Sensory description of marine oils through development of a sensory wheel and vocabulary

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Abstract

The Omega-3 industry lacks a defined methodology and a vocabulary for evaluating the sensory quality of marine oils. This study was conducted to identify the sensory descriptors of marine oils and organize them in a sensory wheel for use as a tool in quality assessment.

Samples of marine oils were collected from six of the largest producers of omega-3 products in Norway. The oils were selected to cover as much variation in sensory characteristics as possible, i.e. oils with different fatty acid content originating from different species. Oils were evaluated by six industry expert panels and one trained sensory panel to build up a vocabulary through a series of language sessions. A total of 184 aroma (odor by nose), flavor, taste and mouthfeel descriptors were generated. A sensory wheel based on 60 selected descriptors grouped together in 21 defined categories was created to form a graphical presentation of the sensory vocabulary. A selection of the oil samples was also evaluated by a trained sensory panel using descriptive analysis. Chemical analysis showed a positive correlation between primary and secondary oxidation products and sensory properties such as *rancidity, chemical flavour* and *process flavour* and a negative correlation between primary oxidation products and *acidic***.** This research is a first step towards the broader objective of standardizing the sensory terminology related to marine oils.

1. Introduction

"Marine oils" is a collective term for oils extracted from fish or marine mammals that are rich in healthy polyunsaturated fats. The range of oils is large, and the chemical composition including the combination of omega-3 fatty acids and fat classes varies. Marine oils have a broad range of applications, from health food supplements and pharmaceuticals to cosmetics.

Norway has a large omega-3 industry, and delivers approximately 40 % of the world's refined omega-3 concentrates with a turnover around 3550 million NOK (Richardsen, 2014). The benchmark is *pure and safe products of high quality*. The Norwegian health directorate recommends a daily intake of 2.1 grams of omega-3 (https://helsedirektoratet.no). When eating too little fat fish, it can be difficult to meet the need for these essential fatty acids through diet alone. A typical Norwegian diet provides only around 0.3 grams of omega-3 per day, and a supplement consisting of omega-3 lipids is recommended (Bockisch, 2010; Frøyland et al., 2011).

Marine oils oxidize easily, and lipid oxidation is one of the main causes of deterioration (Olsen 2005). The oxidation process contributes to changes in flavour and reduced quality of the oils (Ruyter et al. 2010). This oxidation, which results in rancid odours and flavours, is detected earlier using sensory analysis than using chemical analyses that identify the traditional oxidation products peroxide and anisidine (Arab-Tehrany et al., 2012; Ritter & Budge, 2012).

The use of sensory evaluation in quality assessment of marine oils requires standardized methods for which relevant experience and knowledge can be found in the oil plant industry and in the olive oil industry. In the 1980s the International Olive Council (IOC) developed a method to evaluate the sensory attributes of virgin olive oils that was later adjusted and adopted by the European Commission (Reg 64/2008). The IOC standards for sensory evaluation of oils provide an effective method for assigning oils to categories such as *extra virgin* or *virgin*. In the last thirty years, such sensory standard procedures have been improved thanks to a continuous research effort. Properties for quality control purposes as well as for better positioning products on the market has been developed (see Monteleone & Langstaff, 2014). In particular, a sensory wheel describing positive and negative aromas, appearance and mouthfeel of olive oil was developed in the early 1990s (Mojet and de Jong, 1994). This tool has also been used to develop appropriate sensory descriptors of oils and to further study the correlation between volatile compounds (Morales et al., 1995, Aparicio et al., 1996), the influence of olive ripening and storage on sensory properties of oils

(Monteleone, Caporale, Lencioni, Favati, & Bertuccioli, 1995), and consumers' expectation with regard to the sensory properties of virgin olive oils.

More recently Langstaff (2014) discussed and arranged negative descriptors of olive oils in 'The Defect Wheel'. This is a tool for learning how to recognize sensory off-flavours in olive oil associated with processing and storage.

The sensory properties of marine omega-3 oils vary depending on several factors, including species, raw material, process parameters, fatty acid composition and oxidation. Although sensory properties determine the use of oils (e.g. oils for functional foods should have no off-flavour), there is a lack of a defined methodology for evaluating the sensory quality of oils. Given the importance of a common and appropriate vocabulary to describe both positive and negative sensory properties of marine oils, this study was conducted to identify the sensory descriptors of marine oils and organize them in a sensory wheel for use as a tool in quality assessment.

2. Materials and Method

The methodological approach is illustrated in Figure 1, showing the different steps in the developing of the sensory wheel and vocabulary.

2.1 Collection of marine oil samples

Forty-six oils representing the most common products delivered from the marine oil industry were collected from eight omega-3 producers (Table 1). The selection included oils from cod and pelagic species like anchovies and was delivered in Triglyserid form and with i were included to represent the sensory variety among products. Oils were collected from the producers' daily production line over a six-months period. They were produced under normal industrial processing conditions and were all newly refined. The oils were labelled with species, EPA- and DHA-concentration[1], and production method (i.e. if they were triglycerides or ethyl esters). Oils were bottled under a nitrogen blanket and centrally stored at -20 °C until further analysis.

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[1] EPA (Eicosapentaenoic acid) and DHA (Docosahexaenoic acid) are recognized as our two most important omega-3 fatty acids. The omega-3 industry concentrates these two fatty acids in their omega-3 products to maximize the health effect.

Twenty oils were selected for the descriptive analysis. In addition, 24 oils where were selected for the language development sessions with the marine oil expert panels and for the training of the sensory panel (Table 1).

2.2 Sensory description of oils

Marine oil expert panel

Twenty-two assessors representing six marine oil expert panels took part in language sessions aimed at generating descriptive terms and developing a sensory language for marine oils. The expert panel consisted of assessors familiar with the potential defects, off-flavors and problems that can arise from poor materials, processing, handling, packaging or storage of marine oils as described in H. Lawless, Liu, and Goldwyn (1997). During language sessions assessors were presented with oils selected to represent the whole range of oils. They were asked to smell and taste the oils and write down, according to their own vocabulary, attributes and key associations detected in the different samples. After these language sessions, each of the six expert panels carried out a new term generation session in their own facility using in-house oil products similar to the ones collected for this study.

Descriptive analyses by a trained sensory panel

The selected oils were evaluated by a trained sensory panel using descriptive sensory profiling according to Generic Descriptive Analysis as described by Lawless and Heymann (2010). The panel consisted of nine female judges, age range 32–66 years. The assessors were selected and trained according to guidelines in ISO:8586:1 (1993), and had an extensive experience with descriptive analysis of a wide range of products.

The sensory laboratory was designed in accordance with ISO:8589 (2010). During the term generation phase assessors developed a vocabulary describing samples, and they agreed upon a list of 22 attributes in total (Table 2). No attribute describing appearance of the oil was included. In a pretest session, as described in H. T. Lawless and Heymann (2010), the judges were trained in the definition of the attributes by testing samples that were considered extreme with respect to selected attributes typical for the oil.

Samples were presented to the assessor in fifty ml cups with a lid, containing 20 ml of oil at 20° C. A continuous, non-structured scale was used for evaluation. The left side of the scale corresponded to the lowest intensity of each attribute (value 1.0) and the right side corresponded to the highest intensity (value 9.0). Each assessor did a monadic evaluation of the samples in two replicates at individual speed on a computerized system for direct recording of data (CSA Compusense, version 5.24, Canada). All samples and replicates were served in a randomized order.

During the evaluation, the assessors were instructed to lift the lid of the sample and smell the sample before tasting. The panel was asked to rinse their palates between the samples using water (37°C), and, if necessary, apple, cucumber or bread.

The sensory profiling was done over two days with a total of 10 sessions each day, including four samples. Between sessions the panellists had a 15-minute break, and after three sessions the panel had a 1.5-hour break.

2.3 Term selection and grouping

Attributes generated through the language sessions with the expert panels and the descriptive analyses with the trained sensory panel were listed in alphabetic order, before being grouped together on a semantic basis by a sensory researcher. Redundant terms were eliminated, and expressions that were similar or had the same meaning were grouped together. Attributes suggested by both the expert panel and the trained sensory panel were used as a foundation for identifying coherent groups of attributes, later called 'categories'.

2.4 Consensus on the sensory vocabulary and design of the sensory wheel

The grouping of the terms was discussed with the panel leaders of the six expert panels during two joint sessions (Table 2) to reach a consensus on the sensory vocabulary (Figure 1). During these sessions, additional tasting of marine oils with specific characteristics was included, and adjustments and refinement of the consensus list were made. In particular, the marine oil experts discussed possible causes for specific attributes due to process or species and some modification of the groupings were made. Consensus was reached when all the panel leaders from all the expert panels agreed on the terms and their classification.

In addition to the process of creating a sensory vocabulary, reference standards were prepared and discussed to better define specific terms. During sensory analysis and language development the use of reference standards are useful for the panel in order to familiarize themselves with the product and the scaling system (Monteleone & Langstaff, 2014). Reference standards were developed or adjusted based on Delgado and Guinard (2011); Monteleone and Langstaff (2014); NMKL:183 (2005) for 12 of the characteristics in the vocabulary (Table 3).

2.5 Chemical characterization

The twenty oils from the sensory profiling were analyzed for oxidation parameters and fatty acid composition (shown in table 1). Primary and secondary fat oxidation in the samples was determined by analyzing the peroxides-, anisidin-, and free fatty acid values. Oils were analyzed regarding free fatty acid (FFA) content and determined according to IUPAC (Method no 2.201, 1987). Results are expressed as g FFA 100 g^{-1} lipids. The peroxide value was determined according to AOCS (1997a). Results were expressed as meq peroxide kg^{-1} lipids. The anisidin value was determined according to AOCS (2003). The TOTOX-value gives a picture of the total oxidation, and is a combination of the secondary (AnV) and the primary (PV) oxidation products (Ruyter et al., 2010). The fatty acid composition was determined according to AOCS Official Method Ce 1b-89 (AOCS, 2009).

2.6 Statistical analysis

Analysis of Variance (ANOVA) was performed on the sensory descriptive data. The model included main effects of product (oil) and main effect of assessor, plus interaction effects between product and assessor. The effects of products were considered fixed, while the effects of assessors and the interaction effects were considered random. Panel performance was monitored using PanelCheck Software (version 1.3.2). Principal Component Analysis (PCA), Partial Least Squares (PLS) and Multiple Scatter Plot (MSP) were conducted using Uncrambler (version X 10.2). The PCA was used to study the main sources of systematic variation in the sensory descriptive data. PLS was used to compare the relationship between the sensory data and the oxidation parameters/ the fatty acid profile. Both the oxidation parameters and the sensory data were standardized. Correlation between the sensory data and the chemical data was examined using MSP. The sensory wheel was designed using Adobe Illustrator (version CS6).

3. Result

3.1 Sensory description of oils

Table 2 shows an alphabetical list of the terms generated in the language sessions by the expert panels and in the descriptive analysis by the trained sensory panel. A total of 108 descriptive terms were generated through the language sessions conducted by the marine oil expert panels. Three taste attributes, three mouthfeels attributes and 91 aroma attributes. Through term generation, training and calibration a total of 76 different sensory attributes were generated by the trained sensory panel. Thirty-two of these descriptors were new compared to the results of the language session with the marine oil expert panels. Efficient sensory profiling, however, requires reducing the number of terms to about 10–20 (Vannier, Brun, & Feinberg, 1999). For the sensory descriptive profiling, the trained panel selected 9 aromas and 13 taste/flavor attributes.

Results from the descriptive profiling are shown in Figure 2. The PCA loadings plot (Figure 2a) displays the relationship between the marine oil attributes. The plot shows, from left to right, a separation between the 'positive' characteristics a*cidic, nut, butter* and *grass* and the 'negative' characteristics *fermented, rancid, fish* and *process*. The first Principal Component explains 79 % of the variation in the data, while the second Principal Component explains 10 %. The characteristics *acidic* and *rancid* are positioned on each side of the plot and are negatively correlated (R^2= 0.72). *Fish aroma* and *fish taste* are marked closely together in the plot and have a positive correlation (R^2= 0.95). The same result, regarding aroma and taste, is shown for *rancid* (R^2= 0.94), *metal* (R^2= 0.97), *process* (R^2= 0.93) and *burnt* (R^2= 0.91). The attributes *acidic* and *grass* have a positive correlation (R^2= 0.92); the same goes for the attributes *butter* and *nut* (R^2=0.91).

3.2 Term selection and grouping

The language sessions with the marine oil experts and the sensory profiling by the trained panel generated a total of 184 sensory attributes. Table 2 shows an alphabetical list of all attributes. Through term selection and grouping (Figure 1) 41 terms were suggested eliminated and/or merged with similar terms. This was done prior to the joint sessions with the expert panels (the consensus session in Figure 1). For instance, *ethanol* was suggested merged with *liquor*, and *petrol* with *diesel*. Redundant or less used terms like *sheep* and *vanilla* were eliminated. A total of 18 groups, with the dominant attributes used as main category, were suggested. Eleven of the flavor attributes and one mouthfeel attribute was used in the sensory profiling matches the selected categories.

3.3 Consensus

The next step in the project was a consensus session where the panel leaders from the marine oils expert panels discussed the terms in table 2. During this session a modification of 24 of the terms was suggested. For instance, *apple was* split into two categories, for which the new terms were *green apple* and *ripe apple* respectively. The viscosity attributes *thin* and *thick* were not part of the panel profiling or language development, but were added after discussion with the marine oil experts. After grouping, elimination and modification, the list consisted of a total of 21 categories and 60 key words.

Based on these 21 categories a vocabulary with a definition and 2–4 suggested keywords for each category was created (Table 3). In addition, a marine oil sensory wheel, presented in Figure 3, was created as a graphical illustration of the vocabulary. The sensory wheel consists of three layers. In addition to the 21 categories and 60 keywords, two main groups – 'mouthfeel' and 'flavour and taste' – are introduced.

3.4 Chemical characterization

The quality of the oils used in the second profiling was good. Only four out of 20 oils had peroxide levels above the recommended limit provided by GOED:v.4 (2014). The connection between the sensory and oxidation parameters were investigated both using PSL (Partial Least Squares) plot and 'predicted vs. reference' plot. The correlation between the sensory and chemical properties was low when analyzing the triglycerides together with the ethyl esters. In addition, one triglyceride was an evident outlier. Based on these results, further analyses were made on 13 of the triglycerides, deselecting all the ethyl esters and one of the triglycerides.

The peroxide value had the highest positive correlation with the flavor and taste of *metal*, with R^2=0.92 and 0.90, respectively (figure 4). The anisidin number had the highest positive correlation with the aroma of *chemistry* and *process*, with R^2=0.91 and 0.74, respectively. This was also the case for the TOTOX-values. The free fatty acids had the highest correlation with the *burnt* aroma and taste, with R^2=0.72 and 0.73, respectively.

4. Discussion

The aim of this study has been to identify descriptors of marine oils and organize them in a sensory wheel for use as a tool in quality assessment. When developing a sensory wheel it is important to have a selection of samples which covers different sources of variation and with a wide range of sensory attributes (Drake, Gerard, Wright, Cadwallader, & Civille, 2002). The 44 different marine oil samples produced by six different companies, represented a wide selection of the available marine oil products in the marked, based on a selection of raw materials caught in both Norwegian and foreign areas (Table 1). The same approach was used in Koch, Muller, Joubert, van der Rijst, and Næs

(2012) discussing 69 different samples of rooibos tea from 64 producers, and Theron et al. (2014) who included 58 samples from six different honey bush species when forming their sensory wheels. To ensure a wide sensory variation in this study, the producers delivered products with specific characteristics selected during their quality control. Some of these would normally not have reached the consumer due to elimination during the producer's quality control. Another strategy was used by Aparicio, Morales, and Alonso (1996). When investigating the relationship between volatile components and sensory attributes in 16 olive oil samples, they choose to inlcuded 'virgin' olive oil, and to exclude 'extra virgin' and 'pomance' oil. Even if the variety of the collected marine oils in this study was broad, other oils produced from other raw materials or using other processing methods, may have other sensory characteristics. The sensory and chemical attributes that are revealed in this study are nevertheless a good foundation for further investigations.

The sensory profiling of the marine oils was conducted by nine professional assessors. In addition, the six marine oil expert panels performed several language development sessions. Aparicio et al. (1996) choose to use six different professional panels from five different nationalities and with different type of experience (EC:2668, 1991; ISO:8586:1, 1993) when testing olive oil, while Hersleth, Ilseng, Martens, and Næs (2005) used five expert assessors to evaluate cheese before it was profiled by a trained sensory panel. The last approach is somewhat comparable to the one used in this study. Gawel *et. al* (2000), characterizing mouthfeel in red wine, and Theron (2012), developing sensory profiling for Cyclopia Species (Honeybush), chose to use a trained sensory panel in the language development sessions. Neither used expert panels.

The sensory profiling done by a trained sensory panel combined with the language sessions done by the marine oil expert panels generated a total of 184 aroma, flavour, taste and mouthfeel attributes. As this study is the first seen in the literature which discuss and organize sensory attributes of marine oils it is important to capture as much as possible of the sensory variation of the different oils, accordingly modification and grouping of the attributes was necessary. The selection of the descriptors and categories was conducted through sorting, ranking and grouping. The method is similar to the one used by Gawel, Oberholster, and Francis (2000) regarding descriptions of mouthfeel of red wine, and Murray and Vickers (2009) regarding development of terminology for the feeling of hunger and fullness. While Gawel et al. (2000) used panellists for the sorting, the sorting was conducted by a panel leader in Murray and Vickers (2009). This procedure is similar to the present study.

The initial list of attributes for marine oils (184 attributes) were trough the sorting task and consensus reduced to 21 categories and 60 keywords. This is still a large group of sensory attributes, and for the profiling by the trained panel only 9 aromas and 13 flavour/taste attributes where used. This is in line with the number of attributes recommended by Vannier et al. (1999) for the purpose of efficient sensory profiling. When choosing to keep 21 categories and a total of 60 keywords as a basis the sensory wheel, this is based on experience shown by other authors stating that a rigid reduction of descriptors could result in a loss of specific attributes that would be essential in characterizing the unique sensory profiles of the product (Theron et al., 2014; Wolters & Allchurch, 1994).

In a future study a correlation between the categories and the descriptors should be investigated in the same way that the correlation has been studied in the case of sensory profiling of olive oil (Mojet & de Jong, 1994; Monteleone & Langstaff, 2014). After discussion with the marine oil expert panels viscosity was added as a characteristic in the sensory wheel and vocabulary. This is consistent with the work done on olive oil (Gawel, 2014; Mojet & de Jong, 1994).

The marine oil industry usually separates their sensory characteristics into positive and negative attributes during their quality control. The PCA plot (figure 2) plot shows the location of *acidic, butter, nut* and *grass* aroma and tastes on the left side of the plot while *metal, rancid, fish* and *process* aromas and tastes are located on the right side of the plot. Thus, a negative correlation between the 'positive' attribute *acidic* and the 'negative' attribute *rancid* confirms the industries' experience, namely that oils with an acidic taste are rarely rancid. However, it is important to note that the sample set presented in Figure 2 is too small to make any conclusion about positive and negative attributes. The negative attributes are usually evidence of unsuccessful refining, raw material of low quality or inadequate storage. For olive oil, wine and beer defects wheels including negative attributes have been developed (Langstaff, 2009a, 2009b; Langstaff, Aparicio, & Group, 2011). These wheels can be useful for detecting errors during the production or storage. A similar wheel could also be beneficial for the marine oil industry.

A PCA loadings plot can also be used to investigate whether some attributes used in the profiling are redundant. This may reduce or simplify the set of terms, and also prevent different attributes from being used to describe identical sensory characteristics (Næs, Brockhoff, & Tomic, 2010). The PCA loadings plot can also demonstrate whether correlations exist between aroma and flavour attributes that have been analysed by nose (orthonasal, ON) and by mouth (retronasal, RN), respectively. All the ON and RN attributes in this study (like *grass, acidic, metal, fish, rancid, process*) were closely associated with each other, which indicates that these notes were perceived similarly in the nose and on the palate. Accordingly, these attributes have been merged in the sensory wheel. The correlations between the attributes *acidic* and *grass* and *butter* and *nut* are also relatively high. In a future study, merging these attributes could be considered. On the other hand, the characteristics of olive oil *nut, butter*, *grass* and *citrus* (*acidic*) are maintained as separate categories in the oliveoilvocabulary (Delgado & Guinard, 2011; Mojet & de Jong, 1994; Monteleone & Langstaff, 2014).

No preference testing of oils was conducted in the study, and the oils were not graded in different quality categories. This makes it difficult to draw conclusions regarding 'negative' and 'positive' attributes. On the other hand, oils with high oxidation parameters and hence lesser quality seem to correlate positively with the attributes on the right side of the PCA plot like *rancid, process, metal* and *fish*. Koch *et. al* (2012) showed that tea given the lowest quality grade correlated with negative attributes like *hay* and *bitter*, while tea given the highest quality grade correlated with positive attributes like *caramel* and *wood*.

The PSL-plot in Figure 4 shows that the sensory characteristics *rancid, chemical, metal* and *process* are positively correlated with high peroxide and anisidin values (figure 4). Earlier studies have shown that fresh marine oils correlate with the sensory characteristics *fish, sweet, grass* and *butter*, while stored marine oils with increased peroxide and anisidin values correlate with *acidic, metallic, pungent* and *paint* (Serfert, Drusch, & Schwarz, 2010).This corresponds to the findings in our study, Except for *acidic flavor*. *Acidic* flavor has earlier been described as a sensory attribute of fresh sunflower oil (Serfert et al., 2010). Free fatty acids correlate positively with the attribute *burnt flavor*. In earlier studies a high level of free fatty acids has been linked to a burnt flavor in heated soybean oil (Warner & Mounts, 1993). A more accurate division of the quality of the oils, including storage stability studies, may be done in a future study. It would also be interesting to look at the consumers emotions towards the different flavors in the marine oils using a Emosensory® wheel as described by Schouteten et al. (2015).

5. Conclusion

The study has shown that the sensory characteristics of marine oils give an accurate representative description of the quality of the oils and that sensory analysis could be a valuable tool in the industries' quality control. A marine oil vocabulary was developed that provides a clear, defined set of sensory terminologies and a marine oil sensory wheel was assembled from 21 marine oil attributes, providing the industry with a simple and convenient tool that summarizes and displays a wide range of product attributes. The sensory wheel may be used both in future research about sensory quality of marine oils and in training sensory panels and quality control personnel in the industry. The sensory wheel and vocabulary may also facilitate a distinction between high and low-quality oils based on sensory attributes. Samples with low primary and secondary oxidation were associated with sensory attributes like *acidic, grass, butter* and *nut*, while oils with higher values along the oxidation parameters were associated with sensory attributes like *rancid, metal, process* and *fish*.

This research is a first step towards a standardizing of the sensory terminology for marine oils and will be followed up by new studies to confirm the findings.

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Table 1 List of marine oils used in the study. Twenty oils selected for a sensory profiling and analyzed for the oxidation parameters peroxid value (pV), anisidin value (AnV), ToTox, free fatty acids (FFA), acid value (AV) and fatty acid composition (EPA and DHA). Oils 1–7 were produced as ethyl esters and oils 8–20 were produced as triglycerides.

Nr	**Raw material**	**PV**	**AnV**	**ToTox**	**FFA**	**AV**	**EPA mg/g**	**DHA mg/g**
1	Anchovy+	3.03±0.04	14.27±0.05	0.23±0.0	0.45±0.00	0.01±0.00	150.19±0.25	8.26±0.00
2	Squid	6.12±0.45	10.27±0.29	22.50±0.61	1.40±0.01	2.78±0.02	223.85±7.25	319.81±8.84
3	Anchovy+	3.74±0.00	5.09±0.26	12.57±0.26	1.53±0.03	3.04±0.06	329.85±17.65	317.36±17.48
4	Cod	3.04±0.02	5.68±0.41	11.76±0.37	0.34±0.01	0.67±0.01	355.66±7.82	256.59±11.96
5	Anchovy+	3.99±0.08	6.98±0.45	14.96±0.29	1.77±0.02	3.53±0.04	365.43±0.21	227.20±1.03
6	Anchovy+	1.63±0.04	1.06±0.06	4.31±0.13	0.18±0.01	0.36±0.01	520.37±0.94	87.64±0.64
7	Anchovy	0.94±0.02	1.77±0.00	3.66±0.04	0.15±0.01	0.31±0.02	544.82±2.33	92.17±0.32
8	Anchovy+	5.45±0.00	3.24±0.03	14.15±0.04	0.29±0.02	0.57±0.04	569.65±14.41	151.37±4.12
9	Anchovy+	3.88+0.03	3.57±0.04	11.32±0.02	0.31±0.01	0.62±0.01	578.13±3.52	154.32±1.11
10	Trout	2.25±0.07	5.69±0.09	10.20±0.23	0.13±0.01	0.25±0.02	142.59±1.95	501.23±5.68
11	Squid	6.11±0.02	9.82±0.67	22.04±0.71	0.22±0.01	0.44±0.02	144.39±2.28	350.39±9.87
12	Trout	2.38±0.09	5.95±	10.71±0.31	0.10±0.00	0.19±0.01	145.46±1.00	507.73±2.21
13	Anchovy+	3.10±0.00	11.40±0.53	17.61±0.53	0.81±0.05	1.61±0.01	198.02±7.04	132.38±3.35
14	Anchovy	1.00±0.06	1.47±0.01	3.46±0.10	0.12±0.01	0.25±0.01	365.89±0.62	248.11±1.66
15	Anchovy	0.68±0.00	1.58±0.02	2.95±0.01	0.11±0.00	0.21±0.00	370.50±0.51	249.93±0.58
16	Anchovy	3.68±0.07	15.04±0.036	22.41±0.23	0.18±0.01	0.36±0.01	473.66±16.9	239.41±12.37
17	Cod	0	1.99±0.13	1.99±0.13	0.08±0.00	0.16±0.00	86.64±0.66	99.19±0.39
18	Anchovy	0.22±0.02	1.85±0.04	2.28±0.08	0.08±0.00	0.17±0.01	89.66±2.11	102.17±1.96
19	Anchovy	0	2.30±0.07	2.30±0.07	0.13±0.01	0.25±0.01	95.13±2.65	121.85±3.89
20	Anchovy	0	0.83±0.01	0.83±0.01	0.19±0.00	0.37±0.01	96.39±2.34	123.27±2.86

In addition, 24 oils were used during the language sessions and panel training

12 anchovy oils produced as triglycerides

1 anchovy oil produced as an ethyl ester

3 cod-liver oils produced as triglycerides

2 cod-liver and trout oils produced as triglycerides

3 squid oils produced as triglycerides

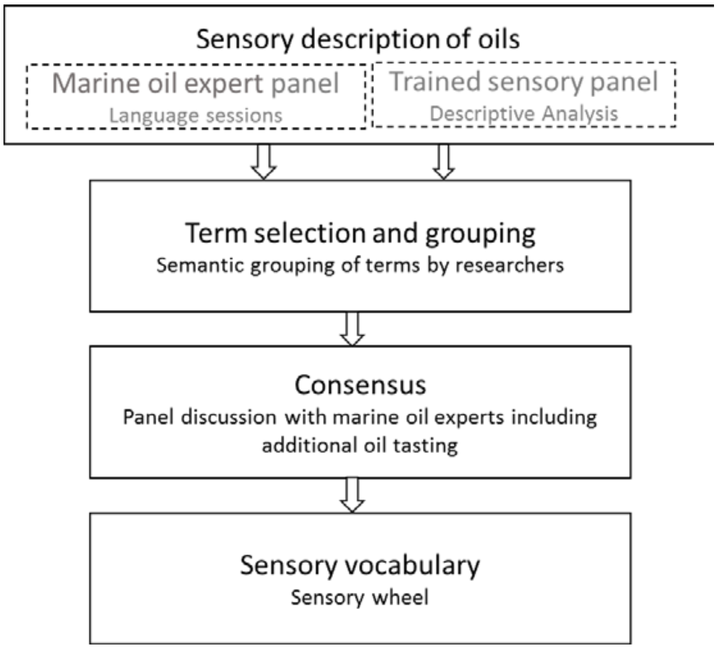

Figure 1 Flowchart describing the path to create a sensory vocabulary through sensory descriptions.

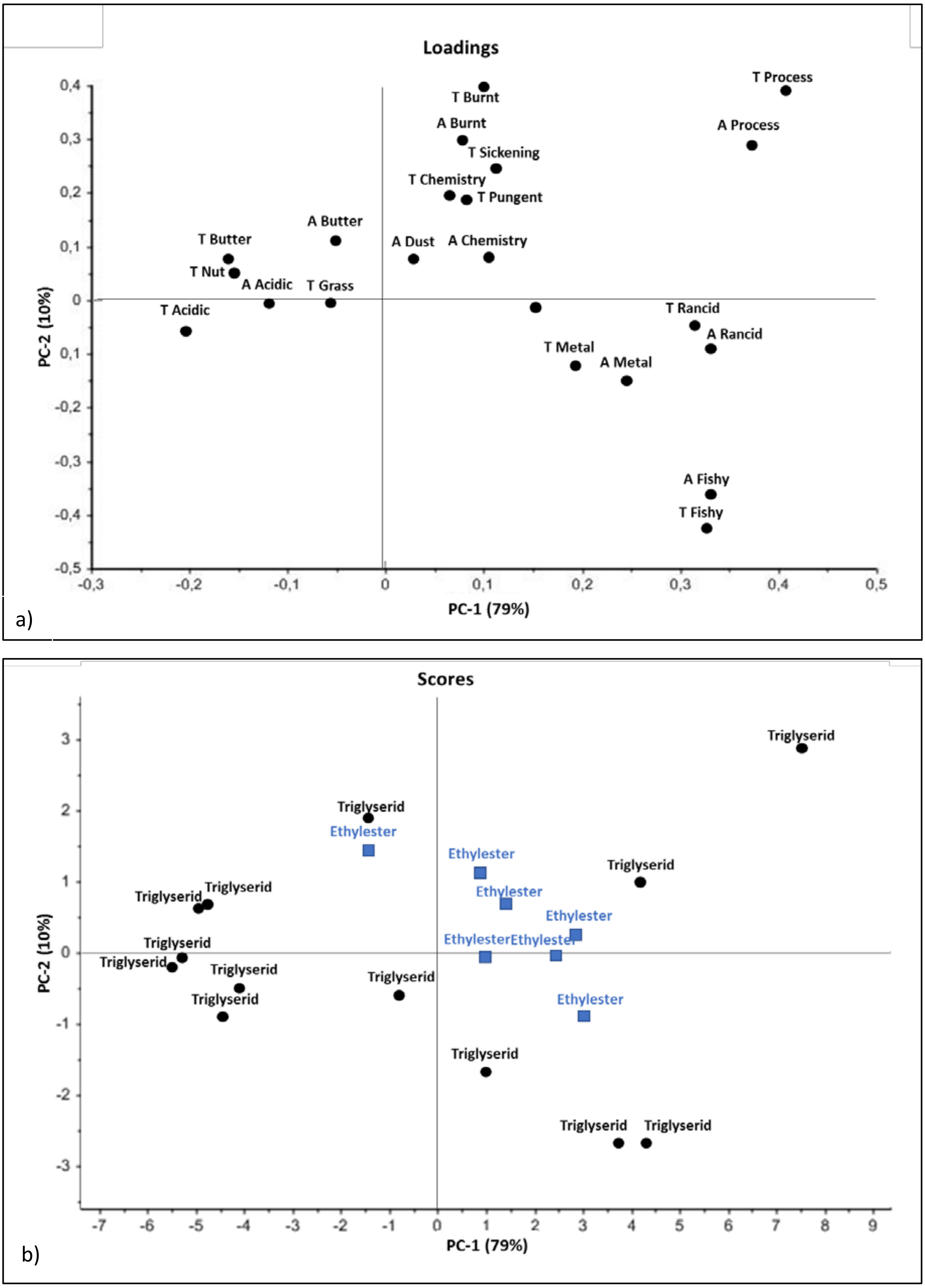

Figure 2 PCA loadings (a) and scores (b) plots showing the positioning of the 22 sensory attributes and the 20 marine oil samples, respectively. In the loadings plot the letters "A", and "T" in front of an attribute refer to aroma and taste attributes, respectively. The oils are divided in to triglycerides an ethylester in the scores plot reflect the production method of the oil.

Table 2 Sensory attributes generated through the language development sessions (LD), and attributes added during final consensus (FC). The numbers represent the frequency of the attribute through several sessions. Bold text represents the attributes chosen for the sensory profiling.

Attributes	LD	FC	Attributes	LD	FC	Attributes	LD	FC	Attributes	LD	FC
Acidic	3		Ethyl ester	3		Medicine		1	Rotten fruit	1	
Alcohol	1		Exhaust	1		Melon	3		Rotten hay	1	
Almond	2		Fat fish		1	**Metal**	4		Rubber	2	
Ammonia	1		**Fermented**	1		Metal Shavings		1	Salmon	1	
Apple	3		**Fish**	6		Motor Oil	3		Sea	3	
Artificial		1	Fish guts	1		Mustard	1		Seaweed		1
Astringent	1		Fresh nuts		1	Nauseating		1	Sheep	1	
Beans	1		Freshly cut grass		1	Neutral	1		Shellfish	1	
Bitter	5		Fruit	2		**Nut**	7		**Sickening**	1	
Bleaching Earth	2		Glue	1		Oregano	1		Silage	1	
Blood	1		Grapefruit	1		Packing	1		Soap	1	
Blubber	1		**Grass**	8		Paint	7		Sour	3	
Burned	2		Green apple		1	Peach	1		Spice	2	
Burned oil		1	Green tomato	3		Pepper	3		Stearin	2	
Burning		1	Hawking		1	Perfume	2		Stockfish	2	
Butter	4		Hay	4		Petrol	1		Straw	1	
Carton			Hazelnut	1		Pharmacy	1		Strong (hot)		1
Chemical	5		Herbs	1		Pig fat	1		Sweet	3	
Chemical irritation		1	House dust		1	Plastic	1		Sweet alcohol		1
Chilli	1		Incense	1		Popcorn	1		Synthetic	2	
Citrus	1		Iron	1		**Process**	2		Tide	1	
Clarified butter		1	Juniper	1		Propane	1		Toast	1	
Cod-liver oil	2		Lighter fluid	1		Prudish sense		1	Tobacco	1	
Corn	1		Linseed	1		Pungent	2	1	Turpentine	1	
Coughing		1	Linseed oil	2		**Rancid**	2		Unripe apple	2	
Dental Office	1		Liquor	1		Rapeseed oil	1		Vanilla	1	
Diesel	2		Mackerel	1		Ripe fruit	2		Vegetable oil	2	
Dry sense		1	Mangos	1		Roasted	1		Vomit	1	
Dust	3		Margarine	2		Rosemarie	2				
El. short circuit	1		Mature apple		1	Rotten fish	1				
Ethanol	3		Matured fish		1	Rotten fish gut		1			

Table 3 Vocabulary and reference standards describing flavor, taste, mouthfeel and viscosity of marine oils.

Characteristic	Definition	Key-words	Reference standard
Acidic[1]	Related to a fresh aroma and taste due to organic acids.	Citrus and green apple	50ul lemon oil added 100 ml sunflower oil.
Astringent[2]	Related to a dry sensation in the mouth.	Contractile and dry feeling	0.15 g of tannic acid added 100 ml of sunflower oil.
Bitter	Related to a bitter taste (caffeine or quinine).	Grapefruit and caffeine.	8–15 mg quinine added 100 ml of sunflower oil.
Butter	Related to a smooth, full taste and aroma of dairy butter.	Clarified butter and popcorn	0,5µl 2,3 butanedione added 100 ml of sunflower oil.
Chemical[3]	Related to aroma and taste of chemicals.	Glue, plastic, synthetic and artificial.	7.5 ul of methyl methacrylate added 100 ml sunflower oil.
Dust	Related to aroma and taste of dry dust.	House dust, carton and corn and hay.	
Fermented[3]	Related to aroma and taste of matured fish.	Dried and matured fish	10 g of trimethylamine is dissolved in 10 ml distilled water. 150ul of the basic solution added in 100 ml sunflower oil.
Fish	Related to aroma and taste of fresh fish.	Sea, seaweed, mackerel and shellfish.	
Fruit[1]	Related to a sweet, overripe aroma and taste of the fruit.	Melon, ripe apple, sweet alcohol and sickening (nauseating).	100 µl apple essence added 100 ml sunflower oil.
Grassy[1]	Related to the taste of fresh grass.	Fresh grass and green tomato.	15 µl of 1-cis-3-hexene added in 100 ml sunflower oil.
Herbs	Related to aroma and taste of dried herbs.	Rosemary, oregano and incense.	
Medicine[3]	Related to aroma and taste of medicine.	Pharmacy, dental offices, ethanol and soap.	2mg iodoform (tri-iodo-methane) added 100 ml sunflower oil.
Metal	Related to aroma and taste of iron sulfide ($FeSO_4$).	Metal shavings, iron and blood.	
Nut and seed[2]	Related to aroma and taste of fresh nuts and seeds.	Fresh nuts, almonds and linseed.	6 ml hazelnut oil added 100 ml sunflower oil.
Process	Related to a aroma and taste of the refining process.	Diesel, motor oil, burned oil and clay.	
Pungent[2]	Related to a stinging, hawking, coughing feeling.	Chemical irritation (hark, prickly, cough).	0.2 mg capsaicin added 500 ml sunflower oil.
Rancid	Related to aroma and taste of oxidized fats.	Paint, linseed oil and wax.	100 ml cod liver oil on stirring for 2 days at room temperature.
Hot	Related to a burning sensation in the oral cavity.	Burning, pepper and chilli.	
Thick	Related to a filling viscous liquid.	Rich (high viscosity).	
Thin	Related to a watery light liquid.	Aqueous (low viscosity).	
Vegetable oil	Related to aroma and taste of vegetable fat.	Margarine.	

[1-3] Reference standards with some adjustments obtained from Monteleone and Langstaff (2014)[1], Delgado and Guinard (2011)[2] and NMKL:183 (2005)[3].

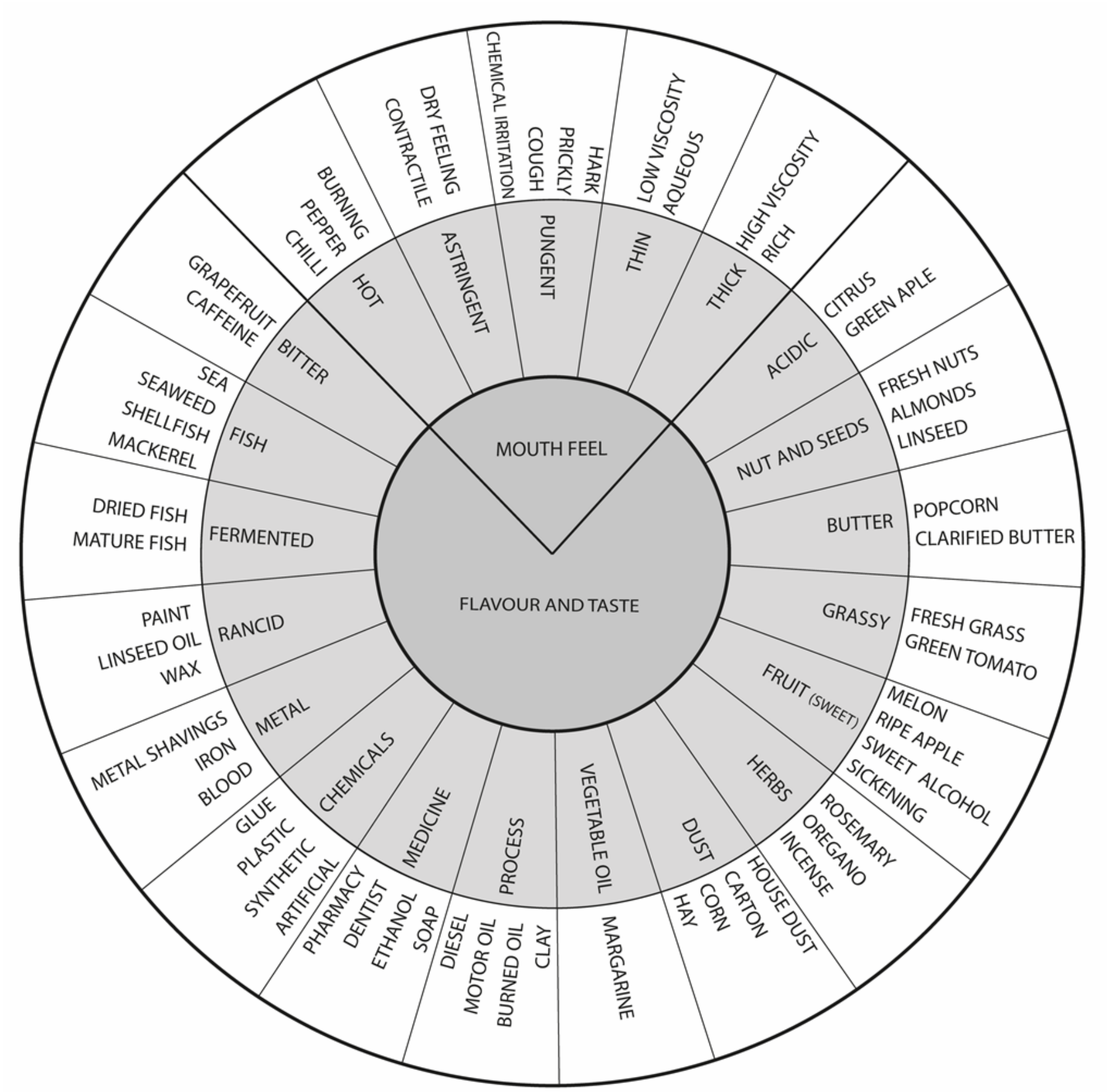

Figure 3 The sensory wheel comprising 21 terms describing the sensory attributes of 44 marine oils.

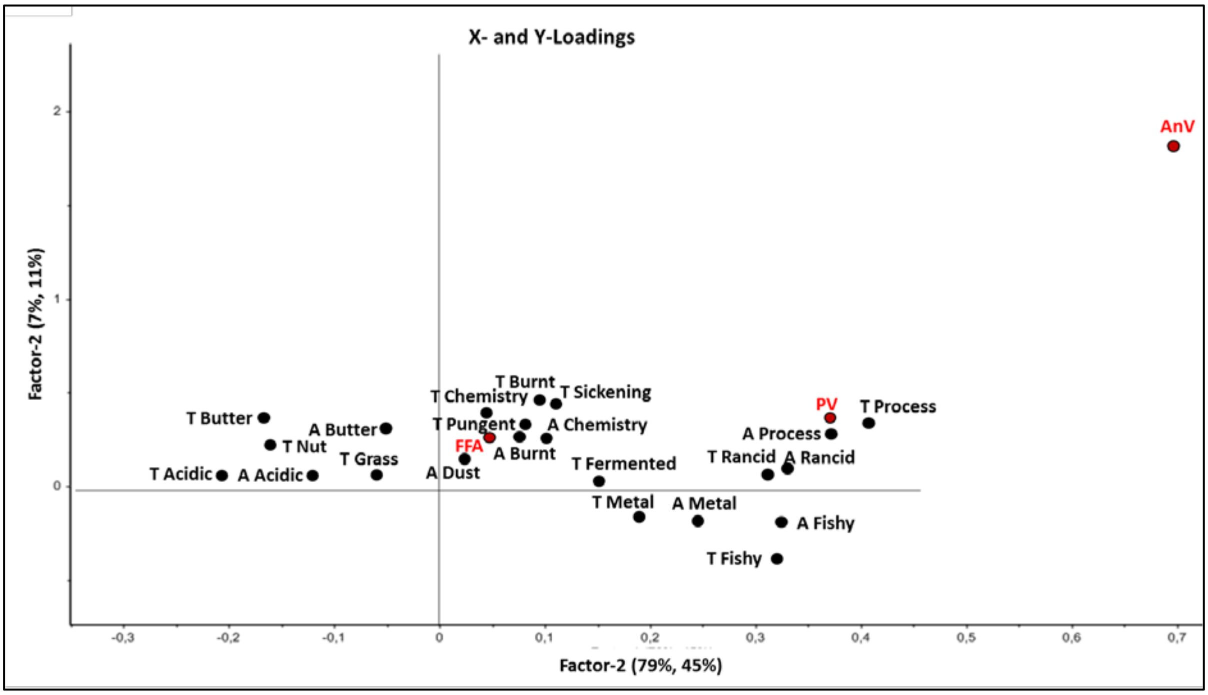

Figure 4 PLS loading plot showing the positioning of the 22 sensory attributes and the correlation between the sensory characteristics and the oxidation status in 20 marine oil samples. The letters “A” and “T” in front of an attribute refer to aroma and taste attributes, respectively.