Title

Farmed fish as a functional food: perception of fish fortification and the influence of origin – Insights from Portugal

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Abstract

Being a rich source of important nutrients, including highly digestible proteins, vitamins (A, D3), trace minerals (iodine, selenium) and n-3 long chain polyunsaturated fatty acids (n-3 LCPUFA), fish consumption is generally regarded as part of a healthy dietary pattern. Exogenous feeding in aquaculture unlocks the possibility to tailor fish composition with healthy valuable nutrients. However, the use of supplements in the fish feed during fish production may undermine consumers' perception opinion of these fortified products. The effectiveness success of a functional food is a combination of its efficacy and meeting consumers' expectations. A self-administered questionnaire was designed to assess consumers' preferences regarding fish consumption, and their perception of farmed seabream as a functional food. A high consumption rate of fish, (between daily, and a minimum of three times a week), was reported by 47% of the respondents. Freshness, flavour, quality and price were the four most valued attributes. Good acceptance of the fish fortification concept was observed (53%), as well as positive receptiveness to its consumption (50%). Anti-oxidants and omega-3 fatty acids were the most accepted compounds for fish fortification. Additionally, two consumer groups were established based on their high (HIG) or low (LIG) interest in fish origin (wild vs aquaculture). The LIG was more receptive to all aspects of fish fortification and showed willingness to buy and consume it. This suggests that fortified fish could be targeted to the LIG profile group, which represents 42% of the studied population. With appropriate communication, farmed fish may be a good candidate for functional food.

Keywords

Consumers' questionnaire; Fish consumption; Aquaculture; Functional-food; Portugal

Highlights

- Almost half of respondents consume fish daily or at least three times a week

- 52% agreed with fish fortification and 50% showed willingness to its consumption
- Omega-3 and antioxidants were the preferred fortification compounds
- Respondents with low interest on fish origin were more receptive to fortification

1. Introduction

The strong move towards healthier eating has promoted the consumption of seafood products (Pieniak et al., 2008). The world *per capita* fish as food supply increased from 9.9 kg in the 1960s to 20 kg in 2014 (FAO, 2016). Portuguese consumers record the highest fish consumption in the EU, around 56.8 kg/capita/year, while the European average is less than half of that (24.9 kg/capita/year) (PCP, 2016). World demand for seafood products for human consumption is projected to keep rising in the next decades (FAO, 2016). With capture fisheries stagnated, aquaculture production is expected to counterbalance this supply issue. Under farming conditions, fillet quality traits such as fatty acid profiles and concentration of trace nutrients, may be influenced by the diet composition. The International Life Sciences Institute defines functional foods as "foods that, by virtue of the presence of physiologically-active components, provide a health benefit beyond basic nutrition" (Diplock et al., 1999). In 1999 the American Dietetic Association defined functional foods as foods that are "whole, fortified, enriched, or enhanced," but more importantly, states that such foods must be consumed as "… part of a varied diet on a regular basis, at effective levels" for consumers to reap their potential health benefits (ADA [American Dietetic Association], 1999). Moreover, food fortification has been the primary strategy to battle nutrient deficiency in populations worldwide (WHO and FAO, 2006). Under this context, and considering the high nutritional value of fish, there is a significant potential to develop fish as a functional food.

Consumers' acceptance of new products is crucial for their market success, but their acceptance or rejection is of a multi-factorial nature. Food choice behaviour is a complex process, influenced by several factors and their interaction. Determinants like past behaviour, habits and hedonic appreciation are usually good predictors of food choice behaviour (Koster, 2007). Would a fortified aquaculture fish be well accepted by consumers with a high fish consumption level? Indeed, beliefs about the characteristics of a certain product and the way it is produced can have a relevant influence on consumer perception, such as in the case of farmed fish. Several studies on the behaviour of fish consumers often describe farmed fish as

86 being less healthy and with lower quality when compared to wild fish (Claret et al., 2014;
87 Verbeke et al., 2007). Comparatively lower costs, perception of artificial-like product, and lack
88 of information on sustainable farming practices are among the key elements conditioning the
89 image and acceptance of aquaculture fish (Altintzoglou et al., 2010; Claret et al., 2014;
90 Vanhonacker et al., 2011). Furthermore, it has been shown that consumers are willing to buy
91 and to pay higher prices for healthy attributes in fish products when information is made
92 available (Kole et al., 2010). It has thus been suggested that the aquaculture sector should
93 evolve to cope with market demands by differentiating their offer, searching for new niche
94 markets, and combining diversification of products, species and farming methods with the
95 development of added value products (Barazi-Yeroulanos, 2010), such as “functional fish”.
96
97 The functional foods market continuously presents new products to meet consumers’
98 expectations and is experiencing an annual average growth rate of about 8.5% (Bogue et al.,
99 2017). However, barriers and concerns about the use of functional foods have been highlighted
100 in many studies. Urala and Lähteenmäki (2007) described a general suspiciousness towards
101 the functional food concept, though it may not necessarily influence the willingness to use
102 concrete functional products. Consumers were not willing to sacrifice naturalness and taste for
103 healthiness and convenience (Grunert, 2010; Siró et al., 2008). Also, costs, adverse or
104 unknown effects (Vella et al., 2013) and manipulation (Bech-Larsen and Grunert, 2003) were
105 referred as barriers to functional foods consumption. Moreover, the factors influencing
106 decisions during purchasing do not only include sensory qualities and health beliefs, but also
107 other intrinsic aspects, that should be considered in the formulation and characterization of
108 functional foods, like prevention of diseases, (Pappalardo and Lusk, 2016). Some reviews on
109 functional food products highlighted the importance of ingredient selection, and how crucial it
110 is to find the right combination between ingredient and carrier to comply with consumer
111 acceptance (Ares and Gámbaro, 2007; Bech-Larsen and Scholderer, 2007; Grunert, 2010).
112 Functional foods presumably enable the consumer to lead a healthier life without changing
113 eating behaviour. Tailoring aquaculture products with health promoting compounds may create

114 new opportunities in the production sector, leading to novel foods in a receptive and growing
115 market (Siró et al., 2008).
116
117 Information about consumers' acceptance of "fortified fish" is very scarce. Cultural factors may
118 play a significant role in the acceptance of functional foods (Siegrist et al., 2015), and
119 particularly interesting is the perception of "fortified fish" by a population, like the Portuguese,
120 who have a high fish consumption level. The main aim of the present study was to assess
121 consumers' acceptance of farmed fish fortified with beneficial and healthy compounds. The
122 study comprised also an assessment of fish consumption preferences following the
123 segmentation of respondents according to the importance of knowing the fish origin (wild vs
124 farmed). The first hypothesis in this study was that in general, consumers are sceptical about
125 fish from aquaculture, particularly fish that have undergone any type of enhancement or
126 manipulation. Moreover, considering that functional foods might not be readily accepted by
127 consumers, a second hypothesis was formulated: within a population there is a group of
128 consumers, segmented by the importance of knowing the fish origin, that are more receptive
129 to new products developed from enhanced aquaculture fish, will vary depending on
130 consumers' knowledge of fish origin.
131
132 **2. Methodology**
133
134 *2.1 Participants/ Description of recruitment*
135 The questionnaire was addressed to the Portuguese population aiming at a maximum number
136 of participants, and the only prerequisite was to have internet access. The questionnaire was
137 developed in Portuguese language and built using an on-line software platform -
138 surveymonkey®. The recruitment was carried out by email invitations and facebook®
139 announcements using the snowball sampling technique (Grbich, 1999). In the introduction, the
140 enquiries' anonymity and the utilization of the answers only within the study purposes were

guaranteed. Answers were collected over two months, from July until September 2011. A total of 932 answered questionnaires were collected, though only 778 respondents' answer all the proposed questions, and these were the ones considered valid (response rate 83,5%).

2.2 Description of questionnaire

The questionnaire was structured in four sections assessing:

2.2.1 Fish consumption and preferences:

In this section three items were assessed: a) fish consumption frequency (never, less than once a month, 2-3 times per month, 1-2 times per week, 3-6 times per week, daily); b) the three most frequently consumed species, from a list of 10 given possibilities (cod, hake, mackerel, meagre, seabream, seabass, salmon, sardine, trout, tuna and a blank space to non-listed species); c) the two most valued fish attributes (freshness, taste, price, quality, nutritional value, texture, convenience of use, easy to cook, ecological impact, origin (aquaculture/fisheries) and species). The selection of enclosed species was based on several criteria with potential interest to producers and retailers: expected highly consumed species (cod, tuna, salmon, hake, sardine and mackerel), main produced species from Portuguese aquaculture (seabream, seabass and trout) and a farmed species emergent in the Mediterranean region (meagre) (Cardoso et al., 2013; Ernst and Young, 2009).

2.2.2 Acceptance of aquaculture fish and fish fortification:

Concerning the interest in fish origin (wild vs aquaculture) participants were asked about their consumption of farmed fish (yes or no); the importance of knowing fish origin, using a five-point importance scale (from not important: 1 to very important: 5); and also the listing of two attributes that could be improved in farmed fish from a list of seven options (colour, texture, odour, taste, fat content, nutritional value and higher diversity of products), using a five-point importance scale (from nothing to improve:1 to very much to improve: 5). The options were

168 selected based on described differences between the perception of wild and farmed fish,
169 related to taste, sensory traits and nutritional value (Grigorakis et al., 2003; Verbeke et al.,
170 2007).
171
172 Seafood fortification aims to provide nutrients that tend to be deficient in the diet. Participants
173 were asked about their agreement on fish fortification through feeding, with beneficial nutrients
174 for the human health, using a five-point scale (from totally disagree: 1 to completely agree: 5).
175 Gilthead seabream (hereafter will be referred as seabream) was mentioned as target species,
176 since it is the most cultivated species in the Mediterranean area and one of the most consumed
177 farmed fish in Portugal. Participants were also requested to identify two nutrient types suitable
178 for farmed fish fortification from an eight options list (antioxidants, iodine, magnesium, omega-3
179 fatty acids, selenium, taurine, vitamin D, none). A brief description of the nutrients beneficial
180 effects was made available to help respondent's make an informed decision. The information
181 provided was carefully balanced to avoid any influence in the respondents' answers.
182
183 *2.2.3 Consumption and purchasing options of fortified fish*
184 Participants were asked about their willingness to consume fortified seabream (from not willing:
185 1 to totally willing: 5); their buying preference without a price change (selecting between
186 common or fortified seabream); and their willingness to pay a higher price for fortified
187 seabream (yes or no). A set of four additional questions concerning daily life aspects that could
188 influence purchasing decision were presented: what is the importance you give to food? What
189 is the level of association between food and health? (a five-point importance scale from not
190 important: 1 to very important: 5 was used); the presence of children in the household (yes or
191 no); and the respondent's role in food purchasing (yes or no).
192

193 *2.2.4 Demographic characterization*

194 Participants' demographic characteristics included: age (date of birth); gender; education level
195 and monthly family income (less than or equal to 1000€; between 1001 and 2000€; between
196 2001 and 3000€ and more than 3000€).

197

198 *2.3 Data analysis*

199 Fish consumption frequency was evaluated as frequencies of consumption. Analysis regarding
200 suggested improvements of farmed fish was performed by clustering respondents who
201 answered categories 4 and 5, and by expressing data as percentage of total answers for each
202 option. This data treatment aimed to include, in the outcomes, all the answers obtained for
203 each option combining high and low scale scores. Concerning respondents age, four classes
204 were defined: less than or equal to 25 years; between 26 and 40 years; between 41 and 65
205 years and more than 66 years.

206

207 *2.3.1 Consumer groups*

208 Answers regarding the importance of knowing fish origin (wild *versus* aquaculture) allowed the
209 establishment of two groups with distinct profiles and attitudes towards fish attributes and
210 acceptance of farmed and fortified fish. Respondents with rating scores 4 and 5 were classified
211 as high interest group (HIG), while those with lower rating scores were classified as low interest
212 group (LIG).

213

214 *2.3.2 Statistical data treatment*

215 Cross tabulations with Pearson's Chi-square tests were applied to test associations between
216 categorical variables. One-way analysis of variance (ANOVA) was applied to compare means
217 when continuous variables were used. Statistical significance was tested at 0.05 probability
218 level. Additionally, data was subjected to an exploratory analysis using Principal Component
219 Analysis, conducted with 12 variables with orthogonal rotation (varimax). The Kaiser-Meyer-

Olkin measure was at the lower limit for sampling adequacy (KMO=0.704). Bartletts' test of sphericity (2095.55) presents a P<0.001 indicating that variables are significantly correlated. Four components accounted for 60% of the variance observed across the 12 variables. Variables were selected focusing on questions related to: a) acceptance and willingness to buy enriched fish; b) origin of fish; c) valued fish characteristics such as convenience (ready to eat, easy to cook) and sensorial properties (freshness, flavour); and d) price-related aspects. All statistical tests were performed using IBM SPSS®22 software.

3. Results and Discussion

3.1 Demographic characterization of survey respondents

A total of 778 complete answers were obtained through a self-administered online questionnaire. A detailed demographic characterization is presented in Table 1. By comparing the studied sample with the Portuguese population census from 2011 (INE, 2012) several differences were revealed, whereby extrapolations for the Portuguese population could not be made. The main differences found concerned the age distribution and education level. In a 2011 census, 55% of the population ranged between the ages of 25 and 64, and 19% were over 65 years old. Respondents also showed to be more highly educated than the national average, since only 12% of the population has a higher education. The gender difference is not very pronounced (48% men vs 52% women) compared to the survey. Nevertheless, although the sample of participants in this survey was not representative of the general Portuguese population a large age range (16 – 83 years) was obtained. Another recent online survey on seafood consumption patterns in the Portuguese population (1083 answers) described a very similar sample characterization: only 2.2% of individuals were over 65; 64% were women and 83% had higher education (Cardoso et al., 2013). The recruitment via internet surely reached a larger educated fraction of the Portuguese population and a lower representativeness of the older age group. Census revealed that in 2011, 93% of individuals

247 with secondary education and 95% with higher education had internet access in Portugal (INE,
248 2012). Online surveys are becoming a commonly accepted method of reaching volunteers for
249 consumer research (Evans and Mathur, 2005; Wright, 2005). A common limitation of these
250 web-based approaches is the lack of control of sample characteristics and the possible bias
251 for the research cohort, despite the saving of time and efforts; the access to large populations
252 and the increased anonymity of participants give online surveys significant advantages over
253 other formats (Campos et al., 2011; Riva et al., 2003). To maximize the information from the
254 data obtained, two consumer groups were established, based on their high (HIG, 58%) or low
255 (LIG, 42%) interest in fish origin (wild vs aquaculture). This clustering of respondents resulted
256 in distinct demographic profiles (P<0.05) regarding age distribution and gender but did not
257 affect (P>0.05) sample characteristics on education level, monthly family income, presence of
258 children in the household, and fish purchasing decisions (Table 1).
259

260 Approximate position of Table 1.

261

262 *3.2 Fish consumption and health concerns*

263 Strong fish consumption levels were found in this study (fig. 1), reflecting previously reported
264 data for Portuguese consumers (FAOSTAT, 2011). The sampled population showed high fish
265 consumption rates, with 47% eating fish daily, or more than three times a week, and 87%
266 eating fish at least one or two times a week. This consumption comprises both high levels of
267 wild and cultured fish since respondents were very positive regarding consumption of fish from
268 aquaculture, with 79% affirmative answers. Outcomes also revealed that the frequency of fish
269 consumption was positively influenced by children in the household (P = 0.021), by age (P =
270 0.046), and by higher family incomes (P< 0.001). Similar conclusions were drawn in studies
271 performed in other countries where fish consumption increased in elderly populations (Brunsø,
272 2003; Jahns et al., 2014; Olsen, 2003); with higher incomes (Jahns et al., 2014; Verbeke and

273 Vackier, 2005) and with education levels (Jahns et al., 2014). In this study, and probably due
274 to the methodology, most respondents (88%) had a higher education, whereby a correlation
275 between education and consumption was not observed.
276
277 Approximate position of Figure 1.
278
279 Consumers' awareness of the relationship between food and health is clearly established.
280 Food consumption, and fish in particular, has been frequently associated with beneficial health
281 effects, with new evidences being acknowledge every day. Pieniak et al. (2008) described
282 European consumers as very involved with their health and very interested in healthy eating.
283 Accordingly, Portuguese enquiries in the present study stated similar interest, where 93% of
284 participants reported to give much importance to food concerns on daily life and 99% believed
285 in a strong relation between food and health. Healthy eating is known to positively influence
286 fish consumption among European consumers since fish and seafood are considered healthy
287 dietary choices and part of a balanced diet (Altintzoglou et al., 2011; Brunsø et al., 2009; Olsen,
288 2004).
289
290 *3.3 Preferred selected species and preferred attributes of consumed fish*
291 Portuguese fish markets offer a large diversity of species which allows for good dietary
292 diversification. Some species, however, are seasonal, and their consumption is less
293 representative. According to our study, the main species consumed were cod (68%), tuna
294 (51%) and hake (45%) coming from wild fisheries, followed by salmon (41%) and seabream
295 (33%) mainly produced in aquaculture systems. These findings are consistent among the
296 studies. The same species were recently reported as the top five fish consumed in Portugal in
297 a survey conducted by Cardoso et al. (2013, 2016). Ernst and Young (2009) had previously
298 referred cod, tuna, hake, mackerel and sardine as the most consumed species in Portugal.
299 This consistency may be supported by studies on consumer attitudes describing habits and
300 past behaviour as main determinants associated with fish consumption patterns (Verbeke and

301 Vackier, 2005). Also, Trondsen et al. (2004) reported that seafood consumption is strongly
302 related to traditional food and knowledge passed down through generations.
303 Besides daily habits, food choice behaviour is a complex process dependent on several
304 factors. In general, taste and sensorial attributes are the main drivers, according to several
305 consumer behaviour studies on food selection (Olsen, 2003). Januszewska et al. (2011)
306 performed a study of European consumers assessing the factors that most influence daily food
307 choice, and found as primary motivation sensory appeal, followed by health, natural content
308 and price ahead of convenience. Published information on consumers' attitudes when buying
309 seafood shows diverse results, with consumption varying between countries, with different
310 habits and consumers' groups (such as fish lovers or experienced consumers) (Brunsø, 2003).
311 Still, sensorial attributes were considered one of the main factors motivating fish consumption
312 in numerous studies (Bredahl and Grunert, 1997; Olsen, 2001), followed by freshness and
313 price (Brunsø, 2003). However, other works give taste a minor role (Leek et al., 2000) and
314 point out health concerns as a major influence for seafood consumption (Olsen, 2004; Pieniak
315 et al., 2008; Pieniak et al., 2010). In the present study, freshness, flavour and overall quality
316 were the most important fish attributes selected by the sampled population, ahead of price (fig.
317 2). Being easy to cook and to consume, together with convenience, were referred only by 20%
318 of the enquiries. Convenience is often considered as an important factor in food choice
319 (Steptoe et al., 1995) and with seafood in particular (Brunsø, 2003; Olsen, 2003; Olsen et al.,
320 2007). Fish may be perceived as not convenient due to the time and effort required in its
321 preparation, as well as the bones, which might be a barrier for its consumption (Brunsø, 2003).
322 Whole fish consumption is still a main preference for Portuguese consumers and is closely
323 associated with the freshness and quality attributes (Cardoso et al., 2013) and much less to
324 convenience issues. Nutritional value, often the second food criteria for consumers after
325 sensory appeal (Roininen et al., 1999), was only seventh choice, maybe because fish is
326 already perceived as healthy and nutritious food (Verbeke et al., 2005) and is thus not a priority
327 to consumers at the purchasing moment. Ecological impact also scored very low as observed
328 by Pappalardo and Lusk (2016).

329

330 Approximate position of Figure 2.

331

332 *3.4 Farmed fish and selected improvements*

333 The supply of farmed fish is increasing, along with its positive image among European
334 consumers, as described in different research works in this field (Altintzoglou et al., 2011;
335 Claret et al., 2014; Vanhonacker et al., 2011). The population sample assessed in the survey,
336 where fish consumption was high, revealed that fish from aquaculture was consumed
337 extensively (78%). Some differences were found between gender and age groups. Men were
338 more favourable than women (83% vs 75% P = 0,006) to consume farmed fish. The older age
339 groups were more receptive to aquaculture fish consumption with 83%, 79% and 80% for the
340 three older age groups compared with 64% observed in the <25 group (P = 0,016). Recently,
341 Cardoso et al. (2016) described older respondents as more unwilling to consume aquaculture
342 fish than younger ones, however this tendency was not observed in the present survey. The
343 relative proportion between age classes is very similar between surveys, and therefore the
344 differences may arise from having questions formulated differently or having distinct
345 populations generating diverse preferences (results). The acceptance of aquaculture fish and
346 its consumption are influenced by several perceptions that may be based on real events,
347 experience, and sometimes on preconceived ideas. Some consumer opinion studies suggest
348 that aquaculture fish is regarded as less healthy and with lower nutritional value than wild fish
349 (Claret et al. 2014). However, in a study performed in Belgium the majority of sampled
350 consumers did not report differences between wild and farmed fish, although mean perception
351 of taste, health and nutritional value still scored slightly higher for wild fish (Verbeke et al.,
352 2007). Consumers also expect the sensory properties of farmed fish to be similar to those of
353 wild fish (Sérot et al., 1998). Fish consumers, particularly experienced ones, are able to
354 distinguish between farmed and wild fish, depending on the species (Grigorakis et al., 2003;
355 Fuentes et al., 2010), although these differences may not be transversely perceptible among

356 consumers. Verbeke et al. (2007) and Vanhonacker et al. (2011) suggested that perceived
357 differences between farmed and wild fish were mainly driven by emotion rather than by
358 rationality, and also that consumers' opinions on farmed fish might be a reflection of intensive
359 livestock farming.
360 In the present study, respondents showed strong attitudes concerning aspects to improve in
361 aquaculture fish. Most participants clearly selected flavour, more diversity, nutritional value, fat
362 content and texture as the main desired improvements in farmed fish (fig. 3). Food choice tests
363 revealed that participants were able to distinguish between wild and farmed fish mainly based
364 on taste and texture descriptors (Fuentes et al., 2010; Grigorakis et al., 2003; Grigorakis,
365 2007). Farmed fish sensory traits, such as odour, flavour intensity and texture, were shown to
366 be positively correlated with the fat content present in the fillet (Grigorakis et al., 2003; Valente
367 et al., 2011) but also quite dependent on production practices (Valente et al. 2011).
368
369 Approximate position of Figure 3.
370
371 *3.5 Fish fortification: concept and selected nutrients*
372 In terms of one of the main goals of this questionnaire, results revealed a good receptiveness
373 of the fish fortification concept (fig. 4). More than half (52%) of the respondents agreed with
374 fish fortification, 27% disagreed and 21% neither agreed nor disagreed, men being generally
375 more favourable (59%) than women (49%) ($P = 0.003$). Moreover, 49% of respondents showed
376 willingness to consume fortified fish, mainly among the oldest (90 %) and youngest (68%)
377 groups ($P = 0.001$), though all groups were positive towards such consumption. These results
378 did not confirm the first established hypothesis grounded on consumers' scepticism about the
379 enhancement of fish from aquaculture.
380
381 Approximate position of Figure 4.
382

383 Of prime importance is nutrient used in fortification and the combination between food carrier
384 and beneficial ingredient. Some studies have concluded that the carrier product may be a more
385 important predictor of intention to purchase than the health claims related to the food item (Lyly
386 et al., 2007), or the main health effects of an ingredient (Krutulyte et al., 2011). Moreover, it
387 was described that food fortification with an already present compound would improve the
388 perceived naturalness (Grunert, 2005) and healthiness (Ares and Gámbaro, 2007) of the
389 product. It was also observed that consumers fear an off-flavour caused by a functional
390 ingredient when there is no natural link to the carrier product (Grunert, 2010). In this study,
391 omega-3 fatty acids and anti-oxidants were the most popular nutrients for fish fortification (fig.
392 5), followed by vitamin D and magnesium. Familiarity with omega-3 fatty acids and anti-
393 oxidants, and knowledge of their beneficial health effects, probably owed to strong media
394 advertisement, even if associated with other products, may have induced participants' choice.
395 It has been referred that consumers are more likely to accept functional ingredients that they
396 are familiar with, usually due to better knowledge of their health benefits, but also influenced
397 by longer market permanencies (Bech-Larsen and Scholderer, 2007; Urala and Lähteenmäki,
398 2007). Omega-3 fatty acids were previously chosen in other studies as preferred nutrients in
399 functional foods (Bech-Larsen and Grunert, 2003) and included in the top bioactive ingredients
400 considered as most effective for improving health (Vella et al., 2013). Moreover, fish is already
401 known for its high omega-3 levels, and fortification with a naturally present nutrient may be
402 perceived as a more *natural product*.
403
404 Approximate position of Figure 5.
405

406 *3.6 Fish fortification: purchasing intentions*

407 The evaluation of consumers' purchasing intentions allows predicting, at least to some degree,
408 future behaviour and market viability of theoretical food items. If fortified seabream was
409 marketed with the same price as common farmed seabream, more than half the respondents

410 (55%) would buy it. Additionally, the oldest and youngest segments (68%) were slightly more
411 favourable to this purchasing than the other age groups (52%: 26-40 and 55%: 41-65) (P =
412 0.047). In the case of a higher market price consumers were still receptive to purchasing
413 fortified seabream, though to a lesser extent (35%).
414 An interesting fact is that the percentage of respondents willing to buy fortified seabream (55%)
415 was higher if compared with the number of respondents who agreed with fortification (52%)
416 and were willing to consume it (49%), which suggests that price accessibility may positively
417 influence undecided consumers. In fact, about 20% of respondents undecided about fish
418 fortification (P=0.000) and 22% undecided about fortified fish consumption (P=0.000) would
419 select fortified seabream. Only when faced with the question of paying a higher price for
420 fortified fish the score was quite lower, but still 35% showed interest in purchasing. Recently
421 Pereira et al. (2016) assessed the receptiveness of institutional buyers such as hotels and
422 schools to fortified seabream, but also evaluated potential commercialization channels for this
423 new product. Results showed that 45.8% of respondents would probably buy fortified
424 seabream if it was currently available in the market, while only 20.9% stated the opposite.
425 Additionally, it was found that participants were willing to pay a premium price for this food
426 item, on average 7.8% more than the current seabream price, though for some consumer
427 segments the price could be 20% higher. Studies describe that price may impact consumers'
428 choice of functional foods (Annunziata and Vecchio, 2013). Consumers are willing to pay
429 premium prices for products that convey health benefits (Maynard and Franklin, 2003) but only
430 up to a certain cost (Siró et al., 2008). Norwegian consumers would pay 15% extra for organic
431 and animal welfare-labelled salmon compared with conventionally farmed salmon (Olesen et
432 al., 2010). Whitmarsh and Palmieri (2011) also described the willingness to pay premium for
433 salmon produced under minimized pollution methods. Price has been referred as one of the
434 barriers for purchasing functional foods, but not the most important one. The carrier product
435 (Ares and Gámbaro, 2007) and taste (Vella et al., 2013) were referred ahead of price as
436 barriers to try functional foods. It was also referred that the type of product and associated
437 health benefits would greatly influence the disposition to pay premium prices for improved

products (West et al., 2002). Overall, fortified fish seems to be a promising functional food with potential niche markets.

3.7 Description and characterization of consumer segments

Previous studies on consumer behaviour showed that structuring consumers into segments with similar characteristics results in a better understanding of consumption patterns (Brunsø, 2003; Pieniak et al., 2007). Differences related to functional food acceptance were reported among consumer segments, depending on age, gender (Ares and Gámbaro, 2007), education, and presence of children in the household (Gulseven and Wohlgenant, 2014). Purchasing fish and seafood products can be linked with specific criteria such as health beliefs, eating habits, convenience or production method (i.e. origin: farm vs wild) (Carlucci et al., 2015). Even if not the most important criteria, knowing the origin of fish could influence purchasing decisions (Vanhonacker et al., 2011). This criterion was found more relevant in populations with high fish consumption levels, as Spain and Portugal (Brunsø et al., 2009; Cardoso et al., 2016; Pieniak et al., 2010). In the present study two consumer groups were identified based on their high or low interest in knowing the origin of purchased fish: wild *versus* aquaculture. Knowing the fish origin was claimed to be important or very important by 58% participants, corresponding to the high interest group (HIG), while 42% of participants did not prioritise information about fish origin. This result showed that the majority of the studied population was receptive to the consumption of farmed fish, although being aware or not indifferent to the differences between wild and farmed fish.

The Socio-demographic characterization of LIG and HIG is very similar (table 1), as the surveyed groups tended to reflect the sampled population. In both groups more than 86% of respondents had higher education (total sample: 87%), more than 55% were married (total sample: 56%), and 35% to 39% were single (total sample: 37%). Family income was well distributed among the group, with incomes being slightly higher for HIG. Children in the

household were almost equally present in both groups (about half as in total sample: 53%). An important fact was that the participants responsible for buying foods at home were evenly distributed among interest groups (LIG: 86%; HIG: 89%; total sample: 87%). Significant differences were found only concerning gender, with more men included in the HIG (187) compared with the LIG (110), unbalancing the gender ratio. Men seem to be more aware of food issues and sharing both meal planning/preparing and food shopping activities (Flagg et al., 2014). In the present survey 82% of men and 92 % of woman reported they were responsible for buying food at home.

3.7.1 Fish consumption and valued attributes of fish

Reflecting the total sampled population, both HIG and LIG showed to be heavy fish consumers. Nevertheless, HIG presented a higher (P=0.002) consumption frequency, revealed a stronger belief in the relation between food and health (P=0.039), and a greater concern with food issues on a daily basis (P=0.001). The preferences of fish consumption by species were similarly distributed among interest groups, reflecting a cultural pattern, as previously discussed, rather than a casual option or individual attitudes. Regarding consumption of fish from aquaculture LIG scored higher (86%) when compared to HIG (75%) (P<0.001), though both groups were still very positive.

One of the main differences found between groups was the relative importance given to each fish attribute (fig. 6). Interestingly, the four preferred attributes of consumed fish were the same as for the total group, however LIG and HIG ranked the attributes differently. For LIG, flavour (P=0.002) was the first most important attribute followed by quality and freshness (P<0.001). Price (P=0.016), easy cooking and consuming (P=0.001), and convenience were significantly more important for LIG. In contrast, LIG showed little concern regarding fish species or ecological impact. HIG selected freshness as first priority, followed by quality, and flavour. Convenience and being easy to cook and to consume were not as important as for LIG. As remarked before, this group was more concerned about fish origin (P<0,001) and ecological

493 impact (*P*=0,001). Interestingly, HIG gave the same importance to fish origin as to being easy
494 to cook and the convenience aspect. These findings suggest a preference on the part of HIG
495 for whole and wild fish consumption rather than convenience products, and a stronger concern
496 with environmental factors. Vanhonacker et al. (2011) also described a tendency among
497 respondents that were more interested in fish origin being predominantly wild fish consumers.
498 As mentioned previously, price and convenience are key purchasing factors for younger
499 people (Krystallis et al., 2008), a tendency reflected by LIG.
500
501 Approximate position of Figure 6.
502
503 The performed PCA as complementary analysis (supplementary material, fig. S1) showed that
504 both interest groups are more populated in the higher scores of acceptance and willingness to
505 buy enriched fish (component 1) suggesting a positive receptiveness to fish enhancement
506 questions. LIG showed higher scores for characteristics related to aquaculture fish
507 consumption and very few observations on lower scores associated with fish origin issues, on
508 the contrary HIG presents more observations on the lower scores for component 2 (fish origin
509 issues and flavour).
510
511 The selected characteristics to improve aquaculture fish were ranked almost by the same order
512 in both groups (fig. 7) and coincided with the results found for the total sample. This suggests
513 that both groups had a similar perception of farmed fish traits. The only difference found
514 between groups is that LIG scored nutritional value in third and texture in fourth place, while
515 HIG ranked them in the inverse order.
516
517 Approximate position of Figure 7.
518

519 *3.7.2 Fish fortification concept*

520

521 Differences between the groups were observed regarding the concept of fish fortification
522 through feeding. LIG showed a higher acceptance level (sum of answers scoring 4 and 5: 56%
523 - LIG and 49% - HIG; *P*<0,001) and a stronger desire to consume fortified seabream (56% LIG
524 vs 44% HIG; *P*<0,001) (fig. 8). Nevertheless, both groups showed good receptiveness to
525 fortified fish. Almost half of HIG respondents agreed with this concept, and HIG had more
526 participants willing to consume it (sum of answers scoring 4 and 5: 44%) than not (sum of
527 answers scoring 1 and 2: 37%). Regarding fortification compounds, both HIG and LIG referred
528 omega-3 fatty acids and anti-oxidants as most requested nutrients, as observed for total
529 sample.
530 A very sceptic fraction was found in HIG who did not agree with fish fortification (31%), did not
531 choose any nutrient for supplementation (23%), and showed no willingness to consume
532 fortified fish (37%). However, it is interesting to notice that the HIG includes more participants
533 in the scale extremes (agree totally/ disagree totally) concerning fish fortification (Fig. 8).
534 Maybe owed to a greater concern about health issues observed in HIG, and consumers with
535 higher health concerns were also more likely to buy functional foods (Krutulyte et al. 2011).

536

537 Approximate position of Figure 8.

538

539 Purchasing intentions reflected, as expected, the receptiveness previously showed towards
540 the fortification concept. Both groups of respondents showed a positive intention to buy fortified
541 seabream, 59% and 52% respectively for LIG and HIG, if accessible at the same price as
542 commonly produced seabream (*P* = 0,042). At a higher price, receptiveness was lower in both
543 groups (LIG: 39% and HIG: 33%). As observed for the total sample, market price may influence
544 undecided consumers in both interest groups. The results from the present study showed
545 segmentation between groups, with consumers valuing fish attributes differently, having
546 distinct expectations for fish as a food product and revealing different receptiveness towards

547 fish fortification. There was a clear tendency for a higher acceptance and willingness to buy
548 and to consume fortified seabream within the LIG.
549
550 **4. Conclusion**
551 The present study showed high fish consumption frequency among all ages of the sampled
552 population and high concern with health issues in daily life. Outcomes also revealed that fish
553 consumption increased with children in the household, and with age and family income. Fish
554 from aquaculture was very well accepted among consumers as was the concept of fish
555 fortification. Based on the importance that participants gave to fish origin, two consumer
556 segments were defined: a high, and a low interest group. The characterization of the HIG
557 profile was more associated with older people, higher seafood consumption but less of farmed
558 fish, and more interest in freshness, health issues and impact on sustainability. The LIG
559 included younger people, with slightly lower seafood consumption, but of more aquaculture
560 products, and more interested in flavour, convenience products and price. Both interest groups
561 were consistent in their preference of fish species, attributes to improve in aquaculture fish,
562 and selected ingredients for fish fortification. Corroborating the second formulated hypothesis,
563 LIG was more receptive to all aspects of the fish fortification concept and showed willingness
564 to buy and consume fortified seabream. However, the sampled population included a highly
565 educated fraction of Portuguese consumers, not reflecting the characterization made in the
566 Portuguese census 2011 (INE, 2012), which is a major limitation in making an extrapolation of
567 the results for the Portuguese food market. Nevertheless, specific fortified fish products
568 combined with an appropriate communication strategy could be designed for targeting LIG
569 profile, which represented almost half of the population in this study.
570 Consumers may find enrichments as interfering with nature, therefore the perceived
571 healthiness of the base product, the combination carrier-ingredient and the communication
572 strategy are considered key factors for consumer acceptance of functional foods. Fish which
573 is generally accepted as healthy and an integrant part of a balanced diet could be considered
574 a suitable carrier product, in particular if omega-3 or anti-oxidants were the main functional

575 compounds used. Enhanced fish may act as a novel food and may be an opportunity for the
576 aquaculture industry to enter the fast-growing market of functional foods. However, the data
577 produced are hypothetical since such products do not exist in the Portuguese market and
578 consumers' reactions in real events may be different from the considerations made during the
579 on-line questionnaire. Nevertheless, new products will be developed in the aquaculture sector
580 to face rising demand, and to cope with a changing consumer mentality associated with the
581 importance of health care and prevention. Moreover, the development of new products and
582 new technologies are also gradually eliminating consumption barriers and increasing fish
583 products' convenience (Ernst & Young, 2009).
584 In the present study, as in others (Pereira et al., 2016), several participants asked for more
585 information concerning fortification processes and specific health benefits obtained by
586 consuming fortified fish. Effective and clear communication of farming fortification practices
587 and health benefits were suggested to increase consumers' acceptance of both farmed fish
588 and functional foods (Annunziatta and Vechio, 2013; Siró et al., 2008). Communicating
589 fortification in a transparent way, as well as the health benefits associated with the
590 consumption of such products, may be an efficient approach to increasing awareness and trust
591 in the process. Considering that the effectiveness of a functional food concept is a combination
592 of its efficacy and consumer compliance, farmed fish has a high potential to act as functional
593 food.
594 For future research it would be interesting to assess if consumers who are sceptic about
595 farmed fish and fortification issues would become more positive and receptive after being
596 exposed to information on these topics (leaflets and brochures). Moreover, contact with
597 fortified fish in a real life event would bring more evident conclusions on consumers'
598 receptiveness.
599

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608

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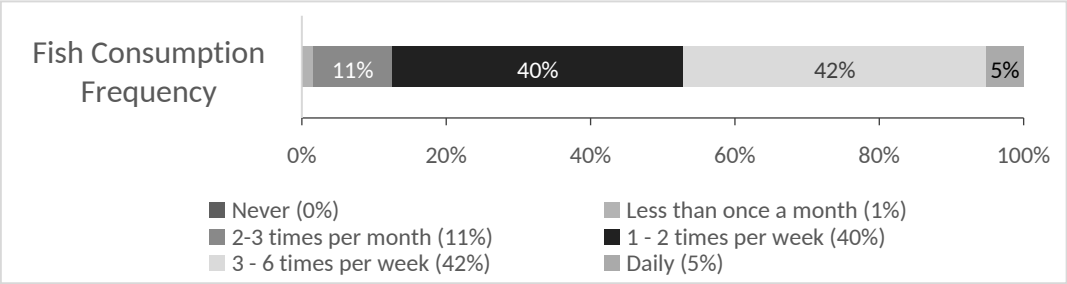
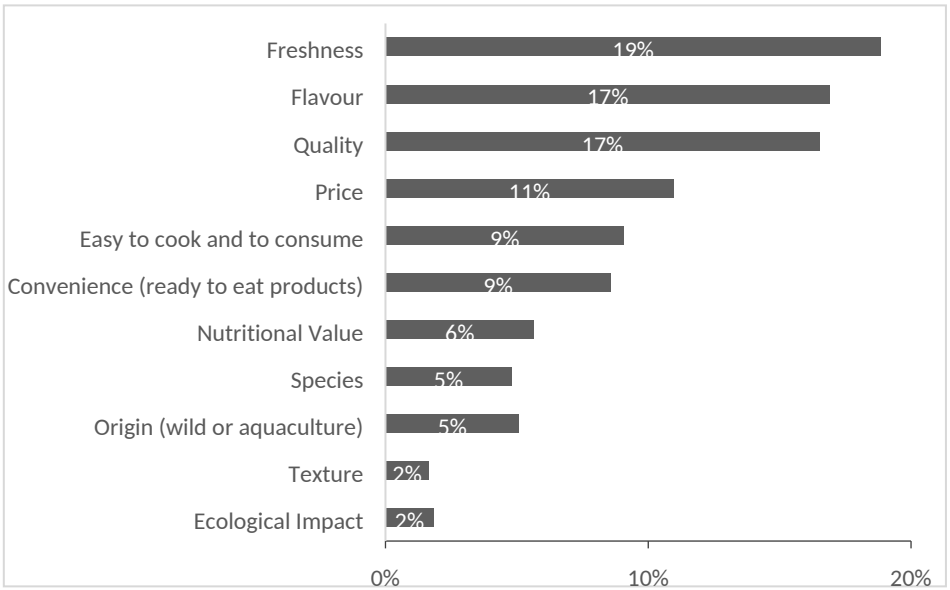
Figure 1.



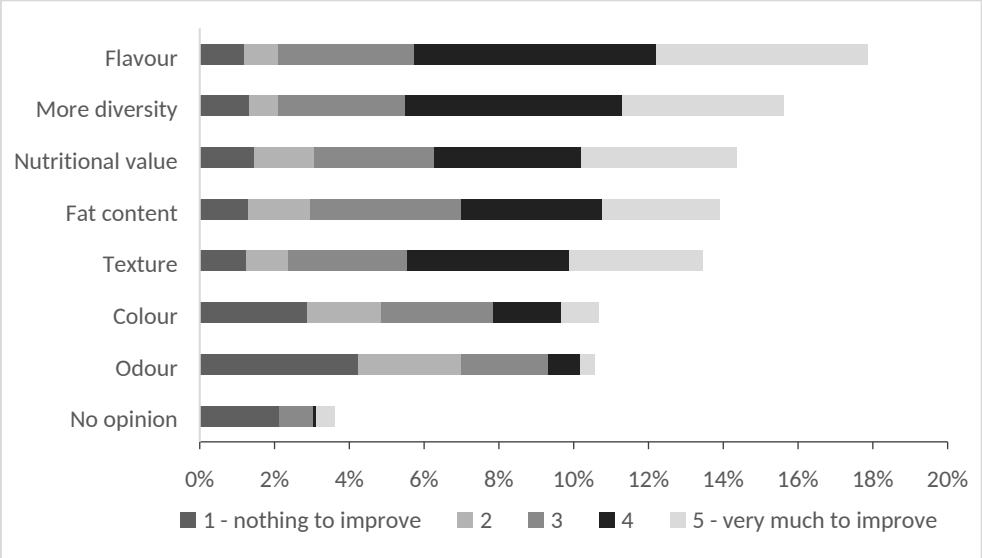
Values represent the percentage of answers for each class.

Figure 2.



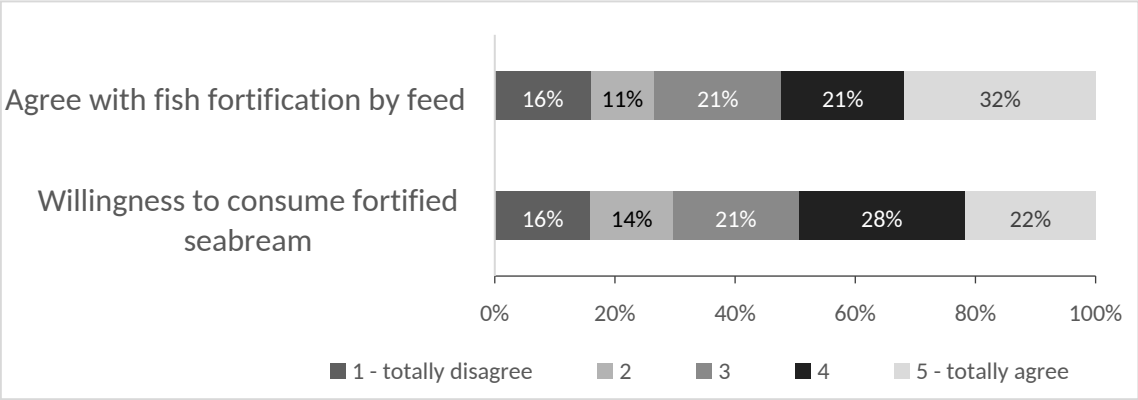
Values represent the percentage of answers for each attribute. Participants selected two valorised attributes resulting in a sum of percentages superior to 100%.

Figure 3.



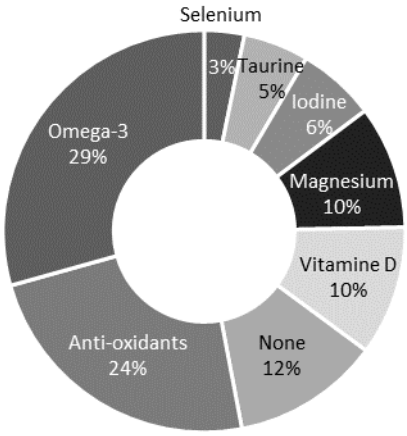
Values represent the percentage of answers for each attribute categorized from nothing to improve (1) to very much to (5).

Figure 4.



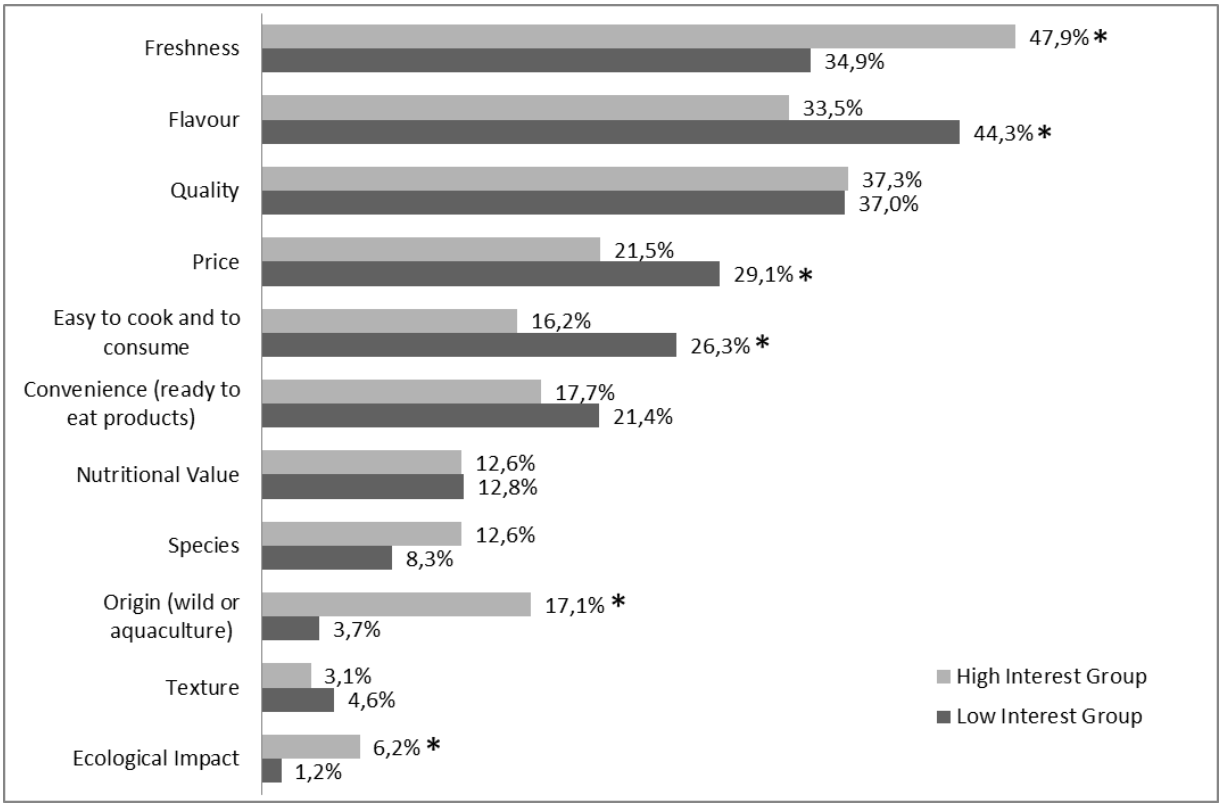
Values represent the percentage of answers for each question categorized from totally disagree (1) to totally agree (5).

Figure 5.



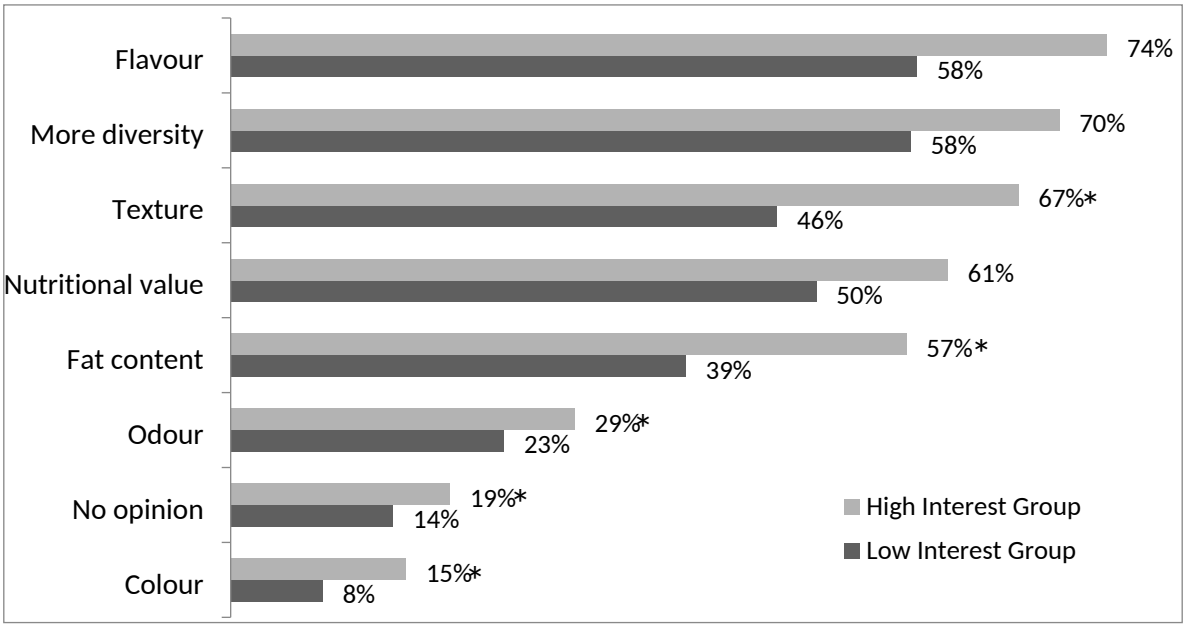
Values represent the percentage of answers for each nutrient.

Figure 6.



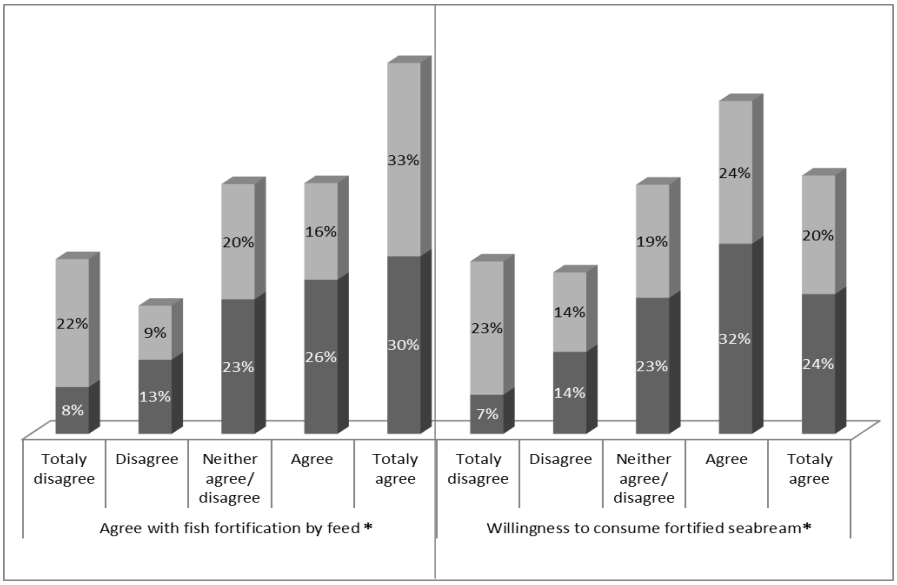
Values represent the percentage of high score answers (4 and 5) in comparison with total numbers answers (categories 1 to 5) for each option and within each interest group. Each participant chose two or more characteristics therefore the sum of percentages is superior to 100% in both groups.
**indicates statistical differences between groups. Dark grey colour represents LIG and light grey colour represents HIG.*

Figure 7.



Values represent the percentage of high score answers (4 and 5) in comparison with total numbers answers (categories 1 to 5) for each option and within each interest group. Each participant chose two or more attributes therefore the sum of percentages is superior to 100% in both group.
**indicates statistical differences between groups. Dark grey colour represents LIG and light grey colour represents HIG.*

Figure 8.



Values represent the percentage of answers for each question categorized from totally disagree (1) to totally agree (5).
**indicates statistical differences between groups. Dark grey colour represents LIG and light grey colour represents HIG.*

Figure captions

Fig. 1: Fish consumption frequency.

Fig. 2: Valorised fish attributes by Portuguese consumers.

Fig. 3: Attributes to improve in farmed fish chosen by inquired consumers.

Fig 4: Percentage of respondents concerning: 1) agreement on fish fortification and 2) willingness to consume fortified seabream.

Fig. 5: Selected nutrients for farmed fish fortification.

Fig. 6: Fish attributes valorised by consumers when buying or consuming fish, within each interest group.

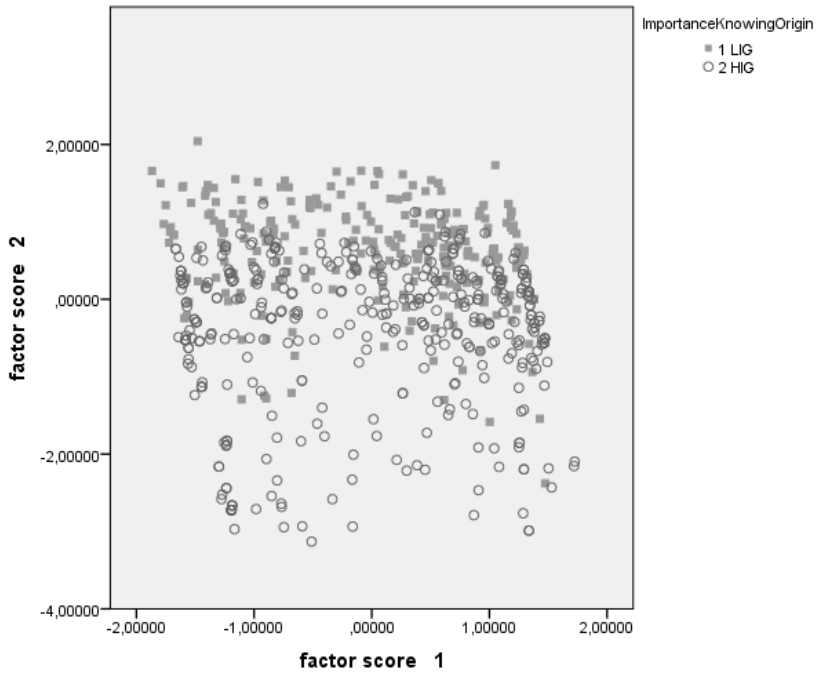
Fig. 7: Attributes to improve in farmed fish chosen by inquired consumers.

Fig 8: Percentage of respondents by interest group regarding: 1) agreement on fish fortification and 2) willingness to consume fortified seabream.

Supplementary material Fig. S1: Principal Component Analysis plot between scores 1 and 2 which accounted for 39.5% of the variance observed across variables

Supplementary material:

Figure S1.



The PCA analysis performed originated four components that accounted for 60% of the variance observed. All the items clustered on the first component were related with the acceptance and willingness to buy enriched fish. The second component included characteristics related with fish origin issues and flavour, while on the third component were characteristics related with convenience and freshness, and on the fourth component were found characteristics related with price and flavour. Circles represents HIG and squares represents HIG.

SPSS output data:

Table S1: Bartletts' test of sphericity

KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		,704
Bartlett's Test of Sphericity	Approx. Chi-Square	2095,554
	df	66
	Sig.	,000

Table S2: Eigenvalues associated with each linear component before extraction, after extraction and after rotation.

Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	3,110	25,921	25,921	3,110	25,921	25,921	2,829	23,576	23,576
2	1,634	13,619	39,540	1,634	13,619	39,540	1,646	13,714	37,290
3	1,279	10,657	50,197	1,279	10,657	50,197	1,482	12,351	49,641
4	1,172	9,769	59,965	1,172	9,769	59,965	1,239	10,324	59,965
5	,941	7,845	67,811						
6	,842	7,021	74,831						
7	,778	6,481	81,312						
8	,745	6,209	87,521						
9	,578	4,813	92,335						
10	,422	3,514	95,849						
11	,312	2,603	98,452						
12	,186	1,548	100,000						

Extraction Method: Principal Component Analysis.

Table S3: Rotated Component Matrix after orthogonal rotation (varimax)

Rotated Component Matrix[a]

	Component			
	1	2	3	4
Which would buy with the same price: enriched or common	,868			
Will to consume enriched seabream	,867			
Agree with fish enrichment by feed	,860			
Will to pay higher price for enriched seabream	,737			
Origin (wild or aquaculture)		-,761		
Importance of knowing fish origin from aquaculture		-,585		
Aquaculture Fish Consumption		,542		
Convenience (ready to eat products)			,772	
Freshness			-,715	
Easy to cook and to consume			,550	
Price				,793
Flavour		,423		-,738

Extraction Method: Principal Component Analysis.

Rotation Method: Varimax with Kaiser Normalization.[a]

a. Rotation converged in 5 iterations.

Table 1: Description of socio-demographic characteristics of respondents.

	Portuguese population[1]	Total respondents[2]	High Interest Group	Low Interest Group	*P value*[3]
Number of participants	10 561 614	778 (100%)	451 (58%)	327 (42%)	
Age (years)					*0.06*
Less 25	26 (%)	76 (10%)	9%	11%	
26 – 40	55 (%)	456 (59%)	55%	63%	
41 – 65		234 (30%)	34%	25%	
Plus 65	19 (%)	12 (2%)	2%	1%	
Gender					*0.027*
Female	52 (%)	481 (62%)	59%	66%	
Male	48 (%)	297 (38%)	42%	34%	
Education level					*0.415*
Primary	74 (%)	6 (1%)	7%	9%	
Undergraduate	14 (%)	87 (11%)	10%	13%	
Graduate	12 (%)	685 (88%)	89%	86%	
Family Income (€)[4]					*0.424*
Less 1000		143 (20%)	20%	21%	
1001 - 2000		219 (31%)	30%	33%	
2001 - 3000		190 (27%)	27%	28%	
Plus 3000		150 (21%)	24%	18%	
Children in the household		53%	55%	51%	*0.308*
Responsible for buying food at home		53%	55%	51%	*0.142*

[1] INE, 2012

[2] The column “total respondents” corresponds to the characterization of all respondents with complete answers either in numbers as in percentages by categories. The columns “low interest group” and “high interest group” correspond to the demographic characterization of these specific groups.

[3] Indicates statistical differences between low and high interest groups following Chi-square analysis.

[4] Calculations were performed with data from 702 respondents, 76 claimed not knowing their family income.