Deliverable Report

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Objective: The objective of this Deliverable was to report the results of sensory descriptive analysis of the developed products: The report refers: (a) to the selection and training of panellists that consistuted the group of experts evaluating the sensory properties of the products, based on specific sensory tests; (b) to the development of vocabulary consisting of specific terms describing the fish products - terms referring to all sensory qualities describing the products (external appearance, odour, taste, flavour, texture, aftertaste); (c) to the main evaluation procedures of the products, including the complete experimental setup; and (d) to the rating of the products for each of the attributes (vocabulary terms). A full map of the organoleptic qualities of each product is presented. Also comparisons between different products were made were applicable.

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1. Introduction

To ensure a high performance of the trained assessors, the internal panel of P1. HCMR was screened prior to sensory evaluation according to ISO standards (ISO 8586: 2012). Profiling the sensory characteristics of the processed fish product prototypes was achieved via generic Descriptive Analysis (DA). The DA is a powerful and widely used technique to acquire sensory profiles of food products (Lawless & Heymann, 2010). In DA, intensity measurements allow acquisition of detailed information regarding attributes, whereas the selection and training of assessors prior to the evaluation ensures the reliability and consistency of measurements (Lawless & Heymann, 2010). Furthermore, the effect of processing on the intra species sensory quality was examined. This included statistical analysis of results for two species, namely meagre (*Argyrosomus regius*) and grey mullet (*Mugil cephalus*), from which two processed products were generated from DIVERSIFY. To allow a complete comparison, the data from ***Deliverable 28.3 Report on product and process solutions for each species based on technological, physical and sensory characteristics*** that profiled the sensory characteristics of the cooked fillets of the species were used as well, and were compared to those of the processed products generated from the same species. Furthermore, a qualitative comparison of their sensory characteristics to those of the corresponding cooked fillets (D.28.3) was performed for greater amberjack (*Seriola dumerili*) and pikeperch (*Sander lucioperca*) processed products.

2. Methodology

2.1. Selection & screening of the sensory panel

The assessors recruited for the screening were P1. HCMR employees (internal sensory panel) with previous experience in sensory profiling of fish and fish products. The general criteria for the recruitment process included the availability of the assessors throughout the period of the experiments, as well as their interest and motivation, willingness for cooperation, their sense of responsibility and concentration, health status, and ability to communicate and describe. The selection of assessors throughout the screening process took into account the indented application, the performance of the candidates at the interviews, and their potential rather than their current performance. Specifically, candidates with high success rates were expected to be more useful than others, however those showing improving results with repetition were likely to respond well to training, thus they were also preferred.

2.1.1. Determining sensory acuity

The tests of determining the sensory acuity (identification & detection of basic tastes) took place in isolated sensory testing booths (ISO, 200707). If possible, 100% correct answers were preferred. A minimum of 2 wrong answers out of 10 was allowed to proceed to the next screening step.

a. Identification of basic tastes

Participants received five samples corresponding to 20-ml water solutions of each of the basic tastes (**Table 1**). Taste solutions were placed in white plastic cups and each of the cups was labeled with a different (random) 3-digit code. All samples were served simultaneously, but participants were instructed to taste the solutions in the order they were presented in the questionnaire. The order of tasting was randomized across participants. Participants were advised to take some time to become familiar with each taste and then write down the word that best described the taste sensation they perceived for each of the sample, together with the

samples' 3-digit code in the questionnaire. Participants were also instructed to clean their palates with plain water between the different samples.

Table 1: Basic taste solutions used for the identification test.

Basic taste	Compound	Dilution (%)	Dilution in 0.5 L
Sweet	Sucrose	1	5 g
Sour	Citric acid	0.09	0.45 g
Salty	Sodium chloride	0.2	1 g
Bitter	Caffeine	0.09	0.45 g
Umami	Monosodium glutamate	0.12	0.6 g

b. Detection of basic tastes - triangle tests (ISO 4120)

One basic taste was tested at a time. All basic tastes were tested in one session. The order of the triangle tests, corresponding to each of the basic tastes, was randomized across participants.

Triangle test principle: two samples of the test material and one sample of plain water, or one sample of the test material and two samples of plain water were presented to participants in each of the triangle tests. Participants had to indicate the sample that was different among the three that they were presented. Participants received instructions to clean their palates with water between samples. The tests of the identification of basic tastes took place in isolated sensory testing booths (ISO, 20077). The concentrations of the basic tastes in water used for the testing and test design are included in **Table 2**.

Table 2: Basic taste solutions (20 ml in water) used in triangle tests.

Basic taste	Compound	Dilution (%)	Dilution in 0.5 L	Design
Sweet	Sucrose	0.6	3 g	ABB[1]
Sour	Citric acid	0.06	0.3 g	ABB
Salty	Sodium chloride	0.15	0.75 g	AAB
Bitter	Caffeine	0.06	0.3 g	ABB
Umami	Monosodium glutamate	0.08	0.4 g	AAB

[1] A-sample solution & B-plain water

2.1.2. Discrimination between levels of intensity – ranking

A satisfactory level of success in this task can only be specified in relation to the particular intensities used. However, participants who inverted the order of more than one adjacent pair of samples were considered unsuitable as assessors and were not allowed to proceed further in the screening process.

a. Basic tastes

Four samples corresponding to different levels of intensity were presented to participants for each of the basic tastes ranking test. The four samples corresponded to sequential dilutions (in 20 ml of water) of the active taste compounds (**Table 3**). Participants were asked to rank the samples in order of increasing intensity. The dilutions were presented simultaneously, but a specific order of tasting was dictated in the questionnaire. Samples were labeled with a 3-digit code each and the random presentation order of samples was the same for all participants, to ensure that comparison of their performance was not influenced by the presentation order.

Table 3: Taste reference dilutions used in the ranking test.

Basic taste	Compound	Dilution a% (g/0.5 L)	Dilution b% (g/0.5 L)	Dilution c% (g/0.5 L)	Dilution d% (g/0.5 L)
Sweet	Sucrose	0.3 (1.5)	0.6 (3)	1 (5)	1.5 (7.5)
Sour	Citric acid	0.02 (0.1)	0.04 (0.2)	0.06 (0.3)	0.1 (0.5)
Salty	Sodium chloride	0.05 (0.25)	0.15 (0.75)	0.2 (1)	0.4 (2)
Bitter	Caffeine	0.02 (0.1)	0.04 (0.2)	0.06 (0.3)	0.1 (0.5)
Umami	Monosodium glutamate	0.02 (0.1)	0.04 (0.2)	0.06 (0.3)	0.1 (0.5)

b. Odour

For the odour ranking test, four samples with a different intensity of a specific odour were presented to all participants, who were required to rank them in order of increasing intensity. The four samples corresponded to sequential dilutions of the active odour compound (**Table 4**). The dilutions were presented simultaneously, but a specific order of tasting was indicated in the questionnaire. Samples were labeled with a 3-digit code and the random presentation order of samples was the same for all participants, to ensure that comparison of their performance was not influenced by the presentation order.

Table 4: Odour reference dilutions used in the ranking test.

Odour quality	Active compound	Dilution a (%)	Dilution b (%)	Dilution c (%)	Dilution d (%)
Green/fresh cut grass	cis-3-hexenol	0.01	0.02	0.04	0.08

c. Texture

For the texture-ranking test, three samples with different intensity of a specific texture attribute were presented to all participants, who were asked to rank them in order of increasing intensity. The samples were

physical product references and the level of intensity they represented is given in **Table 5**. All samples were presented simultaneously, but a specific order of tasting was indicated in the questionnaire. Samples were labeled with a 3-digit code and the random presentation order for samples used was the same for all participants, to ensure that comparison of their performance was not influenced by the presentation order.

Table 5: Texture references and the corresponding intensity levels they represent

Texture	Intensity 1 (Low)	Intensity 2 (Medium)	Intensity 3 (High)
Firmness	Halibut	Sea bream	Overcooked sea bream

2.1.3. Descriptive ability of a stimuli

These tests were aimed to determine a candidate`s ability to describe sensory perceptions. Two tests were used. One test was covering odour stimuli and the other textural stimuli. The tests included a stimuli assessment, combined with an interview of the participants. Candidates were presented with nine olfactory stimuli (**Table 6**) related to the processed fish product intended to be evaluated. The set contained some samples that are easy to recognize and others that are less common. The intensity of the odours was well above the recognition threshold, but not greatly above the levels that might be encountered in the products of interest.

Candidates were graded according to performance on a scale as the follows:

- 3 points for a correct identification or a description of the most frequent association
- 2 points for a description in general terms
- 1 point for an identification or description in general terms
- 0 points for no response or a totally wrong response

The satisfactory level of success in this task was specified in relation to the materials used, as related to the difficulty of those for identification.

a. Odour description

The method most commonly used is still that of the evaluation of odours from flasks. The method used for the preparation of the odour samples was as described below (**Table 6**):

For liquids, samples were absorbed in odourless cotton wool, which was placed in odourless flasks that do not have a visual recognition of the colour and could be capped. Sufficient material was allowed to evaporate into the headspace of the flasks and the intensity was checked before presentation of the flasks to candidates.

For non-liquids, samples were directly placed in odourless flasks that did not have a visual recognition of the colour and could be capped. Sufficient material was allowed to evaporate into the headspace of the flasks and the intensity was checked before presentation of the flasks to candidates.

Table 6: References used in the odour description test.

Odour quality	Compound	State
Butter/caramel	Diacetyl	Liquid sample
Butter/milk	Butter	Non-liquid sample
Green (apple/grass)	cis-3-hexenol	Liquid sample
Sardine	Cod oil capsules	Liquid sample
Cheese	Isovaleric acid	Liquid sample
Vinegar	Vinegar	Liquid sample
Smoky	Guaiacol	Liquid sample
Potato	Methional	Liquid sample
Seafood	Surimi	Non-liquid sample

b. Texture description

Candidates were provided with a series of products (**Table 7**) in random order and were asked to describe their textural characteristics. The products were presented as uniformly sized blocks, when possible.

Table 7: References used in the texture description test

Texture quality	Product	Form	Size
Crumbly	Muffin	Piece	3x3 cm
Rubbery	Squid	Piece	2x2 cm
Juiciness	Mellon	Piece	3x3 cm
Pasty	Pure	1 tea spoon	

2.2. Sensory descriptive analysis of the processed fish product prototypes

2.2.1. Samples

Six different fish products were evaluated. The products corresponded to the processed fish products generated in D.28.4, from which six were chosen to be evaluated further via sensory analysis. The products namely were smoked fish fillets (grey mullet), fillets in olive oil (grey mullet), fish pate (pikeperch), fish salad (meagre), fish steak (greater amberjack) and fish burger (meagre). To allow valid comparisons, products were of the same batch and packaging, and they were stored at -20°C prior to evaluation. Smoked fish fillets, fillets in olive oil, fish pate and fish salad were ready-to-eat products, thus samples were served at room temperature and no further preparation was required prior to sensory analysis. Fish steak and fish burger were cooked in fa rying pan covered with a thin layer of olive oil and were thereafter placed in a

thermo chamber set at 60°C until serving. The time between cooking and serving did not exceed 30 min. All samples were served in black ceramic individual containers and the serving portion was approximately 25 g. Preparation and cooking of samples was performed in the facilities of P1. HCMR at Agios Kosmas, Athens, Greece.

2.2.2. Trained panel

The internal trained panel (TP) consisted of 10 employees of P1. HCMR (2 men and 8 women), with prior experience in sensory evaluation of fish and fish products. The assessors that participated in the panel were screened prior to the commencement of the sensory analysis according to ISO 8586 (2012), as described earlier in Section 2.1. Sensory descriptive analysis of the processed products was performed in the sensory laboratory of P1. HCMR at Agios Kosmas in Athens, Greece.

2.2.3. Vocabulary development & attribute references

The first step of training included a vocabulary development session (lasting 1.5 h), during which the trained panel tasted all six products. The trained panel generated a 35-attribute list that described all main characteristics of the aroma, taste, flavour and texture of the products. The rate-all-that-apply (RATA) methodology was used then to select the final attribute list to be used in the descriptive analysis of the products (Ares et al., 2014).

The RATA evaluation session lasted approximately 30 min for all six product samples. Each sample was tasted once (no replicas) and in a monadic sequence. Within modalities, attributes appeared in a fixed order across panelists, and the presentation of modalities in the questionnaire followed the dynamics of sensory perception (Ares & Jaeger, 2013; Ares et al., 2013). Samples were blind-labeled with a three-digit code and the serving order was randomized and balanced to account for first order and carry-over effects (MacFie, Bratchell, Greenhoff, & Vallis, 1989). Mineral water and a piece of green-apple were provided to assessors to cleanse their palates between samples. The RATA evaluation was performed in individual sensory booths (ISO, 2007) in the HCMR facilities of Agios Kosmas, Athens, Greece.

According to the results of the RATA evaluation, attributes that were not discriminant among products and experienced low frequencies were not included in the final attribute list. Specifically, attributes that were overlapping between the aroma and flavour description of the samples were kept in the modality they had higher citation frequency. The umami and seafood flavour attributes, whereas non-discriminant, were kept, since they were important for the description of specific samples. The final 29-attribute list used for the descriptive analysis evaluation, along with the attribute references used during the training of the sensory panel in the products is shown in **Table 8**.

2.2.4. Training of sensory panel on the product set

After the selection of terms, the panel continued with training on the definition and scaling of attributes included the vocabulary list of **Table 8**. The training prior to evaluation included first a familiarization session with attribute physical references (1 session of 1.5 h). This step was performed to ensure a clear definition and consensus among panel members for the meaning of attributes included in the list (**Table 8**). Thereafter, two sessions that lasted 2 h each were dedicated to pair comparisons of samples on 15 cm unstructured line scales, which were followed by panel discussions. This step was included to ensure that for individual attributes there was a consensus among panel members in the scaling of attributes and ranking of samples. Additionally, two more sessions that lasted 1 h each were performed, during which assessors were placed in sensory booths (ISO, 2007) to evaluate the samples using 15 cm attribute scales. These results were used to check consistency and repeatability in the quantification of the attributes' intensities. During training and DA the performance of the TP was evaluated using the Panel Check software V1.4.0.

2.2.5. Evaluation of product prototypes

The final evaluation of the products via sensory descriptive analysis was performed in individual sensory booths (ISO, 2007) in the P1. HCMR facilities. For the evaluation, the vocabulary list was divided in sensory modalities as shown in **Table 8**. Evaluation of attributes was performed in 15 cm unstructured line scales, anchored "not at all" to "very much". Samples were evaluated in a monadic sequence in triplicates and they were blind-labeled with three-digit codes. The serving order of samples was randomized and balanced to account for first order and carry-over effects (MacFie et al., 1989). The evaluation was divided in three sessions with a 15 min break. Questionnaires were filled in by hand. Mineral water and a piece of green-apple were provided to assessors to cleanse their palates between samples.

Table 8: Attribute list along with the references for attributes used for the trained panel descriptive analysis.

Attribute	Physical reference
Aroma	
Butter	Low: halibu[1]; High: halibut1 + butter (10:1)
Green	Sea bream[1] paste + boiled vegetables[2] (1:1)
Lemon	Cotton ball with 5ml of lemon juice
Spicy	Sea bream[1] paste + oregano + Dijon mustard (10:1:2)
Garlic	10g of sea bream[1] paste+ 1.5g garlic powder
Sardine	10 g of greater amberjack[1] paste + 1 ml of cod liver oil
Smoked	Smoked canned herring
Toasted	Toasted bread
Oxidized	Canned tuna in water
Taste	
Sweet	10g of meagre[1] paste + 2% sucrose solution (2:1)
Salty	10g of meagre[1] paste + 0.4% sodium chloride solution (2:1)
Sour	10 g of seabream[1] paste +1.5% citric acid solution (2:1)
Umami	10 g of meagre[1] paste+ 0.1% MSG solution (2:1)
Flavour	
Seafood	10 g surimi
Potato	10 g of seabream[1] paste + boiled vegetables2 (1:1)
Cheese	10 g meagre[1] paste + mozzarella (1:1)
Fatty	10 g salmon[1] belly
Earthy	10 g pikeperch[1]
Canned tuna	10 g canned tuna in rapeseed oil
Sardine	10 g of greater amberjack[1] paste + 1 ml of cod liver oil
Rancid	Rancid oil
Texture	
Rubbery	Squid cooked 35min at 110ºC (no lid)
Chewy	Sea bream cooked 60 min at 110ºC (with lid)
Crunchy	2x2 cm piece of raw carrot
Juicy	Salmon baked 15 min at 110ºC
Greasy	10 g salmon[1] belly
Fibrous	2x2 cm sea bream cooked 70min at 110ºC (no lid)
Pasty	Salmon[1]
Teeth Adherence	Salmon[1]

[1]Baked 20 min at 110 ºC
[2]Green beans + potato (3:1)

2.2.6. Statistical analyses

The statistical analyses had two aims: a) to profile the sensory characteristics of the product prototypes and b) to compare the sensory profiles of products, when applicable. To satisfy the latter aim, the results of the descriptive analysis of the fish fillets of the species, which were obtained in ***Deliverable 28.3 Report on product and process solutions for each species based on technological, physical and sensory characteristics***, were also used to create three different levels of processing for meagre and grey mullet products.

a. Profiling of sensory characteristics of processed fish products prototypes

To identify discrimination ($P<0.05$) between products per attribute, a mixed ANOVA model (fixed effect: product; random effects: assessor, replica) was calculated and post-hoc analysis of results was performed by the Tukey test. Additionally, visualization of the sensory maps and construction of confidence areas around the six processed products was performed via bootstrapping, as described in Husson et al. (2005). In the calculation of the models, only sensory attributes that exhibited a tendency for significant variation ($P<0.05$) were included.

To examine if products were discriminated according to their sensory characteristics, we used bootstrapping to create confidence ellipses around the individual products (Husson et al., 2005). The overall idea behind bootstrapping is that panelists vary in their perception and evaluation of the products. Thus by replacing the measurements of some panel members, with others originating from the same panel, can generalize the results acquired, and provide a measure of uncertainty regarding the products' position. This is achieved via resampling, *i.e.* replacement of some panelists with others, which leads to the creation of new "virtual panels". The sensory description acquired from each virtual panel is then used to create a new configuration of the product set; all new configurations are then used to construct the confidence area of each of the products, for which the product point is in the gravity centre of those (Husson et al., 2005). Bootstrapping was performed by retaining the original panel size (N=10) and choosing randomly J assessors to be replaced by other J assessors of the trained panel. This was performed repeatedly 500 times, resulting in 500 different processed product configurations, obtained via bootstrapping. The coordinates of the 500 newly calculated sample configurations were then treated as the new processed product points, for which a 95% confidence area was drawn around. The position of the processed products in the final map reflected the gravity centre of the 500 individual configurations obtained via bootstrapping. Analyses were performed in XLSTAT® software, 2016 (Addinsoft™).

b. Comparison of different processed products generated from the same fish species:

Since the fillets (D.28.3) and the further processed products of the species were evaluated in two different time periods, the vocabulary used differed. Thus, the results corresponding to the fish fillets of meagre and grey mullet were analysed separately from the ones corresponding to the processed products. For the fish fillets, determination of significant differences for the sensory attributes was performed by a mixed model ANOVA with interactions (fixed factor: sample; random factors: assessors, replicates). Regarding the processed products, sensory results were analysed separately for meagre and grey mullet products using a mixed ANOVA model with interactions (fixed factor: sample; random factors: assessors, replicates). Analyses were performed in XLSTAT® software, 2016 (Addinsoft™). For greater amberjack and pikeperch, since only one processed product was generated, only qualitative comparisons of the sensory profiles of those to their corresponding cooked fillets (D.28.3) were possible.

3. Sensory characteristics of processed fish products prototypes

All six processed fish product exhibited unique and discriminant sensory profiles, as indicated in the Principle Componet Analysis (PCA)_ sensory maps of **Figure 1**. Furthermore the products exhibited significant (P<0.05) variations in all sensory aroma, taste, flavour and texture attributes examined (**Table 9**). The main intense and discriminant characteristics of each product per modality were:

Pikeperch pate: garlic aroma; earthy and secondary potato flavour; pasty and secondary teeth adherence texture.

Meagre salad: lemon and secondary spicy and green aroma; sour taste; seafood flavour; crunchy and juicy texture.

Meagre burger: butter and toasted aroma; sweet and umami taste; cheese and secondary fatty flavour; rubbery and secondary greasy, juicy and chewy texture.

Smoked grey mullet fillets: smoked aroma; salty taste; sardine and secondary rancid flavour; chewy texture.

Grey mullet fillets in olive oil: sardine and oxidized aroma; canned tuna and secondary fatty, rancid and sardine flavour; fibrous and secondary greasy and chewy texture.

Greater amberjack steak: this product did not exhibit any specific discriminant characteristics, but was perceived as having equally high intensities with other processed products in several attributes. Specifically, the steak was perceived as having amongst the highest green aroma, potato and sardine flavour, teeth adherence and secondary fibrous and chewy texture.

The lack of very intense characteristics for the greater amberjack steak was expected, because this was the least processed of all the products examined. The remaining products during their formulation underwent more intense processing, such as heat treatment during smoking, and/or required additional material, such as addition of fat, such as olive oil or Emmental cheese. These processes resulted in the processed products' profiles deviating more from each other than the original fish fillets of the species (D28.3). Specifically, as it can be seen that for 63% of the variation, F1 vs. F2 PCA plot of **Figure 1a**, the products that retained their fillet structure, *i.e.* steak, fillets in olive oil and smoked fillets, were closely located in the plot, whereas the rest of the products acquire distinct place. In F3 vs. F4, these products are separated and their individual characteristics are more evident (**Figure 1b**). Thus, whereas greater amberjack steak was lacking individual discriminant sensory characteristics, it was discriminated with respect to its sensory profile from all other processed products (**Figure 1b**). The same applied for all processed products, indicating that processing was successful in creating products that exhibited different sensory profiles and thus could cover different preferences for sensory attributes (**Figure 1a & b)**

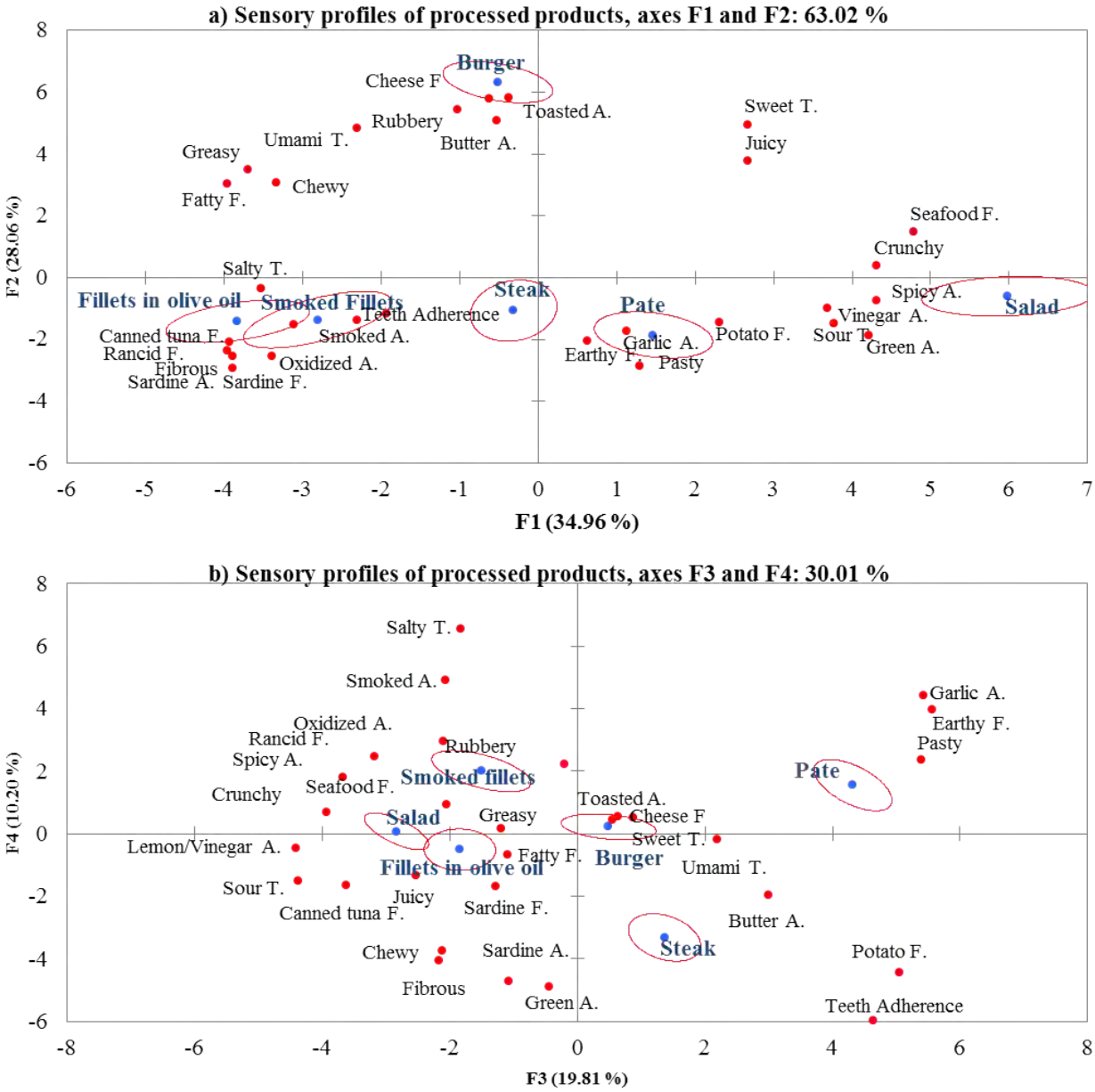

Figure 1: PCA sensory maps of processed products including confidence ellipses around products points indicating the uncertainty of sensory evaluations; the confidence ellipses are built via bootstrapping. Abbreviations used: A. aroma, T. taste, F. favour.

Table 9: Mean ± standard deviation of attributes per processed product (15 cm scale). The F-value and level of significance as obtained by mixed model ANOVA is included in the F-value column.

Attribute	F-value	Steak[1]	Pate[2]	Salad[3]	Burger[3]	Smoked fillets[4]	Fillets in Olive oil[4]
Aroma							
Butter	33.4***[5]	5.2b[6] ±4.3	3.3bc ±3.2	0.2d ±0.9	11.0a ±3.1	1.1cd ±3.0	0.8d ±2.5
Green	22.5***	7.2a ±4.1	4.0b ±3.6	9.4a ±3.4	0.9c ±2.0	0.2c ±1.4	2.0bc ±3.1
Lemon	87.7***	0.5c ±1.1	0.1c ±0.6	13.4a ±0.9	0.1c ±0.3	0.1c ±0.2	4.0b ±4.4
Spicy	38.8***	0.2c ±0.6	1.5bc ±2.6	9.8a ±3.7	0.9bc ±1.5	2.1b ±2.8	0.7bc ±1.5
Garlic	429.9***	0.0b ±0.0	13.2a ±2.1	0.2b ±0.6	0.0b ±0.0	0.0b ±0.2	0.1b ±0.5
Sardine	29.9***	8.3b ±3.3	1.9c ±1.9	0.5c ±1.1	1.2c ±1.8	5.7b ±4.0	9.9a ±3.7
Smoked	274.5***	0.3bc ±1.1	0.1bc ±0.4	0.0c ±0.0	0.1bc ±0.5	13.8a ±0.9	0.9b ±2.4
Toasted	335.6***	0.0b ±0.0	0.0b ±0.0	0.0b ±0.0	12.5a ±2.2	0.0b ±0.0	0.0b ±0.0
Oxidized	8.4***	0.1c ±0.3	2.4bc ±3.6	0.8c ±2.2	0.3c ±1.3	4.0b ±4.0	7.1a ±4.7
Taste							
Sweet	8.3***	3.8c ±3.6	5.0bc ±3.4	6.6b ±4.4	9.5a ±3.2	2.4c ±3.1	2.6c ±3.2
Salty	38.1***	2.3d ±1.8	5.9c ±3.1	3.4d ±3.1	6.7c ±3.0	13.0a ±0.9	8.8b ±3.3
Sour	39.4***	3.6b ±3.7	0.8cd ±1.1	12.4a ±1.3	0.5d ±0.9	2.4bc ±3.1	3.3b ±3.2
Umami	3.9**	5.6b ±3.6	5.8b ±4.1	3.6b ±4.1	9.6a ±4.4	5.1b ±4.7	6.3b ±3.7
Flavour							
Seafood	14.2***	0.8c ±1.6	1.8bc ±2.3	6.5a ±4.2	2.9b ±2.9	0.4c ±1.7	0.3c ±0.9
Potato	6.5***	6.4a ±4.6	5.9a ±3.7	3.1b ±4.9	1.9b ±3.1	0.6b ±1.9	0.9b ±2.4
Cheese	50.1***	0.1b ±0.7	0.2b ±0.5	0.0b ±0.0	11.8a ±4.2	0.1b ±0.3	0.9b ±3.6
Fatty	13.4***	3.5b ±3.6	2.3bc ±2.8	1.1c ±1.8	7.9a ±3.7	4.2b ±3.8	8.3a ±2.6
Earthy	29.6***	0.3b ±0.8	9.6a ±4.9	0.2b ±0.4	0.1b ±0.5	1.3b ±1.6	0.9b ±1.8
Canned tuna	32.0***	0.6b ±1.6	0.0b ±0.2	0.0b ±0	0.0b ±0.0	0.9b ±2.3	10.0a ±4.4
Sardine	9.2***	4.8a ±4.2	1.0b ±2.2	0.0b ±0	0.2b ±0.7	6.1a ±4.9	4.6a ±5.1
Rancid	7.3***	0.9b ±1.7	1.2b ±2.6	0.8b ±2.0	0.9b ±1.6	5.6a ±4.6	7.1a ±4.2
Texture							
Rubbery	41.3***	0.3c ±1.2	0.0c ±0.0	0.4c ±1.4	10.4a ±3.9	3.8b ±3.8	0.1c ±0.5
Chewy	12.5***	5.8a ±2.9	0.0b ±0.0	1.7b ±2.7	6.9a ±4.0	5.3a ±3.7	5.1a ±3.9
Crunchy	40.7***	0.0c ±0.0	0.0c ±0.0	9.6a ±2.7	1.7b ±3.3	0.8bc ±2.0	0.1c ±0.8
Juicy	29.4***	3.0bc ±3.0	0.4d ±1.0	9.4a ±2.9	8.6a ±3.1	1.3cd ±2.0	3.7b ±3.7
Greasy	8.5***	3.9bc ±3.3	3.3bc ±3.1	2.4c ±2.8	9.0a ±2.2	5.3b ±3.7	8.6a ±4.0
Fibrous	15.6***	6.9ab ±4.2	0.4c ±1.0	0.6c ±1.9	0.9c ±2.8	5.9b ±4.9	8.8a ±4.7
Pasty	39.6***	4.0b ±3.5	13.0a ±2.6	3.0b ±3.2	0.5c ±1.2	2.2bc ±2.5	2.7b ±3.6
Teeth Adherence	9.9***	7.6a ±4.4	5.3ab ±4.5	0.3d ±1.4	3.0bcd ±3.8	1.8cd ±4.0	4.5bc ±3.9

[1]Greater amberjack, [2] Pikeperch, [3] Meagre, [4] Grey mullet, [5]*p<0.05; **p<0.01; ***p<0.001, [6]Different letters in the same row indicate statistically significant differences (P <0.05) between the mean values of each species as indicated by Post-hoc analysis (Tukey test).

4. Comparison of different processed products generated from the same fish species

The results indicated that in general, processing altered significantly the sensory profiles of the products, since several new attributes emerged, when compared to the oven cooked fillets of the corresponding species. According to the results of D28.3, the cooked fillets of grey mullet and meagre exhibited low intensities in the attributes used to describe their odour, taste and flavour characteristics. Regarding the differences of those, meagre was perceived as having a more intense butter odour and flavour that grey mullet (**Figure 2**). Grey mullet, on the other hand, exhibited a significantly higher earthy odour and flavour, sour and bitter taste than meagre (**Figure 2**). Comparing attributes belonging to the different modalities, it is evident that while higher intensities were noted for the texture attributes this modality is not the most discriminant between species, since significant variations were identified in only in two of the attributes (**Table 10**). Specifically, the meagre fillets were perceived as more juicy and pasty that the grey mullet ones (**Figure 2**).

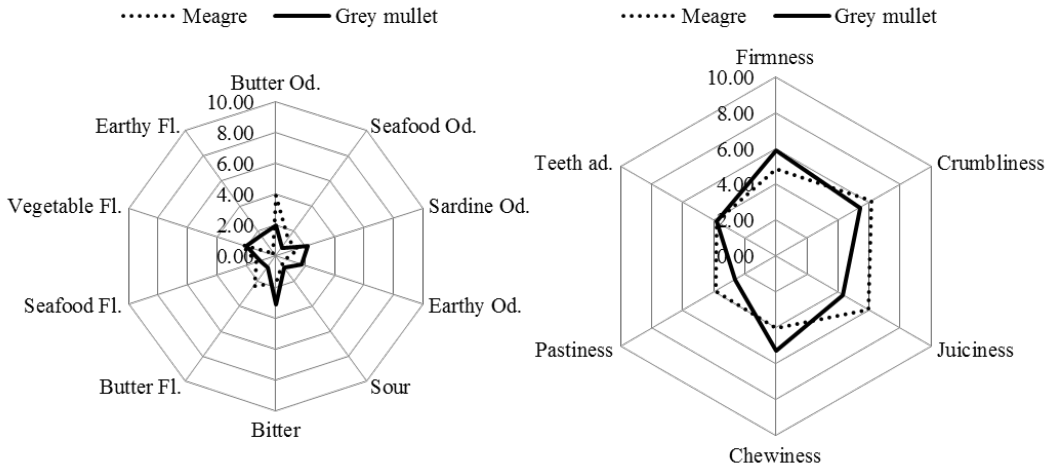

Figure 2: Spider plots of meagre and grey mullet fish fillets' odour, taste, flavour and texture attributes. Attributes were evaluated via descriptive analysis on a 10 cm scale by trained assessors in IRTA, Spain (Data from D28.3)

Table 10: Attribute significance for the 1-way ANOVA models (fixed factor: sample; random factors: assessor, replicate) computed at 95% confidence level. Attributes 1 correspond to the sensory evaluation performed in IRTA (D. 28.3), for the fish fillets of meagre and grey mullet; Attributes 2 correspond to the sensory evaluation performed in HCMR, for the processed products of meagre and grey mullet.

Attributes 1	Fillets	Attributes 2	Meagre products	Grey mullet products	All products
Aroma					
Butter	0.056	Butter	0.001	<0.001	<0.001
Seafood	ns[1]	Green	<0.001	ns	<0.001
Sardine	ns	Lemon	<0.001	0.019	<0.001
Earthy	0.069	Spicy	<0.001	0.078	<0.001
		Garlic	ns1	ns	ns
		Sardine	ns	0.047	<0.001
		Smoked	ns	<0.001	<0.001
		Toasted	<0.001	ns	<0.001
		Oxidized	ns	ns	<0.001
Taste					
Sour	<0.001	Sweet	ns	ns	<0.001
Bitter	0.050	Salty	0.026	0.005	<0.001
		Sour	<0.001	ns	<0.001
		Umami	0.019	ns	0.005
Flavour					
Butter	0.013	Seafood	0.01	ns	<0.001
Seafood	ns	Potato	ns	ns	ns
Vegetable	ns	Cheese	<0.001	ns	<0.001
Earthy	0.038	Fatty	<0.001	0.013	<0.001
		Earthy	ns	ns	0.014
		Canned tuna	ns	0.001	<0.001
		Rancid	ns	ns	<0.001
		Sardine	ns	ns	<0.001
Texture					
Firmness	0.214	Rubbery	<0.001	0.010	<0.001
Crumbliness	0.260	Chewiness	0.006	ns	0.003
Juiciness	0.012	Crunchiness	0.001	ns	<0.001
Chewiness	0.109	Juiciness	ns	0.090	<0.001
Pastiness	0.051	Greasiness	<0.001	0.026	<0.001
Teeth adh.	1.000	Fibrous	ns	ns	<0.001
		Pastiness	0.025	ns	ns
		Teeth adh.	0.071	0.048	0.007

[1]ns, $P>0.1$

After processing, products were characterized by more attributes than the unprocessed cooked fillet of the species (**Table 10**). In many cases, attributes were mainly used to describe one of the processed products (**Figure 3**). These characteristics in their majority can be connected to the added materials and/or the processing method the products underwent for manufacturing. However, contrary to the meagre products, they grey mullet ones' retained some similarities in their sensory profiles (**Figure 3b**). Specifically, 5 out of

9 odour, 1 out 4 taste, 2 out of 8 flavour and 4 out 8 texture attributes varied significantly among the grey mullet products (**Table 10**). From the attributes that varied significantly, butter, lemon and spicy aroma, and rubbery, juicy and teeth adherence texture, corresponded to minor characteristics of the products, since the intensities acquired were 5 or lower for both products (**Figure 3b**). Furthermore, with the exception of the smoked aroma and the canned tuna flavour, which characterized specifically the smoked fillets and fillets in olive oil, respectively, all other discriminant characteristics (sardine aroma, salty taste and greasy texture) were found in both products (**Figure 3b**, **Table 10**). The reason behind this similarity can be attributed, beyond the raw material, to the heat processing that both products underwent, as well as to the lack of addition of materials during their formulation, with the exception of olive oil.

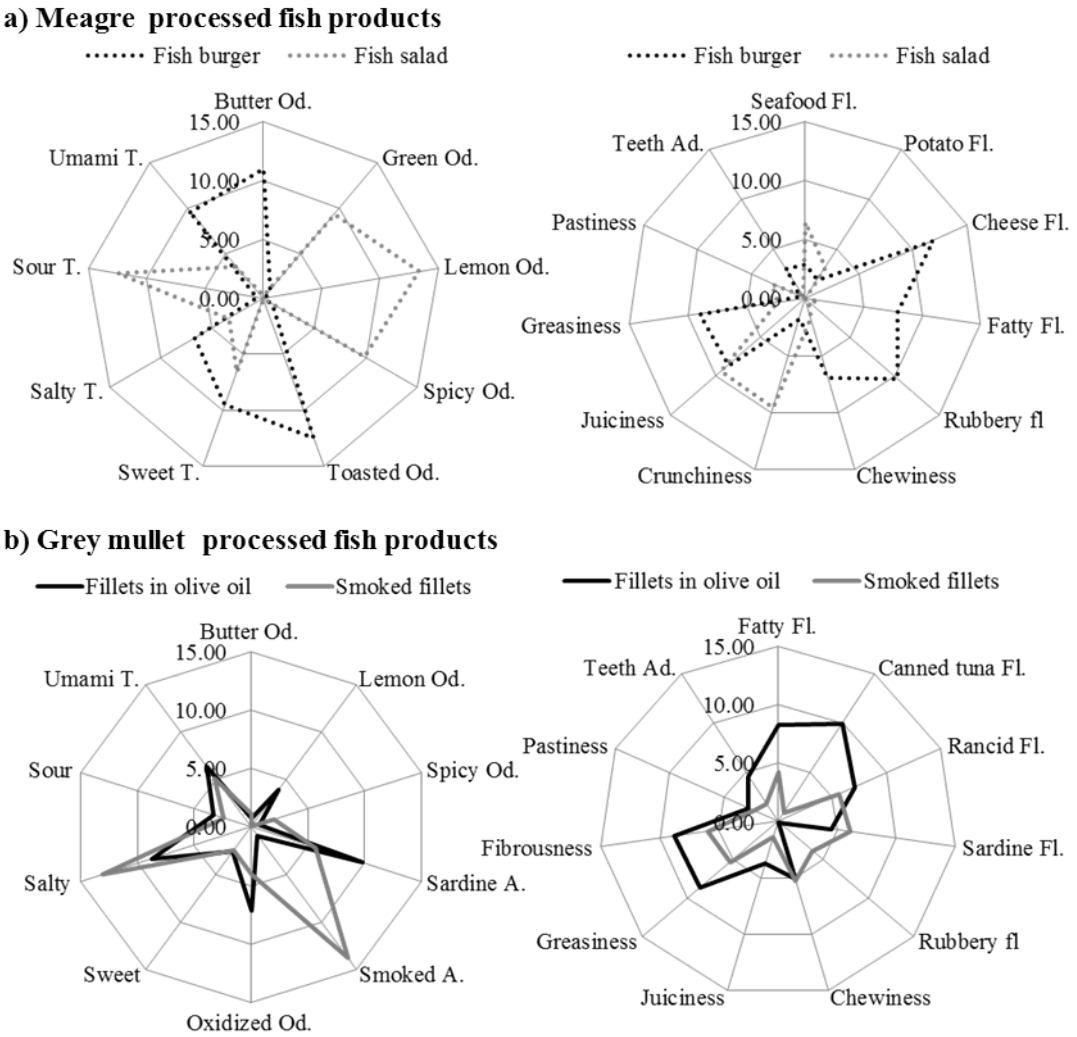

Figure 3: Spider plots of a) meagre and b) grey mullet processed products, taste, flavour and texture attributes. Attributes were evaluated via descriptive analysis on 150 mm scale by trained assessors at HCMR, Greece; attributes that acquired an intensity of 2 and lower and were found non-significant for discrimination (P>0.01) among the individual species processed products are not included in the plots.

In addition to the effect of processing on the sensory quality of meagre and grey mullet processed products, it should be mentioned that the preparation method and processing altered also the sensory profiles of greater amberjack steak and pikeperch pate, as compared to their oven cooked fillets. Specifically, whereas sourness

was the most discriminant characteristic for oven cooked greater amberjack fillets (D.28.3), altering the preparation method made this attribute secondary, since umami was perceived as the most intense taste attribute for the fried steak (**Table 9**). Furthermore, processing altered the profile of pikeperch, since garlic aroma became the main discriminant aroma attribute of the pate (**Table 9**), whereas the oven-cooked fillets of the species were characterized by earthy aroma (D.28.3). However, the earthy characteristics of pikeperch were not masked completely by processing, since earthy remained the most discriminant flavour characteristic of the pikeperch pate (**Table 9**).

5. Conclusion

Six processed fish products were studied to acquire their sensory profiles. To examine the intra species effect of processing, the sensory profiles of the processed products generated from the same species were compared (applies to species for which more than 1 product was generated). Furthermore a qualitative comparison of the processed products attributes to those of the oven-cooked fillets (D.28.3) of the corresponding species was performed.

- All processed products exhibited unique sensory profiles.
- The processed products showed more complicated sensory profiles with more attributes than the unprocessed cooked fillet of the species.
- The developed characteristics of the processed products in their majority could be connected to the added materials and/or the processing method.
- The products generated from grey mullet exhibited more similar profiles than those of meagre, which was attributed to the lack of added materials for the former, with the exception of olive oil.
- The fish steak was the product with the least altered sensory profile, when compared to the corresponding fish fillet of the species, which can be attributed to the low amount of processing it underwent.

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