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Chemical references in sensory analysis of smoke flavourings

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Abstract

A new descriptive language and the corresponding set of chemical standard references for the evaluation of smoke flavourings is proposed. Analysis of variance (ANOVA) and linear discriminant analysis (LDA) were applied to validate this lexicon as well as to analyse reproducibility, discriminatory ability and homogeneity of the panel. Results confirmed that the developed methology was adequate to describe and discriminate commercial smoke flavourings. The number of low correlations demonstrates the need to maintain the majority of the descriptors for carrying out descriptive quantitative sensory analysis of smoke flavourings.

Keywords: Chemical reference; Smoke flavouring; Sensory descriptors

1. Introduction

The age-old art of smoking foods was already well established a few thousand years ago. Smoking, drying and salting, are among the oldest food preservation methods, highly suited to primitive conditions (Barylko-Pikielna, 1977).

The bacteriostatic (Tateo, Caseiro, Orlandi, & Giovanditto, 1995) and antioxidant (Schwanke, Ikins, Kastner, & Brewer, 1996) properties of smoke and smoke flavourings are the subjects of several investigations. In modern food technology, smoke curing, or the smoke flavouring process, has changed from its previous principal objective and should now be considered primarily as a flavouring operation (Pszczola, 1995). Moreover, for consumer health reasons, it has become necessary for the food industry to use smoke flavourings as they do not contain (except possibly in very low concentrations) polycyclic aromatic hydrocarbons (Guillén, Sopelana, & Partearroyo, 2000). For this reason, smoke flavourings are frequently used as novel flavours in several products not previously smoked.

There is no doubt that sensory attributes are important in consumer acceptance, and doubly so when dealing with smoked foods (Bárcenas, Pérez-Elortondo, Salmeron, & Albisu, 1998) because it is their distinctiveness which is held responsible for the continued and increasing demand for smoked foods (Lesimple, Torres, Mitjavilla, Fernandez, & Durand, 1995). This contribution is desired in addition to properties such as coloration (Riha & Wendorff, 1993), texture (Bárcenas, Pérez-Elortondo, Salmerón, & Albisu, 2001) and odour (Helgesen & Naes, 1995).

There are many different techniques used in the addition of smoke flavourings to foods. They may be added to the mixture by injection, immersion, pulverization or by the smoking of stomachs and other such coverings (Girard, 1991); it is possible to use either liquid or solid smoke flavourings, depending on the product to be smoked and the results to be obtained.

Studies have been undertaken to identify, and in a few cases to quantify, the compounds responsible for flavour in smoke flavourings. Most of the compounds identified to date are lactones, furans (Kim, Kurata, & Fujimaki, 1974), phenol derivatives (Baltes, Wittkowski, Söchtig, Block, & Tóth, 1981; Cadwallader, 1996), pyran derivatives, guaiacol, syringol and pyrocatechol derivatives, acids, aldehydes, ketones, (Guillén, 1995; Guillén & Manzanos, 1996), alcohol derivatives, terpenic compounds and alkyl aryl ethers (Guillén & Ibargoitia, 1998).

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Table 1
Characteristics and preparation of the smoke flavourings

Code	Preparation	Characteristics
S1	0.03 g/10 ml H_2O	Small yellow particles
S2	0.03 g/10 ml H_2O	Small brown particles
S3	0.06 g/10 ml H_2O	Mix of particles with different colour and size
S4	0.03 g/10 ml H_2O	Thick yellow particles
L1	200 μl / 10 ml H_2O = SS 5 ml SS + cotton in 60 ml flask	Light brown colour
L2	400 μl / 10 ml H_2O = SS 5 ml SS + cotton in 60 ml flask	Yellow colour
L3	200 μl / 10 ml H_2O = SS 5 ml SS + cotton in 60 ml flask	Orange-yellow colour
L4	100 μl / 10 ml H_2O = SS 5 ml SS + cotton in 60 ml flask	Dark brown colour

S, solid smoke flavouring; L, liquid smoke flavouring; SS, stock solution.

Although research into flavourings is widespread, covering the field of cosmetics (Arctander, 1994a, 1994b) and food (Baltes et al., 1981; Piggot & Paterson, 1994), the sensory characteristics of smoke flavourings have received little attention.

The first stage in establishing a sensory descriptive analysis is the selection of a list of appropriate terms. For this purpose, several procedures may be used, including literature searches, group discussion with panellists on the range of products to be tested, information from consumers or expert knowledge of product attributes (Lawless, 1991). The Repertory Grid Method (RGM) has been used in a number of applications to obtain descriptive terms, for products such as meat (Scriven & Mak, 1991), tequila (Benn & Peppard, 1996), starchy food dishes (Monteleone, Raats, & Mela, 1997) and cheese (Bárcenas, 1999).

The development of a language to describe the sensory characteristics of smoke flavourings enables a panel of assessors to be trained in the use of a common frame of reference to describe these products (Bárcenas, 2000). Prior to training, assessors use a personal frame of reference to evaluate foods. Through training, assessors acquire a commom qualitative and quantitative frame of reference, allowing for homogeneous use of a standard language and common interpretation of scales (Murray & Delahunty, 2000).

Moreover, references that best describe the terms previously defined must be selected to perform sensory profiles. As suggested by Rainey (1986), reference standards are one of the most important aspects in training a panel, as they help panellists to develop the terminology and determine intensities and anchor end points of the attribute scales.

The purpose of the current study was (1) to develop a preliminary standardized lexicon and standard references for smoke flavouring sensory descriptors; (2) to validate the vocabulary using a trained panel of assessors for use in further studies of smoke flavouring sensory characterization.

2. Materials and methods

2.1. Sensory assessors

The sensory panel consisted of 10 assessors, seven females and three males, from the Faculty of Pharmacy at the Basque Country University (Spain). All were selected by the interest that they showed in participating in the study and their previous experience in sensory descriptive analysis of cheeses (Bárcenas, 2001; Lavanchy, 1999).

2.2. Vocabulary development

Commercially available smoke flavourings (four solids and four liquids), exhibiting a wide range of organoleptic characteristics, were used for the vocabulary development. The characteristics and preparation of the smoke flavourings used in this study are set out in Table 1. The composition of some of these smoke

Table 2
Descriptive language used to characterize the odour of the smoke flavourings

Attributes	Description
Burnt (*Quemado*)	Odour produced when foods are scorched.
Fruity (*Frutal*)	Odour associated with different fruits.
Combustible (*Combustible*)	Combination of flavours associated with petroleum, gasoline and tar.
Sharp (*Penetrante*)	Total impression of penetration into the nasal cavity.
Floral (*Floral*)	Aromatics associated with different flowers.
Caramellic (*Caramelo*)	Typical odour of the caramel used in confectionery, custards, etc.
Sweet (*Dulce*)	Odour produced by aqueous solutions of several products such as saccharose or fructose.
Pungent (*Picante*)	Irritative, burnt and/or penetrating sensation in the interior of the nasal cavity.
Acidic (*Ácido*)	Odour produced by some aqueous solutions of several acids (citric, lactic,...).
Wood (*Madera*)	Odour associated with dry wood.
Medicinal (*Medicina*)	Combination of odours associated with a hospital, a chemist's, chemistry, laboratory.
Spice/Aromatic herb (*Especia/Hierba aromática*)	Odour sensation from herbaceous parts of some plants used as food condiments, characterized by their aromatic notes.
Musty (*Mohoso*)	Odour perceived in a closed place where there is some moisture (basement, cellar).

Table 3
References used from the literature for analysis of sensory attributes

Attributes[a]	References	Bibliography
Burnt	0.2 g *pyrocatechol*/5 ml H_2O = SS 3 ml SS + cotton in 60 ml flask	Maga, 1988
	0.1 g *3-methoxypyrocatechol*/10 ml H_2O = SS 3 ml SS + cotton in 60 ml flask	Kim et al., 1974
	0.1 g *1,2-dimethoxybencene*/5 ml H_2O = SS 3 ml SS + cotton in 60 ml flask	Kim et al., 1974
	0.1 g *2,6-dimethoxy 4-methylphenol*/10 ml H_2O = SS 5 ml SS + cotton in 60 ml flask	Kim et al., 1974
	0.1 g *2,6-dimethoxy-4-(1-propenyl)-phenol*/10 ml H_2O = SS 5 ml SS + cotton in 60 ml flask	Kim et al., 1974
	4 g *burnt bread*	([b])
Fruity	100 μl *nerolidol*/3 ml H_2O = SS 3 ml SS + cotton in 60 ml flask	Arctander, 1994b
Combustible	50 μl *ethylbencene*/10 ml H_2O = SS 3 ml SS + cotton in 60 ml flask	Kim et al., 1974
Sharp	100 μl *propionic acid*/3 ml H_2O = SS 3 ml SS + cotton in 60 ml flask	Kim et al., 1974
Floral	50 μl *methylbutyrate*/10 ml H_2O = SS 3 ml SS + cotton in 60 ml flask	Kim et al., 1974
	50 μl *geraniol*/10 ml H_2O = SS 5 ml SS + cotton in 60 ml flask	Mosciano et al., 1991
	50 μl *acetophenone*/10 ml H_2O = SS 3 ml SS + cotton in 60 ml flask	Kim et al., 1974 Girard, 1991
Caramellic	0.1 g *maltol*/10 ml H_2O = SS 3 ml SS + cotton in 60 ml flask 0.1 g *cyclotene*/5 ml H_2O = SS 3 ml SS + cotton in 60 ml flask	Richard, 1992 Arctander, 1994b Kim et al., 1974
Sweet	50 μl *furfural*/10 ml H_2O = SS 3 ml SS + cotton in 60 ml flask 50 μl *5-metil-furfural*/10 ml H_2O = SS 3 ml SS + cotton in 60 ml flask	Kim et al., 1974 Arctander, 1994a Kim et al., 1974
Pungent	50 μl *acetic acid*/10 ml H_2O = SS 3 ml SS + cotton in 60 ml flask	Kim et al., 1974
	50 μl *isobutyric acid*/5 ml H_2O = SS 3 ml SS + cotton in 60 ml flask	Kim et al., 1974
	0.1 g *p-cresol*/10 ml H_2O = SS 3 ml SS + cotton in 60 ml flask	Kim et al., 1974
Acidic	50 μl *acetic acid*/10 ml H_2O = SS 3 ml SS + cotton in 60 ml flask	Kim et al., 1974
Wood	0.1 g *thymol*/5 ml H_2O = SS 5 ml SS + cotton in 60 ml flask	Aldrich Chemical, 1995
	50 μl *guaiacol*/10 ml H_2O = SS 3 ml SS + cotton in 60 ml flask	Aldrich Chemical, 1995
	0.1 g *d-camphor*/10 ml H_2O = SS 5 ml SS + cotton in 60 ml flask	Aldrich Chemical, 1995
	50 μl *eugenol*/10 ml H_2O = SS 3 ml SS + cotton in 60 ml flask	Arctander, 1994a
Medicinal	50 μl *guaiacol*/10 ml H_2O = SS 3 ml SS + cotton in 60 ml flask	Arctander, 1994a
	0.1 g *d-camphor*/10 ml H_2O = SS 5 ml SS + cotton in 60 ml flask	Aldrich Chemical, 1995

(*continued on next page*)

Table 3 (*continued*)

Attributes[a]	References	Bibliography
	50 μl *m-cresol*/10 ml H_2O = SS	Ha and Lindsay, 1991
	3 ml SS + cotton in 60 ml flask	
	0.1 g *o-cresol*/5 ml H_2O = SS	Ha and Lindsay, 1991
	3 ml SS + cotton in 60 ml flask	Aldrich Chemical, 1995
Spice/aromatic herb	50 μl *eugenol*/10 ml H_2O = SS	Maga, 1988
	3 ml SS + cotton in 60 ml flask	Benn and Peppard, 1996
	50 μl i*soeugenol*/10 ml H_2O = SS	Maga, 1988
	3 ml SS + cotton in 60 ml flask	
	50 μl *1,8-cineole*/10 ml H_2O = SS	Richard, 1992
	3 ml SS + cotton in 60 ml flask	Arctander, 1994a
	50 μl *linalool*/10 ml H_2O = SS	Mosciano et al., 1991
	3 ml SS + cotton in 60 ml flask	Luning, Yulcsel, and Roozen, 1994
Musty	0.1 g *o-cresol*/5 ml H_2O = SS	Aldrich Chemical, 1995
	3 ml SS + cotton in 60 ml flask	
	50 μl *1-octen-3-ol*/10 ml H_2O = SS	Benn and Peppard, 1996
	3 ml SS + cotton in 60 ml flask	Murray and Delahunty, 2000

SS, stock solution.

[a] The concentration used in this study is not necessarily the same as suggested in the literature.

[b] No known author has previously used this reference.

flavourings has been carried out previously (Guillén & Ibargoitia 1998; Guillén, Manzanos, & Ibargoita, 1995; Guillén, 2001).

Two replicates for each sample were prepared 24 h before sensory sessions. As Albisu (2000) reported, all samples were refrigerated before the analysis and kept away from air and light influence. Smoke flavourings were maintained at room temperature for two hours before each session.

The first step in obtaining a list of descriptive terms is to generate a great number of such words. The procedure followed to achieve the vocabulary was based on the RGM (Bárcenas, 1999). The group of assessors were asked to describe similarities and differences in odour of pairs of samples. Presentation of samples was carried out to minimize order and carry-over effects, as described by Muir and Hunter (1991/1992). As suggested by Bérodier, Zannoni, Herrero, Lavanchy, Casals, and Adamo (1997), before starting vocabulary development, the panellists were informed of the sensory techniques for assessing odour attributes. They were encouraged to use associative or cognitive terms rather than quantitative or affective ones, such as good, bad, intensive aroma, etc.

The development of the vocabulary took place during two sessions in which the eight samples were presented to the members of the panel. The samples were divided into two groups, in such a way that each group was made up of two solid and two liquid smoke flavourings.

As a second step, a Check List Method was carried out, which consisted of giving an already elaborated list of descriptors to the judges (Moskowitz, 1983). For the purpose of this session, two lists were developed, one of them with the main terms cited in the literature, and another one with the terms developed during the first session. In this way each assessor selected the attributes considered to be representative of any sensory note perceived in the samples.

2.3. Reference selection

After vocabulary generation during four sessions, the panel leader led a discussion whilst the samples were displayed, in order to reach agreement on the descriptors present in the smoke flavourings. As the panel agreed on descriptors, they defined and found a reference for each of them. Chemical standards were preferably considered for this type of reference that could be prepared easily and homogeneously. Krasner (1995) reported that a reference standard can be that of any chemical or natural material that adequately represents the particular characteristic to be described. Standard references were chosen, considering those cited in the literature for describing the same specific attribute. The selection of references was carried out according to Bérodier et al. (1997) guidelines: i.e. smell the chemicals several times, classify sensory perceptions and record the odour family and/or descriptors for each impression. Frequence of citation was considered as an index to label each standard. References were prepared within 24 h prior to sensory sessions.

2.4. Vocabulary validation and homogeneity panel

Vocabulary validation and homogeneity of the panel was carried out with the eight smoke flavourings during

Table 4
Descriptors used by the panel to define the references[a]

Pyrocatechol	3-Methoxypyrocatechol	1,2-dimethoxybenzene	Nerolidol	Ethylbenzene
Combustible (2)	Bitter (1)	Balsamic (1)	Anis (1)	Camphor (2)
Burnt (1)	Burning (1)	Combustible (2)	Floral (4)	Chemical (2)
Chemical (1)	Burnt (1)	Chemical smoke (1)	Fruity (4)	Combustible (1)
Medicinal (4)	Chemical (1)	Chemists (1)	Herbs (1)	Musty (1)
Tyre (2)	Chemists (1)	Chloroform (1)	Orange (1)	Medicinal (2)
	Guaiacol (1)	Medicinal (3)	Sweet (1)	Snacks (1)
	Sharp (1)	Nitrate (1)		Soft mass (1)
	Sweet (1)	Phenolic (2)		
	Wood (2)	Pungent (1)		
		Sharp (3)		
Propionic acid	**Methylbutirate**	**Geraniol**	**Acetophenone**	
Acetic acid (2)	Acidic (2)	Acidic (1)	Benzaldehyde (1)	
Acidic (5)	Cheese (1)	Air freshener (1)	Bitter almond (3)	
Dirty (1)	Chewing gum (1)	Aromatic herb (1)	Chemical (1)	
Propionic acid (1)	Dairy (1)	Citric (2)	Glue (2)	
Pungent (2)	Floral (1)	Floral (5)	Medicinal (2)	
Sharp (4)	Fruity (1)	Fruity (3)	Naphthalene (1)	
Sweated sock (1)	Lactic acid (1)	Pine (1)	Sharp (4)	
Vinegar (2)	Medicinal (1)	Refresing (1)	Solvent (1)	
	Musty (2)	Rose (1)	Sweet (1)	
	Pungent (1)	Sour (1)		
	Putrid (1)			
	Rancid butter (1)			
	Snacks (2)			
Maltol	**Cyclotene**	**Furfural**	**5-Methylfurfural**	
Burnt wood (1)	Aromatic herb (4)	Almond (1)	Almond (1)	
Caramellic (1)	Burning (1)	Benzaldehyde (1)	Aromatic herb (1)	
Floral (1)	Burnt (2)	Bitter (1)	Benzaldehyde (1)	
Fruity (1)	Burnt Caramellic (1)	Bitter almond (1)	Bitter (1)	
Sawdust with smoke (1)	Burnt tyre (1)	Chemical (1)	Bitter almond (4)	
Strawberry (1)	Caramellic (1)	Medicinal (1)	Burnt paper (1)	
Sweet (4)	Liquorize (3)	Musty (1)	Chemical (1)	
Wood (1)	Sharp (1)	Naphthol (1)	Desinfectant (1)	
	Smoke (1)	Sweet- Fruity (1)	Fruity (1)	
	Wood smoke (1)	Tea (1)	Marzipan (1)	
		Wet wood (1)	Medicinal (1)	
			Musty (1)	
			Sharp (1)	
			Spice (1)	
Acetic acid	**Isobutyric acid**	**p-Cresol**	**Thymol**	
Acidic (7)	Acidic (2)	Burning (1)	Chemical (1)	
Sausage (1)	Burnt (1)	Combustible (4)	Chemist (1)	
Sharp (3)	Burnt tyre (1)	Liquorize (1)	Doctor office (1)	
	Butyric (3)	Medicinal (1)	Guaiacol (1)	
	Cresolic (1)	Nail varnish (1)	Medicinal (1)	
	Cheese (3)	Polution (1)	Pepper (1)	
	Dairy (2)	Sharp (1)	Pungent (1)	
	Dye (1)	Solvent (1)	Sharp (1)	
	Musty (1)	Sweet (1)	Spice (1)	
	Pungent (2)	Tyre (1)	Sweet (1)	
	Putrid (1)		Wood (1)	
	Rancid burnt (1)			
	Shap (2)			
	Snacks (1)			

(*continued on next page*)

Table 4 (*continued*)

Guaiacol	d-Camphor	Eugenol	m-Cresol	
Burnt (3)	Acid herb (1)	Burnt (1)	Caramellic (2)	
Combustible (1)	Aromatic herb (4)	Caramellic (1)	Cinder (1)	
Guaiacol (2)	Burnt herb (1)	Floral (3)	Combustible (1)	
Medicinal (5)	Eucalyptus (2)	Medicinal (2)	Cresolic (1)	
Phenolic (1)	Mint (6)	Pepper (1)	Dye (1)	
Pungent (1)	Rosemary (1)	Phenolic (1)	Maltol (1)	
Sharp (2)	Sharp (1)	Seaweed (1)	Medicinal (2)	
Siringol (1)	Spice (1)	Spice (2)	Phenolic (1)	
Smoke (2)	Wood (1)	Sweet (2)	Smoke (3)	
Wood (1)		Burnt (1)	Tar (1)	
			Wood (1)	
o-Cresol	**Isoeugenol**	**1,8-Cineole**	**Linalool**	**1-Octen-3-ol**
Burnt (3)	Fruity (1)	Aromatic herb (5)	Air freshener (1)	Mushroom (7)
Caramellic (1)	Floral (2)	Camphor (2)	Aromatic herb (1)	Musty (3)
Combustible (1)	Guaiacol (1)		Citral (1)	
Cresolic (1)	Medicinal (1)	Eucalyptus (1)	Floral (1)	
Medicinal (2)	Plum jam (1)	Herb air freshener (1)	Fruity (4)	
Musty (1)	Sharp (1)	Mint (5)	Lavender (1)	
Oil (1)	Spice (1)		Lemon (4)	
Petrol (1)	Sweet (2)		Limonene (1)	
Phenolic (1)	Wood (2)		Sweet (1)	
Sharp (3)				

[a] The numbers in parentheses, indicate how many times the attribute was defined by the panellists.

four sessions, using the list of terms and references previously selected by them. During these sessions, each term was evaluated using a scale ranging from 0 (null or slight perception) to 7 (very intense).

2.5. Statistical analysis

Statistical analysis of the data was performed using SPSS 8.0 for Windows 95 (SPSS Inc., Michigan, USA). Two way ANOVA (F_{sample} and $F_{session}$) and linear discriminat analysis (LDA) were done to analyse reproducibility, discriminatory ability and homogeneity of the group, as well as to validate the selected vocabulary (Hair, Anderson, Tatham, & Black, 1998). A correlation analysis was performed to determine whether the sensory terms developed in the study of smoke flavourings were redundant or whether they correlated.

Table 5
Sensory descriptors and standard references selected to describe the smoke flavourings

Attributes	Reference
Burnt	Burnt bread
Fruity	Nerolidol
Combustible	Ethylbenzene
Sharp	Propionic acid
Floral	Geraniol
Caramellic	Cyclotene
Sweet	Maltol
Pungent	Isobutyric acid
Acidic	Acetic acid
Wood	Thymol
Medicinal	Guaiacol
Spice/Aromatic herb	Eugenol
Musty	1-Octen-3-ol

3. Results and discussion

3.1. Development of the lexicon

During lexicon development sessions, panellists freely generated terms that described the odour of the smoke flavourings.

The initial working list included several terms used only by one of the assessors (e.g. smoked, balsamic); thus after panel discussion most of them were eliminated. Many of the terms in the list were very similar it was therefore decided, as suggested by Bárcenas et al. (1999), that they should be excluded on the basis of being synonyms, retaining only the most representative term after panel discussion (e.g. medicinal/chemical/balsamic = medicine; herbaceous/pine/vegetable = wood).

From an initial list of 82 terms, selected in the second session, 13 terms were retained (medicinal, sweet, fruity, spice/aromatic herb, floral, pungent, caramellic, burnt, sharp, acid, combustible, musty, wood), which were defined on the basis of the judges' own criterion. Stone

Table 6
Fisher's comparison test for smoke flavouring sensory terms

	L1	L2	L3	L4	S1	S2	S3	S4	SEM	*F*	Sig.
Burnt	3.9	3.7	3.3	3.2	3.0	3.4	1.2	1.4	0.15	5.84	***
Fruity	1.0	1.2	0.9	1.0	0.9	1.5	2.0	1.0	0.07	3.09	**
Combustible	1.8	1.8	1.5	1.5	1.1	1.2	1.6	1.4	0.09	1.01	NS
Sharp	2.5	2.8	3.4	3.1	1.7	3.4	2.4	1.1	0.12	4.73	***
Floral	1.0	1.2	0.8	0.9	1.0	1.7	2.0	1.1	0.08	3.47	**
Caramellic	2.6	1.8	1.3	3.4	1.3	2.8	1.8	1.0	0.11	6.37	***
Sweet	1.9	1.9	1.4	2.6	1.8	3.5	2.6	1.5	0.11	4.54	***
Pungent	2.1	1.8	2.9	2.9	1.4	2.0	1.5	1.1	0.10	5.24	***
Acidic	1.7	1.2	2.8	2.3	1.5	2.4	1.2	1.1	0.08	6.65	***
Wood	2.5	2.7	1.8	1.2	2.8	2.2	3.5	1.5	0.12	4.38	***
Medicinal	3.1	2.9	1.6	2.1	2.5	2.1	1.9	1.5	0.11	3.26	**
Spice/aromatic herb	2.4	2.2	1.0	1.1	1.7	2.0	4.5	2.7	0.10	13.41	***
Musty	1.6	2.1	1.0	0.8	1.6	0.9	2.3	1.6	0.98	4.32	***

NS, nonsignificant; SEM: standard error of the mean; S, solid smoke flavouring; L, liquid smoke flavouring.
** $P<0.01$.
*** $P<0.001$.

and Sidel (1993) considered this type of reduction completely usual during initial training sessions. It should be taken into account that the terminology is simply a set of labels that a panel agrees upon, which enables them to fully describe the sensory properties of the products being evaluated. Bárcenas et al. (1999), studying ewes milk cheeses, reduced an initial list of 260 attributes to 29 at this stage of the analysis. Byrne, Bak, Bredie, Bertelsen, and Martens (1999) elaborated an initial list of 45 terms to study the odour of pork meat; later, they minimized it to 16 attributes. Warm, Nielsen, and Hyldig (2000) reduced, in two stages, an initial list, containing 46 descriptive words for five fish species, to 15 words.

The final descriptive language was defined as shown in Table 2. Muñoz and Civille (1998) indicated the importance of carrying out a definition of the descriptive terms to obtain better performance by the panel during sensory sessions.

3.2. Selection of references

The next step was to find adequate standard references associated with each attribute. The references found in the literature are shown in Table 3.

Table 4 sets out the frequence of citation for descriptors used by the panel to define the chemical references.

The study of the attribute "burnt" was carried out with the chemical references pyrocatechol, 3-methoxypyrocatechol and 1,2-dimethoxybenzene. However, the panellists considered them inadequate to describe smoke flavourings, because these references resembled medicinal. For this reason, no chemical references were used for this attribute, and paper and burnt bread were tried. Finally, burnt bread was considered as more than adequate by the panel.

For the attributes "fruity", "combustible", and "sharp odour", the panel agreed to consider the references nerolidol, ethylbenzene and propionic acid, respectively, which were described in the literature.

For the attribute "floral", three references from the literature were selected; methylbutyrate, geraniol, and acetophenone. Finally assessors agreed that geraniol was the best chemical substance for characterizing this odour category. This reference was also selected by Lee, Paterson, Piggott, and Richardson (2000) for whisky sensory characterization.

Maltol and cyclotene were considered for the term "caramellic". In the opinion of the panellists, maltol not only described this sensation but also the "sweet" characteristic, with a higher intensity than references such as furfural and 5-methyl-furfural. Finally, maltol was chosen as the reference for "sweet odour" (Lee et al., 2000; Mosciano, Fasano, Michalski, & Sadural, 1991) and cyclotene for the "caramellic odour".

"Pungent" and "acidic" attributes have been related with acetic acid (Kim et al., 1974). However, as Charles, Martin, Ginies, Coste, and Guichard (2000) reported, this compound was considered more adequate to define the acidic characteristic. Although acetic acid and p-cresol, were previously found as representative of the "pungent" term, isobutyric acid was considered as the best chemical reference to define this odour, once frequency of citation was studied.

In the literature, the attribute wood was related to guaiacol (Aldrich Chemical, 1995), thymol, d-camphor (Aldrich Chemical, 1995) and eugenol (Arctander, 1994a). At the same time, guaiacol, d-camphor, m-cresol and o-cresol were described by the panellists to define the medicinal characteristics. Furthermore, the study of the term "spice/aromatic herb" was carried out with the chemical substances eugenol, isoeugenol, 1,8-cineole and linalool.

Following a study of all these references by the panel, thymol and guaiacol were chosen as the references for

Table 7
Classification of the smoke flavouring (Discriminatory ability and panel homogeneity)

	Percentage of cases correctly classified							
	L1	L2	L3	L4	S1	S2	S3	S4
L1	53.8	7.7	15.4	0	15.4	7.7	0	0
L2	6.3	62.5	0	0	25	0	0	6.3
L3	0	0	80	6.7	6.7	6.7	0	0
L4	0	0	16.7	83.3	0	0	0	0
S1	0	6.7	0	0	66.7	0	0	26.7
S2	0	0	0	15.4	0	84.6	0	0
S3	0	0	0	0	0	6.3	93.8	0
S4	0	0	0	0	0	0	0	100

S, solid smoke flavouring; L, liquid smoke flavouring.

the terms "wood" and "medicinal", respectively. To generate the overall concept for the term "spice/aromatic herb", subjects were given both substances; eugenol, and 1,8-cineole.

The study of the term "musty" was carried out with the compounds o-cresol and 1-octen-3-ol. Finally, the latter was selected for this term.

Table 5 shows the final selected materials to be used as standards for smoke flavouring sensory descriptors.

3.3. Vocabulary validation and panel homogeneity

Vocabulary validation and panel homogeneity took place in four sessions, after carrying out development of the lexicon, selection of references and panel training.

Table 6, shows that the group of assessors as a whole were able to distinguish all the attributes, with the exception of the term "combustible". However, it was observed that some smoke flavourings had a greater similarity between them. As suggested Bárcenas, Pérez-Elortondo, and Albisu (2000), very slight differences between samples may make scoring difficult.

LDA results show that 77.7% of the total amount of cases were correctly classified, based on the discriminant functions obtained from the variables studied (Table 7). Although the smoke flavourings L2, S1, and especially L1, did not have a high percentage of classification, the rest of the samples presented a percentage of classification of over 80%. This reveals that the panellists presented a high discriminant ability to differentiate the commercial smoke flavourings. Powers (1982) pointed out that trained panels do not usually obtain classification rates of over 80%. As suggested by Powers, Cenciarelli, and Shinholser (1984), the fact that sensory analysis gives lower correct classification rates than instrumental measures does not mean that the assessors are not performing adequately. The level of similarity among samples, as in this case, may also contribute to lower correct classification scores. These results show that the attributes used in this study, and by the panel, were adequate, not only to describe, but also to discriminate the commercial smoke flavourings studied.

The results obtained from the correlation analysis of the studied attributes are shown in Table 8.

All the attributes, except "medicinal", "sweet" and "floral" presented significant correlations. The highest correlation index ($r > 0.9$) was observed between the attributes "sharp" and "pungent". Moreover, these terms are positively correlated with "acidic" and "musty". Positive correlation is also observed between "musty" and "wood", and between "spice/aromatic herb" and "fruity", whereas negative correlation is observed between "musty" and "acidic". Finally, negative correlation is observed between "fruity" and the

Table 8
Pearson's correlation coefficients for smoke flavouring sensory attributes

Attribute	1	2	3	4	5	6	7	8	9	10	11	12
1 Medicinal												
2 Sweet	0.015											
3 Fruity	−0.210	0.249										
4 Spice/aromatic herb	0.218	0.557	0.832**									
5 Floral	−0.535	0.196	0.395	0.060								
6 Pungent	0.383	−0.195	−0.494	−0.434	0.159							
7 Caramellic	−0.217	0.223	−0.395	−0.468	0.537	0.429						
8 Burnt	0.026	0.020	−0.714*	−0.684*	0.167	0.487	0.887**					
9 Sharp	0.368	0.082	−0.457	−0.331	0.264	0.950***	0.577	0.593				
10 Acidic	0.232	−0.256	−0.319	−0.359	0.357	0.854**	0.269	0.292	0.799**			
11 Combustible	0.462	0.036	−0.732*	−0.425	−0.540	0.476	0.313	0.573	0.491	0.027		
12 Musty	−0.040	−0.128	0.053	0.070	−0.461	−0.794**	−0.334	−0.132	−0.788**	−0.710*	−0.141	
13 Wood	0.475	0.147	0.158	0.381	−0.237	−0.415	−0.134	−0.018	−0.330	−0.317	−0.150	0.660*

* $P = < 0.05$.
** $P = < 0.01$.
*** $P = < 0.001$.

terms "burnt" and "combustible", between "burnt" and "pungent" and "aromatic herb", but positive correlation between "burnt" and "caramellic".

The low correlations demonstrate the need to maintain the majority of the descriptors for carrying out descriptive quantitative sensory analysis of smoke flavourings.

4. Conclusions

Terms and references developed here could be a great help for standardization of sensory analysis of smoke flavourings. This could help to improve sensory quality control in smoked food companies, and the development of new smoked foods and may constitute a better approach to consumer demands. This lexicon is useful and comprehensive for the characterization of the smoke flavourings under investigation here; however, the list of terms may be incomplete. Furthermore, this set of descriptors and references could assist researchers in developing an accurate lexicon adapted to the necessities of smoke flavourings; thus the list should be continually expanded as necessary.

The results obtained confirmed that the panel was able to discriminate the smoke flavourings considered. The information obtained by this method can be considered adequate for ascertaining whether a training procedure has been successfully completed for detecting any major problematic sensory descriptors.

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