})

Protein functional quality was measured by apparent viscosity (Barroso et al. 1998). As shown in Table 4, washed minces exhibited higher apparent viscosity than unwashed minces, indicating very good functional properties of the protein present in the muscle of those species. Most of the minces registered higher apparent viscosity at the beginning of frozen storage, which could be due to the lack of aggregation as reported in the cooking loss section. However, after 6 months of frozen storage viscosity was still high, with the sole exceptions of unwashed Blue Whiting and Red Scorpionfish mince. Blue Whiting belongs to the Gadidae family, whose muscles produce formaldehyde and DMA from trimethylamine oxide (TMAO) during frozen storage, inducing protein aggregation and hence a reduction in protein functionality and viscosity (Rey-Mansilla et al. 1999). Although Red Scorpionfish does not belong to the Gadidae family, it is probable that its muscle also contains some protein-denaturant substance. This effect was not observed in washed Blue Whiting or Red Scorpionfish mince, since TMAO is leached out during the washing process.

Lipid oxidation during frozen storage

Table 4 shows lipid oxidation as measured by TBA index (mg of MDA/kg of muscle). As observed, the TBA index

Table 3 Cooking loss (%) of fish minces

Samples	Month 0 CL (g/100 g)	Month 3 CL (g/100 g)	Month 6 CL (g/100 g)
Blue whiting	6.2 ± 0.62 ^{a1}	4.1 ± 0.41 ^{a2}	10.32 ± 1.03 ^{a3}
Blue whiting w	33.5 ± 3.35 ^{b1}	46.0 ± 4.59 ^{b2}	45.08 ± 4.5 ^{b2}
Mackerel	9.4 ± 0.94 ^{a1}	15.9 ± 1.58 ^{a2}	12.06 ± 1.2 ^{a2}
Mackerel w	30.9 ± 3.09 ^{b1}	41.0 ± 4.09 ^{b2}	41.64 ± 4.16 ^{b2}
Red scorpionfish	9.3 ± 0.93 ^{a1}	13.2 ± 1.32 ^{a2}	11.52 ± 1.15 ^{a2}
Red scorpionfish w	22.9 ± 2.29 ^{b1}	29.0 ± 2.9 ^{b2}	29.07 ± 2.9 ^{b2}
Gurnard	10.9 ± 1.09 ^{a1}	25.9 ± 2.59 ^{a2}	27.30 ± 2.73 ^{a3}
Gurnard w	20.1 ± 2.01 ^{b1}	31.5 ± 3.14 ^{b2}	31.12 ± 3.11 ^{b2}
Pouting	6.5 ± 0.65 ^{a1}	12.8 ± 1.27 ^{a2}	15.91 ± 1.59 ^{a3}
Pouting w	34.8 ± 3.48 ^{b1}	43.4 ± 4.34 ^{b2}	39.74 ± 3.97 ^{b3}

Different letters mean significant differences among washed samples and unwashed samples. Different numbers means differences during the storage period ($p \leq 0.05$)

w washed muscle

Table 4 Apparent viscosity (cP) and TBA index (mg MDA/kg) of fish minces

Samples	Month 0		Month 3	Month 6	
	μ_{app} (cP)	iTBA (mg MDA/kg)	μ_{app} (cP)	μ_{app} (cP)	iTBA (mg MDA/kg)
Blue whiting	6972 ± 240 ^{a1}	0.8 ± 0.03 ^{a1}	6415 ± 188 ^{a1}	1338 ± 621 ^{a1}	1.2 ± 0.01 ^{a2}
Blue whiting w	5044 ± 193 ^{b1}	1.1 ± 0.01 ^{a1}	4712 ± 176 ^{b1}	5224 ± 194 ^{b1}	1.1 ± 0.01 ^{a1}
Mackerel	5251 ± 162 ^{a1}	7.3 ± 0.17 ^{a1}	4987 ± 268 ^{a1}	4903 ± 207 ^{a1}	11.4 ± 0.98 ^{a2}
Mackerel w	3366 ± 138 ^{b1}	4.4 ± 0.15 ^{b1}	3875 ± 206 ^{b1}	4349 ± 127 ^{b1}	6.3 ± 0.42 ^{b2}
Red scorpionfish	7455 ± 223 ^{a1}	3.1 ± 0.09 ^{a1}	2275 ± 58 ^{a1}	437 ± 50 ^{a1}	2.3 ± 0.08 ^{a1}
Red scorpionfish w	9996 ± 269 ^{b1}	1.2 ± 0.03 ^{b1}	10,595 ± 355 ^{b1}	8079 ± 133 ^{b1}	0.8 ± 0.01 ^{b1}
Gurnard	5779 ± 164 ^{a1}	1.9 ± 0.02 ^{a1}	6104 ± 182 ^{a1}	5117 ± 288 ^{a1}	1.5 ± 0.01 ^{a1}
Gurnard w	5870 ± 217 ^{a1}	1.8 ± 0.01 ^{a1}	6838 ± 227 ^{a1}	7433 ± 241 ^{b1}	1.4 ± 0.01 ^{a1}
Pouting	6309 ± 175 ^{a1}	1.6 ± 0.02 ^{a1}	7715 ± 290 ^{a1}	6971 ± 110 ^{a1}	1.4 ± 0.01 ^{a1}
Pouting w	2851 ± 96 ^{b1}	1.4 ± 0.01 ^{a1}	3986 ± 178 ^{b2}	3979 ± 66 ^{b2}	1.2 ± 0.01 ^{a1}

Different letters mean significant differences among washed samples and unwashed samples. Different numbers means differences during the storage period ($p \leq 0.05$)

w washed muscle

was lower in washed than in unwashed mince. This could be due to the removal of part of the lipid content floating in the water during the washing process, as reported by Park et al. (2013).

After 6 months of frozen storage, lipid oxidation increased in all minces, particularly in mackerel, which is a fatty fish. The concentration of TBARS in good quality frozen fish is typically between 5 and 8 mg MDA/kg, whereas levels of 8 mg MDA/kg are generally regarded as the limit of acceptability for most species (Schormüller 1968). The values of the present samples (Table 4) are below those limits, indicating good quality of the frozen fish. Moreover, Baron et al. (2007) reported that lipid hydroperoxides and secondary oxidation products (volatiles) increased dramatically after 13 months of storage

at $-20\text{ }^{\circ}\text{C}$. Nazemroaya et al. (2011) reported similar results, suggesting that lipid oxidation was the main reason for the short frozen storage life of fish.

Sensory analysis

Fish mince The scores in the sensory analysis for the different parameters studied are shown in Table 5. Although all muscles scored well for acceptability at the beginning of frozen storage, washed muscles scored lower than unwashed. Moreover, the highest scores were awarded to Blue whiting, Mackerel and Gurnard, both washed and unwashed. After 6 months of frozen storage scores were slightly lower, but all samples still scored around the

Table 5 Scores of the different parameters studied regrading sensorial analysis on fish minces

Samples	Month 0			Month 6		
	General aspect	Texture	Taste	General aspect	Texture	Taste
Blue whiting	5.7 ± 1.29	6.27 ± 1.57	6.62 ± 0.94	5.21 ± 1.16	5.99 ± 1.46	4.88 ± 0.85
Blue whiting w	6.42 ± 0.98	4.88 ± 1.06	4.84 ± 0.88	5.93 ± 0.85	4.6 ± 0.95	5.6 ± 0.79
Mackerel	5.63 ± 1.02	6.32 ± 1.27	6.79 ± 1.22	5.14 ± 0.89	6.04 ± 1.16	4.25 ± 1.13
Mackerel w	6.11 ± 0.99	4.51 ± 1.30	5.43 ± 1.14	5.62 ± 0.86	4.23 ± 1.19	5.14 ± 1.05
Red scorpionfish	5.8 ± 1.19	5.69 ± 1.13	5.86 ± 1.19	5.31 ± 1.06	5.41 ± 1.02	4.98 ± 1.1
Red scorpionfish w	4.73 ± 1.09	5.42 ± 0.98	4.52 ± 1.07	4.24 ± 0.96	5.14 ± 0.87	3.91 ± 0.98
Gurnard	6.53 ± 0.99	5.35 ± 1.23	5.31 ± 1.26	6.04 ± 0.86	5.07 ± 1.12	5.71 ± 1.17
Gurnard w	5.5 ± 1.10	4.17 ± 1.06	3.72 ± 1.12	5.01 ± 0.97	3.89 ± 0.95	4.68 ± 1.03
Pouting	5.11 ± 0.80	5.46 ± 1.19	5.34 ± 0.86	4.62 ± 0.67	5.18 ± 1.08	4.29 ± 0.77
Pouting w	4.99 ± 1.14	4.45 ± 1.08	4.19 ± 0.95	4.5 ± 1.01	4.17 ± 0.97	4.17 ± 0.76

w washed muscle

middle of the scale for the three sensory characteristics analysed (general appearance, texture and taste).

Consumers test: final restructured products Based on the variation in protein structure and functionality, and also lipid oxidation during frozen storage, several products were prepared following the methodology described in Sects. 4.1 to 4.3. For each final product, different fish minces were used so as to obtain products with desired sensory properties.

“Burgers” were made using unwashed mince from all species to preserve a pronounced fishy flavour.

Minces from washed Blue whiting, Pouting and Red scorpionfish were used to make the “nuggets” and “structured fingers”. These two products are very well accepted by young people, who tend to like the white colour of the meat. The methodology for manufacture of these products entailed protein gelation, so that washed minces were more suitable given their better protein functionality and whiter colour.

The highest scores (between 4.5 and 5) were awarded to “fingers” of Pouting and Red scorpionfish, and above all Mackerel “burgers”.

Consumers aged between 20 and 40 preferred the structured “fingers” (4 and 4.5 points), and the over-40 s liked the Mackerel “burgers” best. Consumers aged from 45 to 70 selected Mackerel “burger” and the structured “fingers” as the best, followed by Red scorpionfish “nuggets”. This last fact is striking given that nuggets are a kind of food specially designed for children.

Conclusion

The various target species are abundant and are seasonally regular enough to be a reliable source of by-catch in coastal Galician trawler fisheries for the industry to make marketable fish products. Some of these species, which are too bony or have a strong taste due to the abundance of fat, are not highly appreciated by consumers. However, it has been concluded that they are suitable for processing in the form of mince to make derivative products. The proposed technology is simple, entailing washing of the mince (optional), further mechanical draining followed by kneading or homogenizing to incorporate the cryoprotectant and the natural antioxidant, and finally freezing. All the minces performed well over 6 months of frozen storage. This was the limit for protein functionality in the case of unwashed Blue Whiting and Red Scorpionfish mince, and also in the case of Mackerel because of lipid oxidation. The three products, made with different textures and appearances, were well accepted by consumers. It is worth noting that products with strong flavours, like mackerel, were more acceptable to older people. Moreover, older people preferred well-known products like burgers and younger people preferred products such as fingers and nuggets.

Acknowledgements Financial support from project VALDESCAR (Fondo Europeo Marítimo y Pesca; Secretaría General de Pesca (MAPAMA)) is acknowledged. The assistance of Ph.D. Ruth Núñez-Flores is also appreciated.

References

AOAC (2000) Official methods of analysis of the AOAC. Association of Official Analytical Chemists Inc, Arlington

- Baron CP, Kjaersgard IVH, Jessen F, Jacobsen C (2007) Protein and lipid oxidation during frozen storage of rainbow trout (*Oncorhynchus mykiss*). J Agric Food Chem 55:8118–8125. <https://doi.org/10.1021/jf070686f>
- Barroso M, Careche M, Borderías AJ (1998) Quality control of frozen fish using rheological techniques. Trends Food Sci Tech 9(6):223–229
- Blanco M (2015) Valorización de descartes y subproductos de pintarroja (*Scyliorhinus canicula*). Doctoral thesis. Vigo University. <http://hdl.handle.net/10261/129012>
- Blanco M, Sotelo CG, Pérez-Martín RI (2015) Hydrolysis as a valorization strategy for unused marine food biomass: boarfish and small-spotted catshark discards and by-products. J Food Biochem 39:368–376. <https://doi.org/10.1111/jfbc.12141>
- Borderías AJ, Jiménez-Colmenero F, Tejada M (1985) Parameters affecting viscosity as a quality-control for frozen fish. Mar Fish Rev 47(4):43–45
- CSIC (2007) Authors: Borderías, A.J.; Carballo, J.; Moreno, H.M. Preparation of restructured fish products comprises joining together layers of surimi or mince mixture comprising a binder for muscle particles thermostable binder and white colour enhancer. ES 2 281 282-A1 (16/09/2008) and W0 2007/090916-A1 (16/08/2007)
- Damodaran S, Paraf A (1997) Food proteins and their applications, chapter 4 and 16, vol 80. Marcel Dekker, New York
- García-Moreno PJ, Pérez-Gálvez R, Morales-Medina R, Guadix EM, Guadix A (2013) Discarded species in the west Mediterranean Sea as sources of omega-3 PUFA. Eur J Lipid Sci Technol 115:982–989. <https://doi.org/10.1002/ejlt.201300021>
- Huidobro A, Mohamed GF (1998) Aggregation of myofibrillar proteins in hake, sardine, and mixed minces during frozen storage. J Agric Food Chem 46(7):2601–2608. <https://doi.org/10.1021/jf970962y>
- Konno K, Imamura K (2000) Identification of the 150 and 70 KDa fragments generated during the incubation of salted surimi paste of walleye Pollack. Nippon Suissan Gakkaishi 66:869–875
- Moreno HM, Carballo J, Borderías AJ (2009) Study of two different cold restructuring processes using two different qualities of hake (*Merluccius capensis*) muscle, with addition of microbial transglutaminase. J Sci Food Agric 89:1346–1351. <https://doi.org/10.1002/jsfa.3592>
- Moreno HM, Borderías AJ, Baron C (2010a) Evaluation of some physicochemical properties of restructured trout and hake during cold gelation and chilled storage. Food Chem 120:410–417. <https://doi.org/10.1016/j.foodchem.2009.10.021>
- Moreno HM, Carballo J, Borderías AJ (2010b) Gelation of fish muscle with transglutaminase added: influence of sodium chloride level and pH. J Muscle Food 21:433–450. <https://doi.org/10.1111/j.1745-4573.2009.00193.x>
- Moreno HM, Carballo J, Borderías J (2011) Application of Response Surface Methodology to study the effect of different calcium sources in fish muscle-alginate restructured products. Cienc Tecnol Aliment Campinas 31(1):209–216
- Núñez-Flores R, Cando D, Borderías AJ, Moreno HM (2018) Importance of salt and temperature in myosin polymerization during surimi gelation. Food Chem 239:1226–1234. <https://doi.org/10.1016/j.foodchem.2017.07.028>
- Nazemroaya S, Sahari M, Rezaei M (2011) Identification of fatty acid in Mackerel (*Scomberomorus commersoni*) and shark (*Carachrinus dussumieri*) fillets and their changes during six month of frozen storage at -18°C. J Agr Sci Tech 13:553–566
- Ordóñez-Del Pazo T, Antelo LT, Franco-Uriá A, Pérez-Martín RI, Sotelo CG, Alonso AA (2014) Fish discards management in selected Spanish and Portuguese métiers: identification and potential valorisation. Trends Food Sci 36(1):29–43. <https://doi.org/10.1016/j.tifs.2013.12.006>
- Park JW, Graves D, Draves R, Yonsawatdigul J (2013) Manufacture of surimi: harvest to frozen block, chapter 3. In: Park JW (ed) Surimi and surimi seafood, CRC Press, Taylor Francis Group, Boca Raton, pp 55–101
- Regulation (EU) No 13880/2013 of the European Parliament and of the Council of the European Union
- Rey-Mansilla M, Sotelo CG, Gallardo JM (1999) Decomposition of trimethylamine oxide during iced storage of blue whiting (*Micromesistius poutassou*). Z Lebensm Unters Forsch 208(4):267–269. <https://doi.org/10.1007/s002170050415>
- Schormüller J (1968) Handbuch der Lebensmittelchemie (Band III/2). Springer, Berlin
- Schubring R (2001) In: Oehlenschläger Jörg (ed) Fishery products: Quality, safety and authenticity. Wiley, West Sussex, pp 173–204
- Vázquez JA, Blanco M, Massa AE, Amado IR, Pérez-Martín RI (2017) Production of fish protein hydrolysates from *Scyliorhinus canicula* discards with antihypertensive and antioxidant activities by enzymatic hydrolysis and mathematical optimization using Response Surface Methodology. Mar Drugs 15(10):306–321. <https://doi.org/10.3390/md15100306>
- Vyncke W (1975) Evaluation of the direct thiobarbituric acid extraction methods for determining oxidative rancidity in mackerel (*Scomber scombrus* L). Fette Seifen Anstrichm 77:239–240. <https://doi.org/10.1002/lipi.19750770610>