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## Using Free-Comment with consumers to obtain temporal sensory descriptions of products

Benjamin Mahieu, Michel Visalli, Arnaud Thomas, Pascal Schlich

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## 1 Title

2 Using Free-Comment with consumers to obtain temporal sensory descriptions of  
3 products

## 4 Authors

5 Benjamin Mahieu<sup>a</sup>, Michel Visalli<sup>a</sup>, Arnaud Thomas<sup>b</sup>, Pascal Schlich<sup>a</sup>

6 <sup>a</sup>Centre des Sciences du Goût et de l'Alimentation, AgroSup Dijon, CNRS, INRAE,  
7 Université Bourgogne Franche-Comté, F-21000 Dijon, France.

8 <sup>b</sup>SensoStat, Dijon, France.

## 9 Corresponding author:

10 Benjamin Mahieu

11 [benjamin.mahieu@inrae.fr](mailto:benjamin.mahieu@inrae.fr)

12 Centre des Sciences du Goût et de l'Alimentation, AgroSup Dijon, CNRS, INRAE,  
13 Université Bourgogne Franche-Comté, F-21000 Dijon, France.

## 14 Highlights

- 15 - A new temporal method not based on a predefined list of descriptors is  
16 introduced
- 17 - Temporal Free-Comment data can be obtained from consumers at home
- 18 - The data can be analysed product-wise and period-wise
- 19 - Temporal discrimination and characterization of the products were highlighted

## 20 Abstract

21 Temporal Dominance of Sensations (TDS) and Temporal-Check-All-That-Apply  
22 (TCATA) are the most popular methods used with consumers for the temporal sensory  
23 characterization of a set of products. However, TDS and TCATA share the same  
24 limitation: they rely on a predefined and necessarily short list of descriptors. Free-  
25 Comment (FC) enables the sensory characterization of a set of products freed of any

26 issue induced by the use of a list of descriptors, but for practical reasons collecting FC  
27 descriptions concurrently to the product intake is nearly impossible. Attack-Evolution-  
28 Finish (AEF) is an alternative to TDS and TCATA that replace concurrent by  
29 retrospective data collection. In AEF, subjects are asked to choose in a list one  
30 descriptor for each of the so-called periods: Attack, Evolution, and Finish. The paper  
31 introduced Free-Comment Attack-Evolution-Finish (FC-AEF) to extend FC to temporal  
32 sensory analysis where descriptor selections of AEF are replaced by FC descriptions.  
33 FC-AEF has been used at home with 63 consumers having tasted five dark chocolates.  
34 The data were analysed product-wise and period-wise and showed that FC-AEF  
35 enabled to provide temporal discrimination and characterization of the products. The  
36 product-wise analyses identified in each period the descriptors of each product  
37 enabling this discrimination. The period-wise analyses identified for each product the  
38 descriptors generating a temporal kinetic of its perception.

## 39 Keywords

- 40 - Free-Comment Attack-Evolution-Finish (FC-AEF)
- 41 - Open-ended questions
- 42 - Temporal sensory method
- 43 - Home Used Test (HUT)
- 44 - Consumer study

## 45 1. Introduction

46 Since it has been advocated that sensory perception is not a static phenomenon but  
47 rather a dynamic one (Lee & Pangborn, 1986), several methods have been developed  
48 to study the kinetic of sensations during the perception of a product. It is possible to  
49 distinguish two subcategories of temporal sensory methods: quantitative-based ones  
50 and qualitative-based ones. Among quantitative-based methods, we can mention  
51 Time-Intensity (Lee & Pangborn, 1986), Dual-Attribute Time-Intensity (Duizer, Bloom,  
52 & Findlay, 1996), Multi-Attribute Time-Intensity (Kuesten, Bi, & Feng, 2013),  
53 Progressive Profile (Jack, Piggott, & Paterson, 1994) and Sequential Profile (Methven  
54 et al., 2010). Quantitative-based methods require a trained panel, which implies a time-

55 consuming and possibly expensive training period before starting product evaluations.  
56 Among qualitative-based temporal sensory methods, the two most popular are  
57 Temporal Dominance of Sensations (TDS) (Pineau, Cordelle, Imbert, Rogeaux, &  
58 Schlich, 2003; Pineau et al., 2009) and Temporal-Check-All-That-Apply (TCATA)  
59 (Castura, Antúnez, Giménez, & Ares, 2016). Contrary to quantitative-based methods,  
60 TDS and TCATA can be used with consumers without specific training (Jaeger et al.,  
61 2018; Rodrigues et al., 2016; Schlich, 2017).

62 During a TDS task, the subjects are asked to select among a predefined list of  
63 descriptors, which one is “dominant” at each time within a product intake (Pineau et  
64 al., 2003; Pineau et al., 2009). A descriptor is considered as dominant from its selection  
65 until another descriptor is selected as being dominant instead. TCATA adopts another  
66 rational than TDS by enabling the subjects to select several descriptors at each time  
67 within a product intake (Castura et al., 2016). In practice, subjects select a descriptor  
68 when they judge it applicable and unselect a descriptor when they judge it no longer  
69 applicable. Both TDS and TCATA share the same limitation: they rely on a predefined  
70 and necessarily short list of descriptors (Jaeger et al., 2018; Pineau et al., 2012).

71 Establishing a list of descriptors is very tedious and represents a critical step for the  
72 relevance of the collected data as it may affect the results of the study (Ares et al.,  
73 2013; Pineau et al., 2012; Varela et al., 2018). Furthermore, several sources of bias  
74 induced by the use of a predefined list of descriptors have been reported in the  
75 literature. The list influences the subjects by suggesting descriptors that they would not  
76 think about otherwise (Coulon-Leroy, Symoneaux, Lawrence, Mehinagic, & Maitre,  
77 2017; Kim, Hopkinson, van Hout, & Lee, 2017; Krosnick, 1999). Since the list contains  
78 only a limited number of descriptors, subjects may select descriptors that are close to  
79 what they perceive but not representing exactly what they actually perceive (Krosnick,  
80 1999) and the collected data can be biased by the dumping effect (Varela et al., 2018).  
81 The first descriptors of the list (in the sense of presentation order) have a greater  
82 chance of being selected (Castura, 2009; Kim et al., 2017; Krosnick, 1999; Pineau et  
83 al., 2012).

84 Free-Comment (FC) (ten Kleij & Musters, 2003), as a response to open-ended  
85 questions, has proven itself an efficient method in characterizing and discriminating  
86 sets of products both with consumers and with experts (Lahne, Trubek, & Pelchat,  
87 2014; Lawrence et al., 2013; ten Kleij & Musters, 2003) even out of the lab (Mahieu,

88 [Visalli, Thomas, & Schlich, 2020](#)). As FC does not require a predefined list of  
89 descriptors, all the issues mentioned above do not longer hold. However, the FC  
90 method does not enable temporal sensory characterization.

91 For the products that have a relatively short tasting duration (say up to 45 seconds),  
92 collecting FC temporal descriptions in continuous time concurrently to the product  
93 intake as in TDS and TCATA is nearly impossible for practical reasons. Indeed,  
94 subjects should have first to identify the sensations they perceive within a complex  
95 signal, then think about the words that best describe these sensations and then finally  
96 transcript these words (handwriting, keyboard input, or voice recording) while staying  
97 focused on their perception. It would therefore not be reasonable to consider the data  
98 as being collected concurrently to the perception.

99 The recently introduced Attack-Evolution-Finish (AEF) method ([Visalli, Mahieu,  
100 Thomas, & Schlich, 2020](#)) proposes an alternative to continuous concurrent data  
101 collection. During an AEF task, subjects are asked to select retrospectively among a  
102 predefined list of descriptors which one they perceived during the so-called periods:  
103 Attack, Evolution, and Finish. The results obtained from AEF and TDS were compared  
104 in a study involving 120 consumers having evaluated five dark chocolates. AEF and  
105 TDS provided equivalent product discrimination and a very similar product  
106 characterization ([Visalli et al., 2020](#)).

107 The paper introduces the Free-Comment Attack-Evolution-Finish (FC-AEF), a method  
108 that integrates AEF and FC. In FC-AEF, the descriptor selection for each of the three  
109 periods (Attack, Evolution, and Finish) is replaced by an FC description, enabling a  
110 temporal sensory characterization without the issues induced by the use of a  
111 predefined list of descriptors.

112 The present study investigated whether consumers can successfully conduct an FC-  
113 AEF protocol at home and whether it enables the temporal characterization and  
114 discrimination of a set of products.

## 115 2. Material and methods

### 116 2.1. Participants

117 To create a situation as close as possible to an everyday consumption situation, the  
118 study took place at home with 63 naïve subjects (25 men and 38 women), 18 to 60  
119 years old. The subjects were recruited from a population registered in the ChemoSens  
120 Platform's PanelSens database. This database has been declared to the relevant  
121 authority (Commission Nationale Informatique et Libertés—CNIL—n° d'autorisation  
122 1148039). The subjects were consumers of dark chocolates at least once every two  
123 weeks and were rewarded for their participation in the study.

## 124 2.2. Products

125 Five dark chocolates provided by Barry Callebaut® were used for this study. They  
126 differed on their percentage of cocoa as well as on the origin of the cocoa used in the  
127 recipe. SDC has 54.5% of cocoa obtained from a mix of cocoa beans. BRA has 66.8%  
128 of cocoa coming from Brazil. EQU has 70.4% of cocoa coming from Ecuador. MAD  
129 has 67.4% of cocoa coming from Madagascar. SAO has 70% of cocoa coming from  
130 Sao Tomé. The chocolates were delivered to the subjects in sealed plastic containers  
131 in the form of callets (pucks of chocolates formulated for melting rather than baking).  
132 The subjects were invited to store the chocolates in a relatively cold place so that they  
133 did not melt or alter.

## 134 2.3. Data acquisition

### 135 2.3.1. General procedure

136 The subjects participated in five home-based sessions on their computers running  
137 TimeSens© software 2.0 (INRAE, Dijon, France). To access the sessions, the subjects  
138 simply had to click on a link sent to them by e-mail. In each session, consumers had  
139 to evaluate and describe only one product; it lasted approximately 5 minutes. The  
140 presentation of the products (and thus the sessions) was arranged following a William  
141 Latin square design. The minimum interval between two sessions was forced to be at  
142 least 24 hours

### 143 2.3.2. FC-AEF task

144 The instructions were given to the subjects at the beginning of the first session: “You  
145 are going to taste five chocolates. Each tasting will be separated from the previous one  
146 by at least 24 hours. For each chocolate, you will be asked to describe the sensations  
147 you perceived during the tasting in the chronological order that you perceived these

148 sensations. You will provide the descriptions using your own words.” An example was  
149 given to the subjects right after the instructions: “Example: At first, I perceived this  
150 chocolate sour and soft, then after a few moments I perceived it sour, sticky and woody,  
151 and at the end of the tasting I perceived it astringent, melting and sweet”. This example  
152 had the objective to inform the subjects that the same word could be used for several  
153 periods and that several different words could be used in the same period. This was  
154 underlined by the following sentence right after the example: “You can use the same  
155 words for several periods and several different words can be used in the same period”.  
156 This was underlined by the following sentence right after the example: “You can use  
157 the same words for several periods and several different words can be used in the  
158 same period”.

159 [Fig. 1](#) shows the FC-AEF data collection screen. For each product evaluation, the  
160 following instruction was given to the subjects: “What sensations did you perceive  
161 during the tasting (textures, flavors, aromas, etc.) in chronological order? (Use your  
162 own words to answer)”. Three text areas corresponding to each period (Attack,  
163 Evolution, and Finish) were displayed on the screen. The text areas were organized  
164 on the screen so that the subjects filled the following sentence when describing their  
165 perception: “At first, I perceived this chocolate..., then after a few moments I perceived  
166 it..., and at the end of the tasting I perceived it...” ([Visalli et al., 2020](#)).

167 No particular restriction was given to the subjects on the manner of stating their  
168 descriptions. The subjects were forced to give at least one word within each period.

## 169 **2.4. FC-AEF data treatment**

170 As descriptions were collected in French, all the pre-treatments were performed in  
171 French. The analysed words resulting from the treatments have been translated into  
172 English for the present paper. The English-French correspondence of the analysed  
173 words can be found in the appendix.

174 All the FC-AEF data treatments were performed using R 3.5.1 ([R Core Team, 2018](#)).  
175 The lexicon provided with IRaMuTeQ© software ([Ratinaud, 2014](#)) was used for  
176 lemmatization and part-of-speech tagging. The data of the three periods were merged  
177 before applying the following pre-treatments. This merging was done only for the pre-  
178 treatments of the descriptions and to ensure that the data from each of the three

179 periods were treated the same manner. The procedure used was the same one as  
180 described in [Mahieu, Visalli, Thomas, et al. \(2020\)](#) and summarized thereafter.

181 The descriptions were first cleaned, lemmatized, and filtered. Then, the words with  
182 similar meanings were grouped into latent-words relying on the chi-square-distance-  
183 based ascendant hierarchical classification.

184 Among all the words and latent words (simply called words hereafter for simplification),  
185 only those mentioned by at least 5% of the panel for at least one same product within  
186 at least one same period were retained for further analysis.

187 Finally, the number of times each remaining word was cited within each period for each  
188 product was computed at the panel level. Three contingency tables, one per period,  
189 containing the citation counts of each word for each product were built. These  
190 contingency tables will be referred subsequently as “product by word contingency  
191 tables”. Five contingency tables, one per product, containing the citation counts of each  
192 word for each period were built. These contingency tables will be referred subsequently  
193 as “period by word contingency tables”.

## 194 2.5. Data analyses

195 All analyses were performed using R 3.5.1 ([R Core Team, 2018](#)).

### 196 2.5.1. Panel behavior

197 The distributions of the number of analysed words (after pre-treatments) cited by each  
198 subject, for each product and each period as well as for the three periods aggregated  
199 were computed. For a given evaluation (product  $\times$  subject), the number of analysed  
200 words for the three periods aggregated corresponds to the sum of citations of analysed  
201 words of the three periods. Thus, for the aggregated data, the same word can be cited  
202 more than once per evaluation. The mean, the mode, and the standard deviation of  
203 these four distributions were computed.

### 204 2.5.2. Contingency tables

205 The eight contingency tables (a “product by word contingency table” for each of the 3  
206 periods [A, E and, F] and a “period by word contingency table” for each of the 5  
207 products [SDC, BRA, EQU, MAD and, SAO]) were analysed the same manner  
208 following the procedure presented in [Mahieu, Visalli, and Schlich \(2020\)](#) and



209 summarized thereafter. A chi-square test using a Monte Carlo approach (1000  
 210 simulations,  $\alpha = 5\%$ ) was performed to investigate the significance of the dependence  
 211 between products or periods and words. If the chi-square test was significant, a  
 212 correspondence analysis (CA) was applied to the contingency table. The standard CA  
 213 biplot was used to display the CA results. The number of significant CA axes was  
 214 determined using the Monte-Carlo tests of dependence (1000 simulations,  $\alpha = 5\%$ ).  
 215 The confidence ellipses for the products or the periods coordinates in the CA space  
 216 were computed with a total bootstrap procedure (1000 bootstrap samples,  $\alpha = 5\%$ ) in  
 217 which Procrustes rotations were performed on the significant axes. To assess relations  
 218 between products or periods and words, Fisher's exact tests ( $\alpha = 5\%$ ) per cell with a  
 219 one-sided greater alternative hypothesis were conducted on the derived contingency  
 220 table corresponding to significant axes. This contingency table is computed by  
 221 reversing the CA computations on the significant axes (Mahieu, Visalli, & Schlich,  
 222 2020). To assess products or periods discrimination, a total bootstrap test ( $\alpha = 5\%$ )  
 223 (Mahieu, Visalli, Thomas, et al., 2020) was performed for each pair of products or  
 224 periods on the significant axes.

## 225 3. Results

### 226 3.1. Panel behavior

227 Fig .2 shows that the three periods had very similar distributions in terms of effective  
 228 words cited. The number of effective words cited ranged from 0 to 4 (Attack period) or  
 229 5 (Evolution and Finish period). The mode of the three distributions was equal to 1, the  
 230 mean was around 1.43 and the standard deviation ranged from 0.82 (Attack period) to  
 231 0.97 (Finish period). The standard deviation slightly increased from the Attack period  
 232 to the Finish period.

233 For all periods aggregated, Fig. 2 (d) shows that the number of effective words cited  
 234 for each subject and each product ranged from 0 to 10 with a mode of 4, a mean of  
 235 4.3, and a standard deviation of 1.96.

### 236 3.2. Product by word contingency tables

Period	P-value: chi-square / axis 1	P-value: axis 2	P-value: axis 3	P-value: axis 4
<i>Attack</i>	<0.001	0.0019	0.0029	0.2257

<i>Evolution</i>	<0.001	0.0119	0.0169	0.4725
<i>Finish</i>	<0.001	0.1288	0.6443	0.6023

237 **Table 1:** p-values of the test of dependence for each axis of each period

238 **Table 1** shows that FC-AEF presented three significant axes for the Attack and the  
 239 Evolution periods and only one significant axis for the Finish period. Therefore, a  
 240 product by word significant dependence was detected in each period, though less  
 241 complex in the Finish period.

242 **Fig. 3** shows that the first dimension of the product configuration was very similar  
 243 across the three periods and mostly opposed SDC to BRA with SAO, MAD, and EQU  
 244 being placed between them. This first dimension seemed to be a gradient of strength  
 245 induced by the opposition of strong and slight flavors. **Fig. 3 (b)** shows that the second  
 246 dimension of the Attack period mostly opposed MAD to the other products. This  
 247 dimension seemed to be a texture gradient of hardness. **Fig. 3 (b)** shows that the third  
 248 dimension of the Attack period mostly opposed EQU and SAO. This dimension seemed  
 249 to be a gradient of sweetness associated with a second gradient of hardness. **Fig. 3**  
 250 **(d)** shows that the second dimension of the Evolution period had high similarity with  
 251 the third dimension of the Attack period, mostly opposing EQU and SAO. This  
 252 dimension seemed to be a gradient of sweetness but it also showed an opposition  
 253 between several flavors and textures. The third dimension of the Evolution period did  
 254 not show an obvious interpretation.

255 The product discrimination was weaker at the Finish period as compared to the Attack  
 256 and Evolution periods. The five products were discriminated for the Attack and  
 257 Evolution periods but not for the Finish period, where only seven pairs of products out  
 258 of ten were discriminated. **Fig. 3 (e)** suggests that the subjects only found large  
 259 differences between SDC and the other products at the finish of the product perception.  
 260 These latter seem not to have any particular characteristics distinguishing them from  
 261 each other at the end of the intake.

262 **Fig. 4** shows that the product discrimination into each period was driven by descriptors  
 263 specific to the period. Indeed, the five products showed a kinetic of the characteristics  
 264 that discriminate them from each other throughout the periods. From the Attack to the  
 265 Evolution period, SDC lost its association with *crunchy\_hard* and became associated  
 266 with *fat*. From the Evolution to the Finish period, SDC lost its association with *fat* and  
 267 became associated with *not\_bitter* and *gentle\_slight*. From the Attack to the Evolution

268 period, BRA became associated with *spicy*. From the Evolution to the Finish period,  
269 BRA lost its associations with *spicy*, *strong\_intense\_powerful*, and *bitter*. At the Finish  
270 period, no significant association was found between BRA and the descriptive words.  
271 From the Attack to the Evolution period, EQU lost its associations with *not\_sweet*. At  
272 the Evolution and Finish periods, no significant association was found between EQU  
273 and the descriptive words. From the Attack to the Evolution period, MAD lost its  
274 associations with *melting\_smooth\_creamy* and *soft*. At the Evolution and Finish  
275 periods, no significant association was found between MAD and the descriptive words.  
276 From the Attack period to the Evolution period, SAO became associated with *bitter*. At  
277 the Attack and Finish periods, no significant association was found between SAO and  
278 the descriptive words. The results concerning the Finish period shown by Fig. 4 tends  
279 to confirm that the subjects did not find large differences between the products at the  
280 Finish period except for SDC that was associated with four words. Indeed, the *sweet*  
281 and *gentle\_slight* characteristics of SDC seem to increase over time as compared to  
282 the other products.

### 283 3.3. Period by word contingency tables

284 For the five products, the two axes of the CA performed on their respective period by  
285 word contingency table were highly significant. The largest of these p-values was  
286 0.0029. This shows that for each product, the three periods were discriminated from  
287 each other.

288 Fig. 5 shows results in line with the tests of dependence: all periods were discriminated  
289 from each other for all products. For each of them, the period configurations were  
290 similar: the first axis mostly opposed the Attack period to the Finish period while the  
291 second axis opposed the Evolution period to the Attack and Finish periods. Words  
292 related to the texture (e.g. *crunchy\_hard*) and words related to the end of perception  
293 (e.g. *long\_tasting*) seemed to be the most important drivers of the period configuration  
294 for all the products. However, these main drivers were associated with flavors and  
295 aromas descriptions that depended on the period for each product.

296 Fig. 6 confirms that the period discrimination was mainly due to the texture and the end  
297 of perception descriptions. Indeed, *crunchy\_hard* was associated with the Attack  
298 period for all the products, *melting\_smooth\_creamy* was associated with the Evolution

299 period for all the products except BRA, and *long\_tasting* was associated with the Finish  
300 period of all the products except SDC. This kinetic was common to all the products.

301 Fig. 6 suggests that all products showed a temporal kinetic since the periods had  
302 different characteristics relatively to each other. SDC showed a texture kinetic, being  
303 perceived more often *crunchy\_hard* and *dry\_pasty* at the Attack period and then *fat*  
304 and *melting\_smooth\_creamy* at the Evolution period. SDC was specifically more  
305 described as *not\_bitter* at the Finish period. BRA showed a multi-modal kinetic, being  
306 perceived more often *crunchy\_hard* and *powdery\_mealy\_granular* at the Attack period,  
307 then *woody\_roasted* at the Evolution period and finally *lumpy* and *long\_tasting* at the  
308 Finish period. EQU showed the strongest kinetic and a very interesting one. It was  
309 perceived more often *crunchy\_hard*, *insipid*, and *not\_sweet* at the Attack period, then  
310 *sweet* and *melting\_smooth\_creamy* at the Evolution period and finally, *bitter* and  
311 *long\_tasting* at the Finish period. MAD also presented an interesting kinetic. It was  
312 perceived more often *crunchy\_hard*, *insipid* and *soft* at the Evolution period, then *fat*  
313 and *melting\_smooth\_creamy* at the Evolution period and finally, *bitter*, *long\_tasting*  
314 and *spicy* at the Finish period. SAO only showed a slight kinetic, being perceived more  
315 often *crunchy\_hard* at the Attack period, then *melting\_smooth\_creamy* and *not\_sweet*  
316 at the Evolution period, and finally, *long\_tasting* at the Finish period.

## 317 4. Discussion

318 The temporal aspect of the FC-AEF task seems to have been understood by the  
319 subjects. Indeed, the words related to texture aspects (e.g. *crunchy\_hard*) were only  
320 mentioned in the Attack period, some sensations related to the end of the perception  
321 (e.g. *long\_tasting*) were only mentioned in the Finish period.

322 The empirical results of Fig. 1 show that on average only one word and half are kept  
323 as an analysed word by period for each evaluation (subject × product). This results in  
324 an average of 4.3 analysed words per evaluation (all periods aggregated), which is not  
325 a huge increase as compared to the three words per evaluation imposed in the AEF  
326 method. However, this might be depending on the product type. It is also interesting to  
327 note that for the three periods, about 10 % of the evaluations were associated with  
328 zero analysed words. This does not mean that subject did not report descriptors, but  
329 that the pre-treatment removes these descriptors. Indeed, some descriptions were

330 composed of only hedonic words (e.g. “good taste”), some others were composed of  
331 low cited words (e.g. “salty”) and the others were composed of uninformative words  
332 (e.g. “aromas”).

333 The results of the analyses of product by word contingency tables enabled to identify  
334 the periods of the product intake that enabled the products to be discriminated as well  
335 as the characteristics of each product leading to this discrimination. The first dimension  
336 remaining stable across all periods suggests that the main latent dimension of  
337 discrimination is independent of time for this set of products. This dimension was a  
338 gradient of strength of the chocolates and did not evolve across periods of the product  
339 intake.

340 The results of the CA applied on the period by word contingency tables presented a  
341 particular period configuration for all the products. The first axis systematically opposed  
342 the Attack period to the Finish period and the second axis systematically opposed the  
343 Evolution period to the Attack and Finish periods. It is mainly due to the texture and  
344 end of perception descriptions of the products. Indeed, it seems that almost all products  
345 were perceived *crunchy\_hard* at the beginning, *melting\_smooth\_creamy* during the  
346 consumption and *long\_tasting* at the end of the perception, at least for several subjects.  
347 This particular period configuration is likely to occur for all types of products that  
348 present an obvious kinetic of some sensations throughout the intake (e.g. textures).

349 Concerning the analyses of period by word contingency tables, the particular case of  
350 the product MAD is interesting: at the Attack period, two words with opposite meaning,  
351 namely *crunchy\_hard* and *soft*, significantly characterized the product. It could be  
352 explained by the fact that from a subject to another, the range of time of the Attack and  
353 Evolution periods were not the same. It could also be that this product was first  
354 *crunchy\_hard* and right after *soft*, leading some subjects to describe it as *soft* and  
355 others as *crunchy\_hard*. Another explanation would be that, depending on their  
356 references of black chocolate, some subjects perceived it *crunchy\_hard* and some  
357 others *soft*. A mixture of these phenomena is likely to be what had happened. Anyhow,  
358 investigating individual representations of the three AEF periods would be of great  
359 interest, especially the range of time considered for each AEF period.

360 If a temporal sensory method relying on a predefined list of descriptors had been used  
361 instead of FC-AEF to characterize this set of products, a limited number of descriptors

362 would have been used. As the product space was the same as in [Visalli et al. \(2020\)](#),  
363 the list would likely have also been the same, or at least very close. This list contains  
364 the following descriptors: *Dry, Floral, Sweet, Bitter, Fat, Melting, Sour, Astringent,*  
365 *Woody, Sticky, Cocoa, and Fruity*. Except for the descriptors *Floral* and *Sticky*, all the  
366 descriptors contained in this list were used by the subjects in their descriptions. This  
367 means that subjects were able to generate an appropriate list of words to be used for  
368 describing this set of products. However, it is interesting to note that *astringent* and  
369 *cocoa* were only sparsely employed relatively to when they are proposed in a list  
370 ([Visalli et al., 2020](#)). *Astringent* maybe not a well-known word by the consumers and  
371 *cocoa* might sounds too obvious for several subjects when they do not belong to a list.  
372 Compared to the pre-defined list, subjects also provided nine additional words that  
373 seem very important for the description of this set of products: *crunchy\_hard, insipid,*  
374 *strong\_intense\_powerful, soft, spicy, gentle\_slight, powdery\_mealy\_granular,*  
375 *long\_tasting* and *lumpy*. This additional information suggests that using a predefined  
376 list would have resulted in a loss of information. [It was expected that the descriptor](#)  
377 [“crunchy\\_hard” appeared in the descriptions since “Crunchy” was originally part of the](#)  
378 [list used in Visalli et al. \(2020\). However, several TDS studies exhibited a systematic](#)  
379 [selection of this descriptor at the beginning of the perception for every black chocolate,](#)  
380 [thus limiting the selection of other descriptors at this stage of the perception. For this](#)  
381 [reason, it was removed from the list of descriptors. Since AEF limits the description of](#)  
382 [the Attack period to a single descriptor, it was even more crucial not to include](#)  
383 [“Crunchy” in the list used in Visalli et al. \(2020\) to avoid obtaining trivial descriptions of](#)  
384 [the Attack period. However, because FC-AEF does not share this limit on the number](#)  
385 [of descriptors with AEF, it was able to highlight “crunchy\\_hard” as a key descriptive](#)  
386 [word of first chewing cycles that discriminated between products and periods, which is](#)  
387 [a nice addition compared to AEF.](#)

388 [The variability of the number of terms that can be selected within each period makes](#)  
389 [FC-AEF closer to TCATA than TDS or AEF, which both forces the subjects to select](#)  
390 [one descriptor at a given time or period. However, by being retrospective, FC-AEF, as](#)  
391 [well as AEF, are different from TDS and TCATA, which are concurrent time-dependent](#)  
392 [measures. As discussed in Visalli et al. \(2020\), AEF, and thus FC-AEF too, rely on](#)  
393 [short-term memory while it is hoped that in TDS and TCATA subjects react more](#)  
394 [instinctively.](#)

395 In this paper, two approaches to analyse the FC-AEF data have been proposed:  
396 product-wise and period-wise. In the product-wise approach, products are compared  
397 by period, while in the period-wise approach, periods are compared by product. These  
398 two approaches are complementary. For example, the product-wise approach informs  
399 that the product SDC was described sweeter than the other products in every period,  
400 while the period-wise approach informs that *sweet* was not used more often in a period  
401 than another for characterizing SDC. Depending on the problematic of the user, one of  
402 the approaches can be more appropriate than the other does. The product-wise  
403 approach is more appropriate if the study aims to investigate the differences between  
404 products at specific steps of the product perception. The period-wise approach is more  
405 appropriate if it is assumed that the temporality of the perception may be different  
406 among products.

407 FC-AEF has been designed for temporal sensory characterization purposes. It is a  
408 suitable method when one wants to avoid the issues induced by the use of a predefined  
409 list of descriptors and when the temporal precision provided by list-based methods like  
410 TDS or TCATA is not crucial. Using FC-AEF implies losing a part the temporal  
411 precision provided by list-based methods but as a counterpart provides several  
412 benefits: descriptions are spontaneous, rich and precise, the dumping effect and the  
413 risk of missing key information are discarded and no limitations on the number of  
414 descriptors used in the descriptions exists. Further, from a practical point of view, FC-  
415 AEF also provides some benefits: no pre-tests for establishing a list of descriptors are  
416 required and the task does not need to be explained to the consumers since it is  
417 spontaneous. FC-AEF can also be considered as a relevant alternative to static FC to  
418 raise awareness of the subjects on the temporal kinetic of their perception in every  
419 application where static FC is suitable. The benefit of FC-AEF over static FC is that it  
420 enables to highlight the kinetics of the perception if any. If no kinetics exists, then FC-  
421 AEF data can be seen as static FC data and treated as such, since it can be expected  
422 that splitting the descriptions into three temporal periods does not flaw the overall  
423 description of the products.

## 424 5. Conclusion

425 This paper introduced a new temporal sensory method called Free-Comment Attack-  
426 Evolution-Finish (FC-AEF). This method is a combination of the Free-Comment and

427 the Attack-Evolution-Finish methods in which for each of the so-called periods (Attack,  
 428 Evolution, and Finish), subjects are asked to provide a Free-Comment description  
 429 instead of selecting a descriptor in a predefined list. FC-AEF was used to collect  
 430 temporal sensory perceptions of dark chocolates with consumers at home. The data  
 431 collected were analysed product-wise and period-wise. The product-wise analysis  
 432 identified in each period the descriptors characterizing each product, while the period-  
 433 wise analysis identifies for each product the descriptors generating a temporal kinetic  
 434 of its perception. FC-AEF provides sensory analysts with a new tool for investigating  
 435 the temporal sensory perception of products by consumers with no need of establishing  
 436 a predefined list of descriptors, which enables shunting this tedious part and removing  
 437 all possible issues and biases due to the use of a predefined list.

438 **Appendix: English-French correspondence of the analysed**  
 439 **words**

<b>English</b>	<b>French</b>
astrigent	astrigent
bitter	amer
cocoa	cacao
crunchy_hard	croquant_dur
dry_pasty	sec_pâteux
fat	gras
fruity	fruité
gentle_slight	doux_léger
insipid	fade
long_tasting	long_en_bouche
lumpy	âpre
melting_smooth_creamy	fondant_onctueux_crémeux
not_bitter	pas_amer
not_sweet	pas_sucré
powdery_mealy_granular	poudreux_farineux_granuleux
soft	mou
sour	acide
spicy	épicé
strong_intense_powerful	fort_intense_puissant
sweet	sucré
woody_roasted	boisé_torréfié

440

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**Fig. 1:** FC-AEF data collection screen (translated from French)

What sensations did you perceive during the tasting (textures, flavours, aromas, etc.) in chronological order?

(Use your own words to answer)

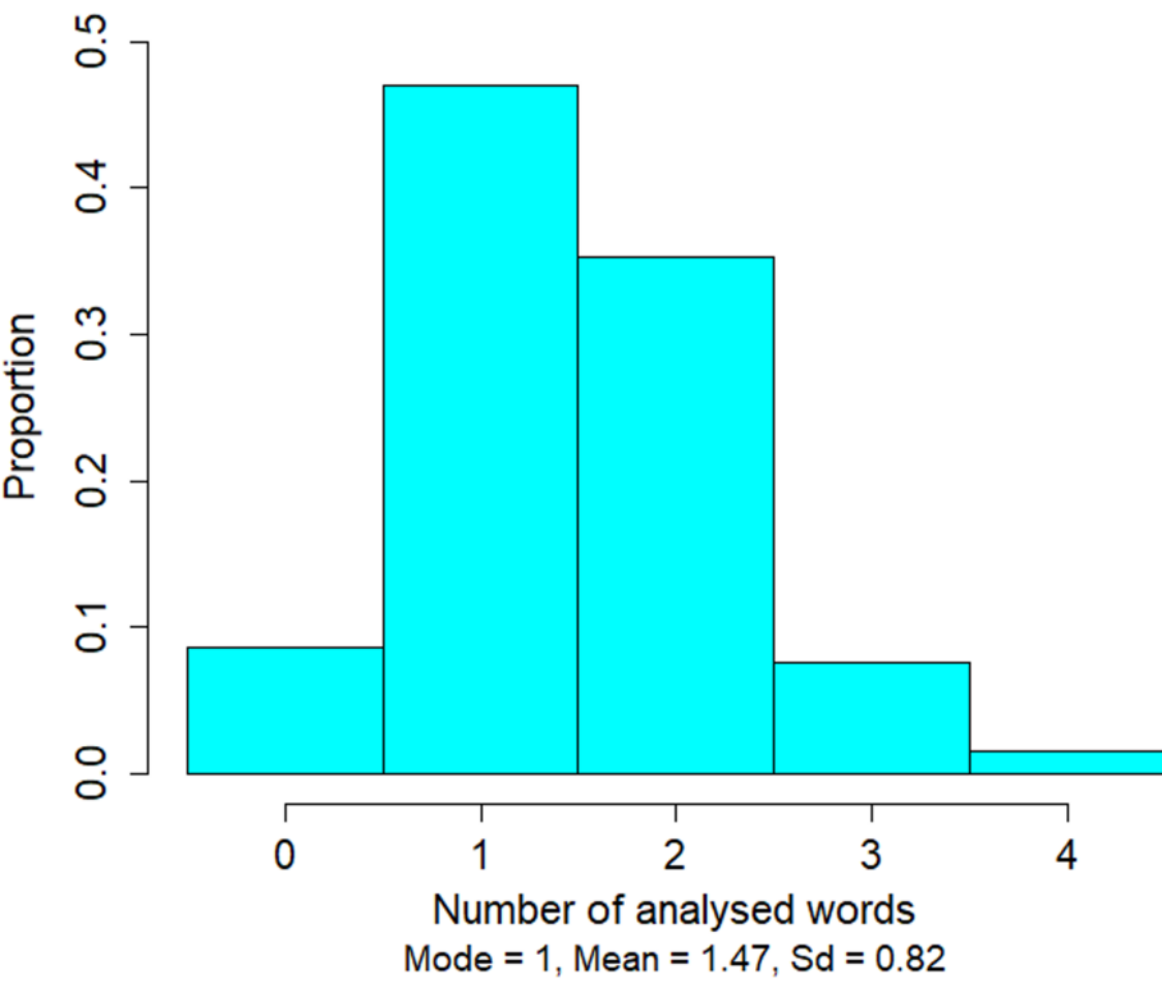
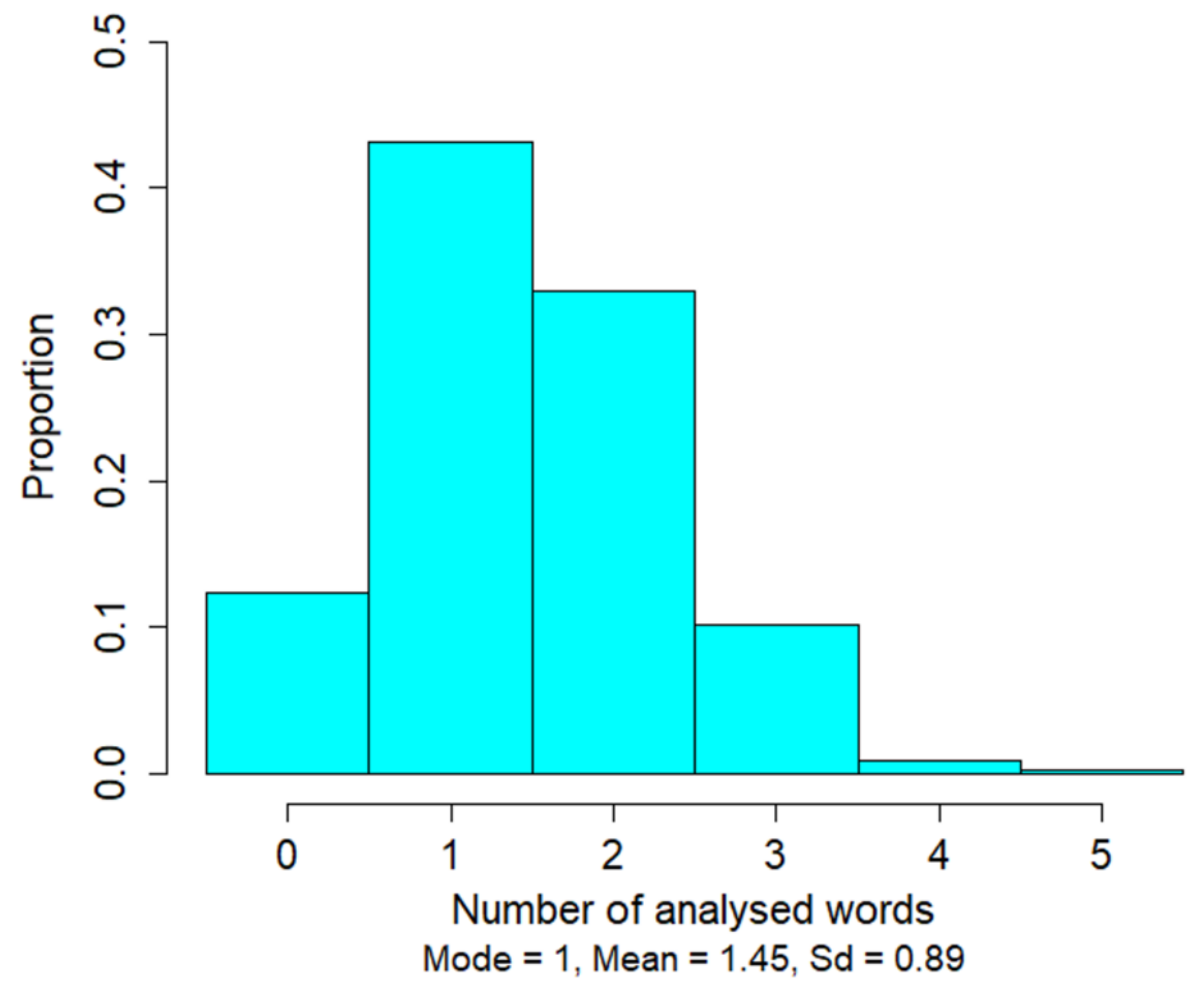
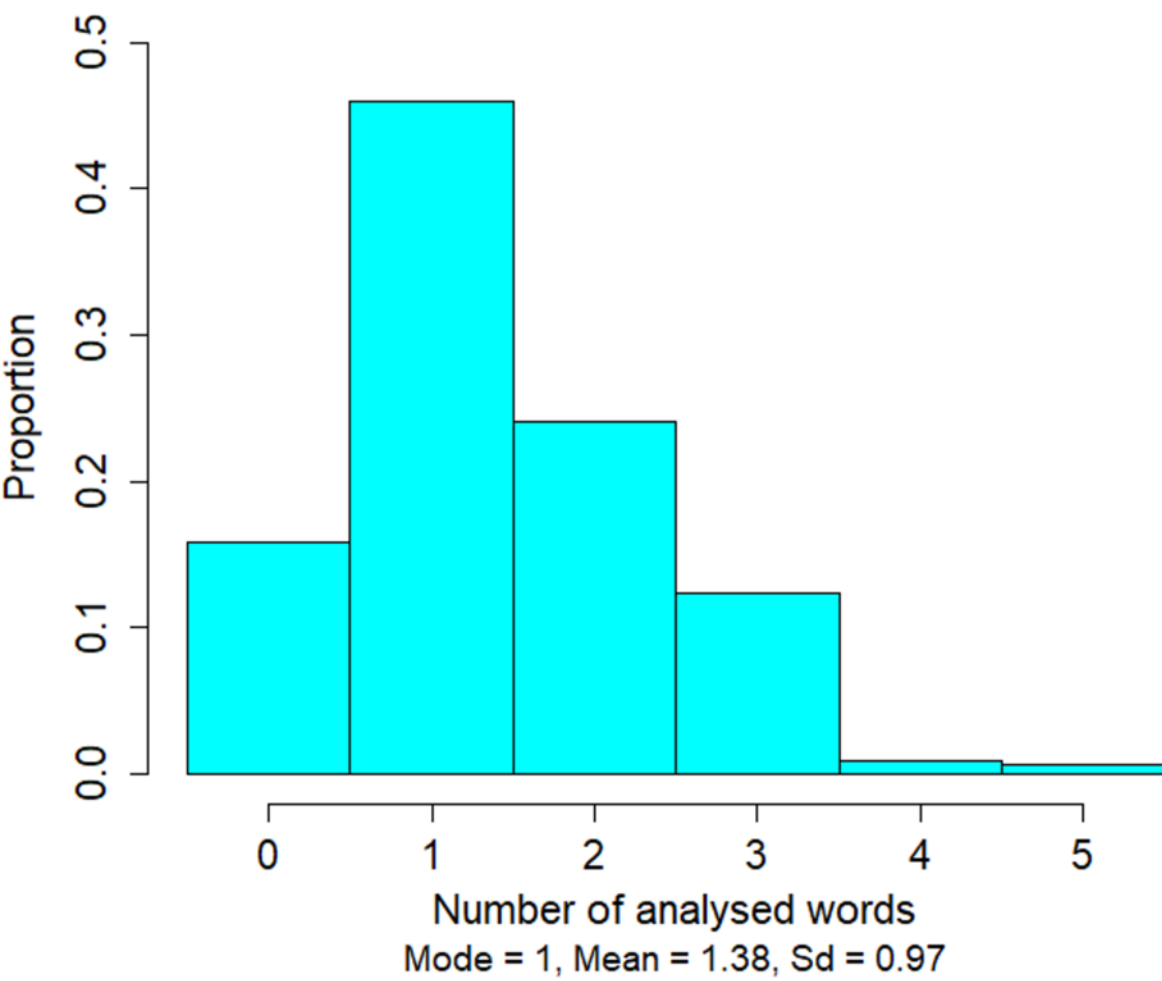
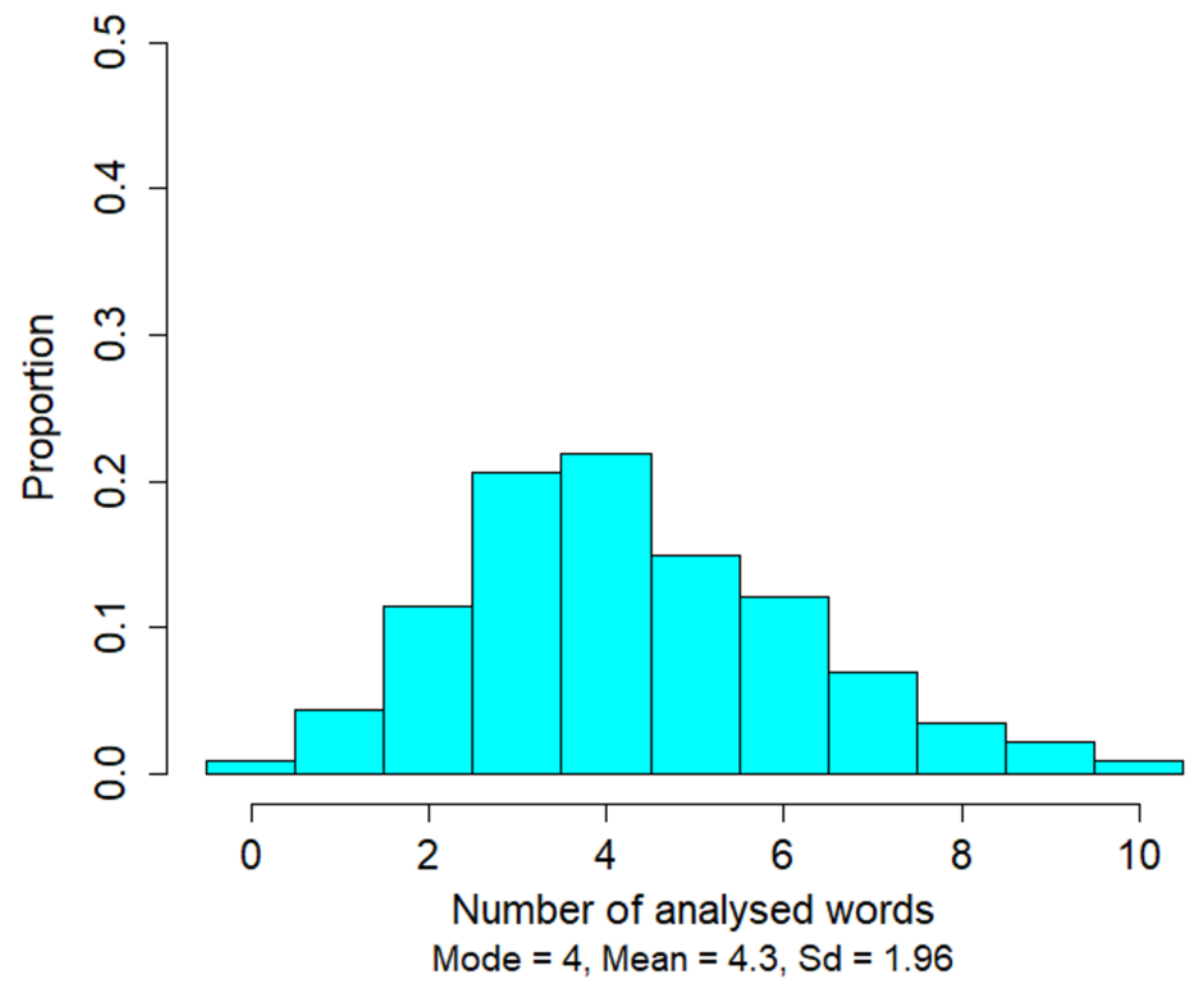
At first, I perceived this chocolate

then after a few moments I perceived it

and at the end of the tasting I perceived it

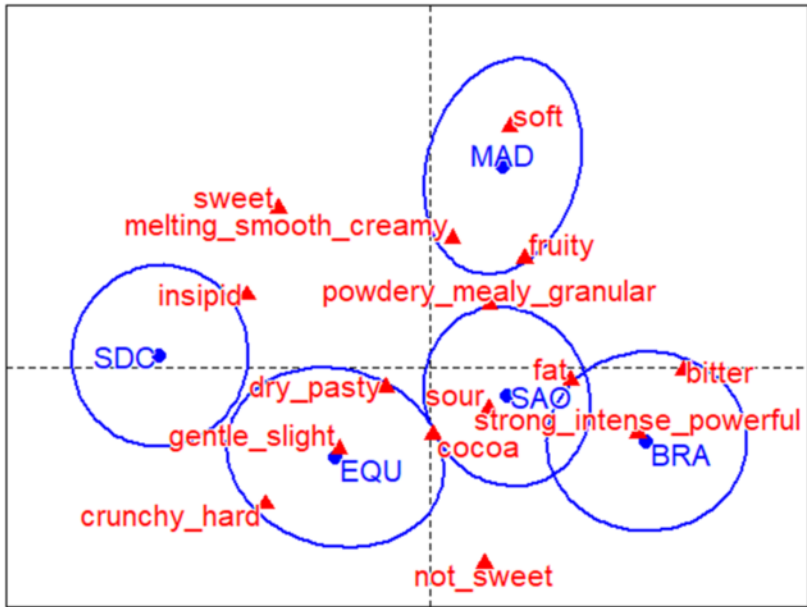
**NEXT**

**Fig. 2:** Distributions of the number of analysed words (after pre-treatments) cited by each subject for each product for: (a) the Attack period, (b) the Evolution period, (c) the Finish period and (d) the three periods aggregated.

**(a)****(b)****(c)****(d)**

**Fig. 3:** Correspondence analysis standard biplot of product by word contingency tables by period: (a) Attack axes 1-2, (b) Attack axes 3-2, (c) Evolution axes 1-2, (d) Evolution axes 3-2 and (e) Finish axes 1-2. Two products linked by a dashed line are not significantly different (total bootstrap test,  $\alpha = 5\%$ ).

Dim 2 (24.01 %)



Dim 1 (52.51 %)

(b)

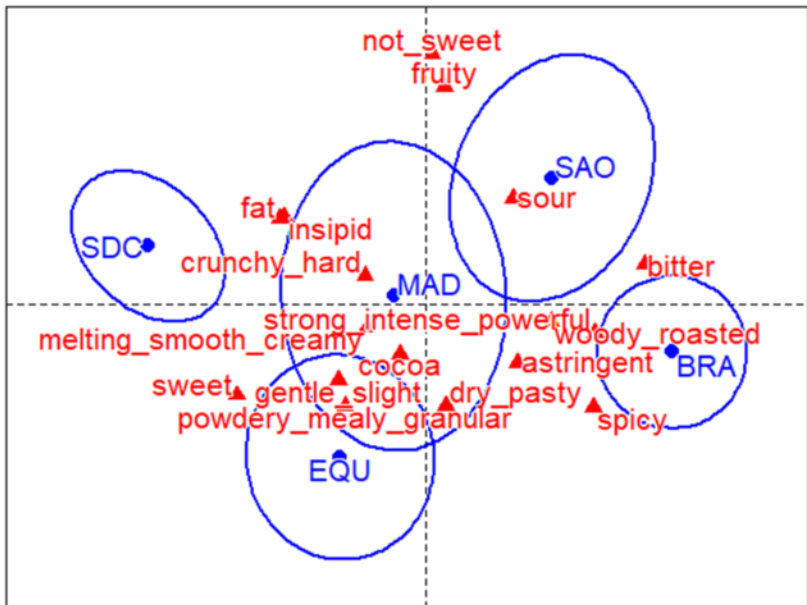
Dim 2 (24.01 %)



Dim 3 (18.34 %)

(c)

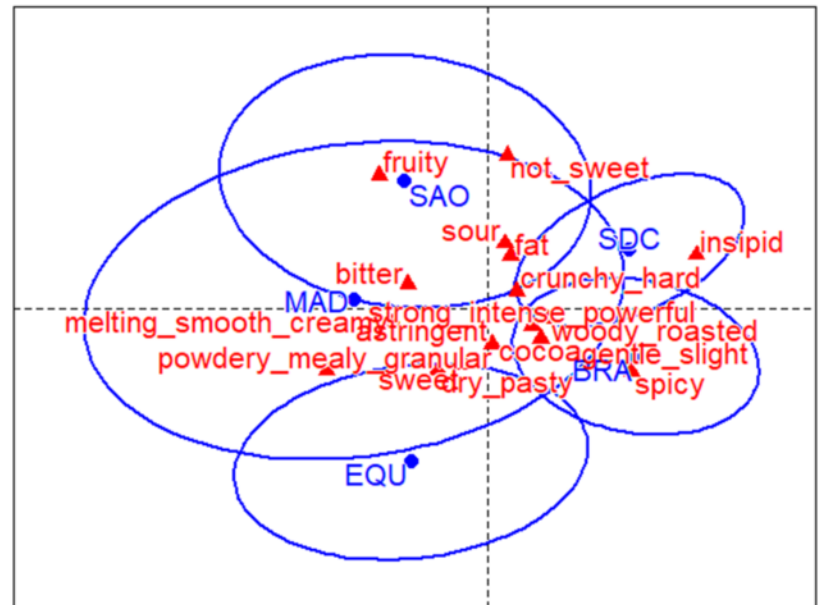
Dim 2 (19.5 %)



Dim 1 (58.8 %)

(d)

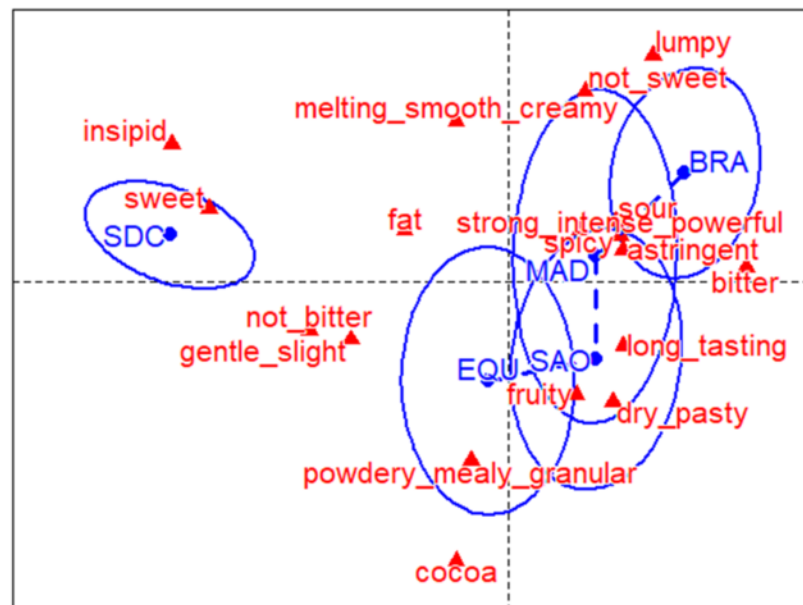
Dim 2 (19.5 %)



Dim 3 (16.72 %)

(e)

Dim 2 (19.26 %)



Dim 1 (69.5 %)



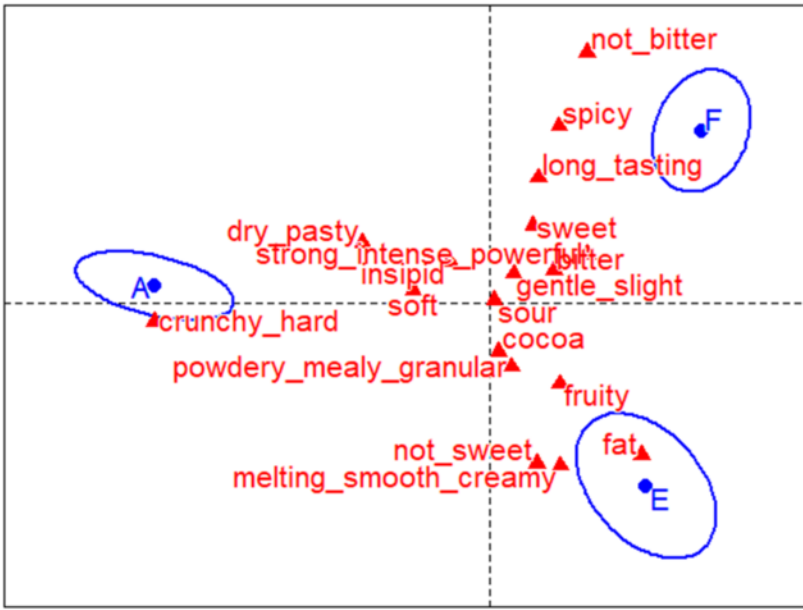
**Fig. 4:** Words by product percentages of citation across the panel for the period: (a) Attack, (b) Evolution and (c) Finish. Cells highlighted in green show the results of Fisher's exact tests ( $\alpha = 5\%$ ). Grey cells correspond to words cited in another period than the one considered.

	(a)					(b)					(c)				
	SDC	BRA	EQU	MAD	SAO	SDC	BRA	EQU	MAD	SAO	SDC	BRA	EQU	MAD	SAO
<b>astrigent</b>	0	0	0	0	0	0	4.8	1.6	3.2	1.6	0	3.2	1.6	6.3	3.2
<b>bitter</b>	4.8	28.6	7.9	17.5	25.4	7.9	38.1	20.6	27	38.1	9.5	38.1	30.2	39.7	31.7
<b>cocoa</b>	11.1	12.7	9.5	6.3	9.5	12.7	12.7	11.1	11.1	7.9	9.5	1.6	12.7	7.9	15.9
<b>crunchy_hard</b>	38.1	17.5	33.3	12.7	33.3	4.8	1.6	3.2	1.6	3.2	0	0	0	0	0
<b>dry_pasty</b>	14.3	11.1	12.7	9.5	11.1	3.2	6.3	7.9	6.3	4.8	4.8	11.1	12.7	11.1	15.9
<b>fat</b>	0	6.3	1.6	3.2	3.2	14.3	3.2	4.8	11.1	4.8	7.9	4.8	4.8	1.6	3.2
<b>fruity</b>	0	3.2	1.6	4.8	1.6	3.2	1.6	0	6.3	7.9	1.6	3.2	3.2	3.2	7.9
<b>gentle_slight</b>	22.2	15.9	25.4	12.7	15.9	22.2	15.9	19	12.7	11.1	23.8	7.9	19	17.5	12.7
<b>insipid</b>	17.5	4.8	11.1	9.5	1.6	11.1	3.2	1.6	1.6	1.6	12.7	0	1.6	1.6	0
<b>long_tasting</b>	0	0	0	0	0	0	0	0	0	0	1.6	7.9	6.3	4.8	9.5
<b>lumpy</b>	0	0	0	0	0	0	0	0	0	0	0	6.3	0	1.6	1.6
<b>melting_smooth_creamy</b>	7.9	9.5	15.9	19	9.5	19	14.3	20.6	25.4	17.5	9.5	7.9	3.2	6.3	4.8
<b>not_bitter</b>	0	0	0	0	0	0	0	0	0	0	6.3	0	3.2	0	1.6
<b>not_sweet</b>	1.6	7.9	6.3	0	0	6.3	3.2	0	3.2	9.5	1.6	4.8	0	4.8	1.6
<b>powdery_mealy_granular</b>	1.6	4.8	4.8	6.3	3.2	3.2	0	7.9	6.3	3.2	1.6	0	4.8	1.6	1.6
<b>soft</b>	1.6	3.2	0	7.9	1.6	0	0	0	0	0	0	0	0	0	0
<b>sour</b>	1.6	3.2	1.6	1.6	6.3	1.6	4.8	0	3.2	4.8	1.6	6.3	1.6	4.8	6.3
<b>spicy</b>	0	0	0	0	0	0	9.5	1.6	1.6	1.6	3.2	6.3	4.8	9.5	4.8
<b>strong_intense_powerful</b>	0	14.3	4.8	6.3	12.7	3.2	19	7.9	7.9	12.7	4.8	12.7	9.5	14.3	9.5
<b>sweet</b>	28.6	6.3	7.9	17.5	19	28.6	9.5	27	20.6	12.7	34.9	7.9	14.3	14.3	11.1
<b>woody_roasted</b>	0	0	0	0	0	0	4.8	1.6	0	3.2	0	0	0	0	0

**Fig. 5:** Correspondence analysis standard biplot of period by word contingency tables of the product: (a) SDC, (b) BRA, (c) EQU, (d) MAD, (e) SAO.

Dim 2 (24.05 %)

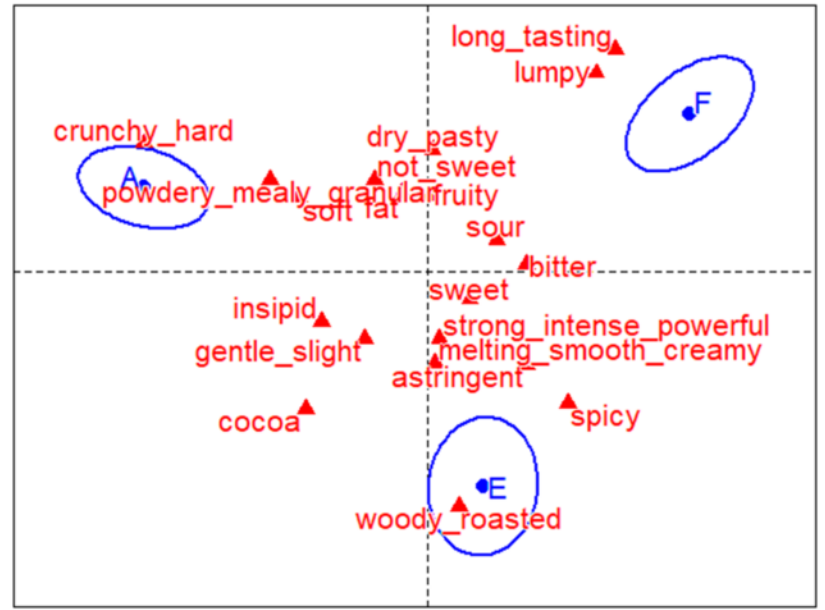
(a)



Dim 1 (75.95 %)

(b)

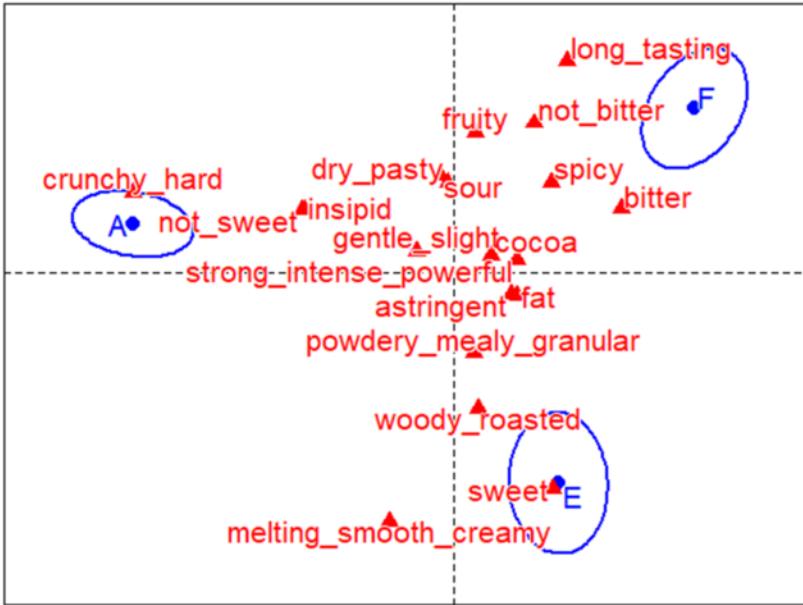
Dim 2 (33.69 %)



Dim 1 (66.31 %)

(c)

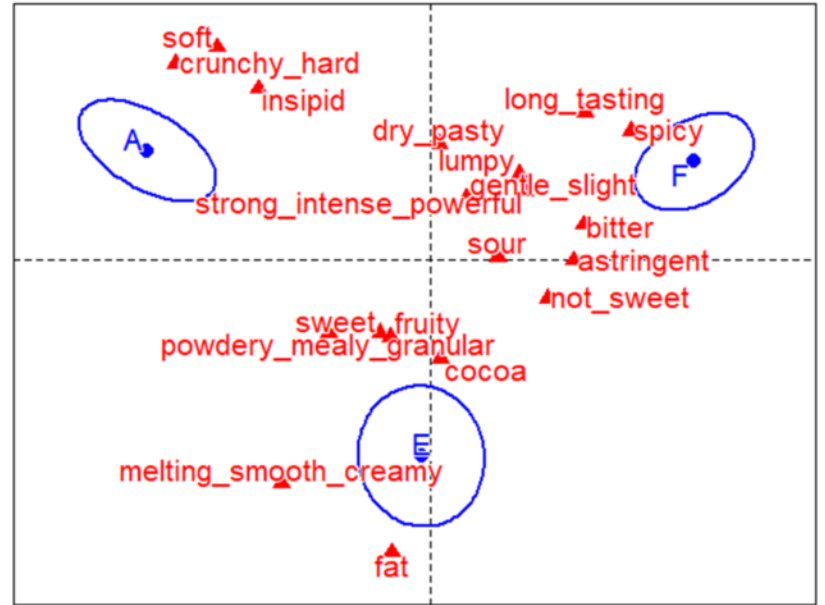
Dim 2 (26.77 %)



Dim 1 (73.23 %)

(d)

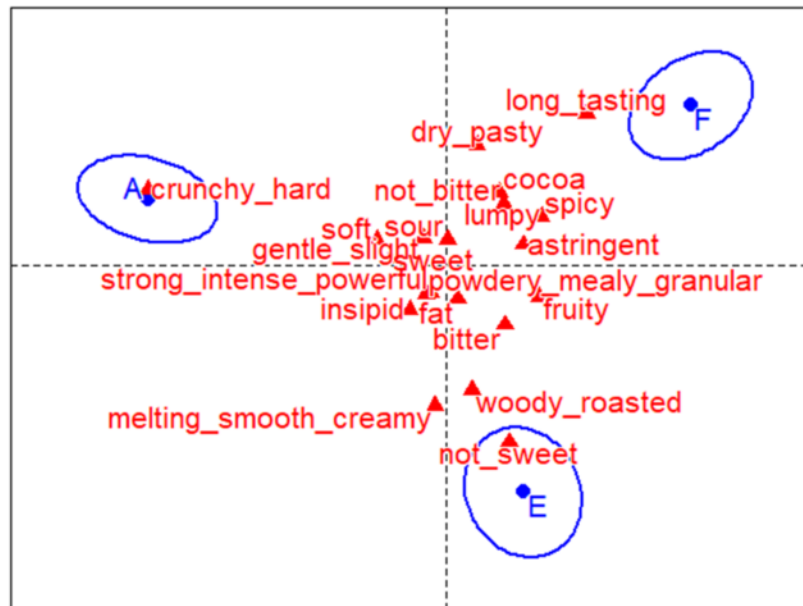
Dim 2 (27.86 %)



Dim 1 (72.14 %)

(e)

Dim 2 (37.56 %)



Dim 1 (62.44 %)

**Fig. 6:** Words by period percentages of citation across the panel for the product: (a) SDC, (b) BRA, (c) EQU, (d) MAD, (e) SAO. Cells highlighted in green show the results of Fisher's exact tests ( $\alpha = 5\%$ ). Grey cells correspond to words cited for another product than the one considered.

	(a)			(b)			(c)			(d)			(e)		
	A	E	F	A	E	F	A	E	F	A	E	F	A	E	F
<b>astringent</b>	0	0	0	0	4.8	3.2	0	1.6	1.6	0	3.2	6.3	0	1.6	3.2
<b>bitter</b>	4.8	7.9	9.5	29	38.7	38.7	7.9	20.6	30.2	17.5	27	39.7	25.4	38.1	31.7
<b>cocoa</b>	11.1	12.7	9.5	12.9	12.9	1.6	9.5	11.1	12.7	6.3	11.1	7.9	9.5	7.9	15.9
<b>crunchy_hard</b>	38.1	4.8	0	17.7	1.6	0	33.3	3.2	0	12.7	1.6	0	33.3	3.2	0
<b>dry_pasty</b>	14.3	3.2	4.8	11.3	6.5	11.3	12.7	7.9	12.7	9.5	6.3	11.1	11.1	4.8	15.9
<b>fat</b>	0	14.3	7.9	6.5	3.2	4.8	1.6	4.8	4.8	3.2	11.1	1.6	3.2	4.8	3.2
<b>fruity</b>	0	3.2	1.6	3.2	1.6	3.2	1.6	0	3.2	4.8	6.3	3.2	1.6	7.9	7.9
<b>gentle_slight</b>	22.2	22.2	23.8	16.1	16.1	8.1	25.4	19	19	12.7	12.7	17.5	15.9	11.1	12.7
<b>insipid</b>	17.5	11.1	12.7	4.8	3.2	0	11.1	1.6	1.6	9.5	1.6	1.6	1.6	1.6	0
<b>long_tasting</b>	0	0	1.6	0	0	8.1	0	0	6.3	0	0	4.8	0	0	9.5
<b>lumpy</b>	0	0	0	0	0	6.5	0	0	0	0	0	1.6	0	0	1.6
<b>melting_smooth_creamy</b>	7.9	19	9.5	9.7	14.5	8.1	15.9	20.6	3.2	19	25.4	6.3	9.5	17.5	4.8
<b>not_bitter</b>	0	0	6.3	0	0	0	0	0	3.2	0	0	0	0	0	1.6
<b>not_sweet</b>	1.6	6.3	1.6	8.1	3.2	4.8	6.3	0	0	0	3.2	4.8	0	9.5	1.6
<b>powdery_mealy_granular</b>	1.6	3.2	1.6	4.8	0	0	4.8	7.9	4.8	6.3	6.3	1.6	3.2	3.2	1.6
<b>soft</b>	1.6	0	0	3.2	0	0	0	0	0	7.9	0	0	1.6	0	0
<b>sour</b>	1.6	1.6	1.6	3.2	4.8	6.5	1.6	0	1.6	1.6	3.2	4.8	6.3	4.8	6.3
<b>spicy</b>	0	0	3.2	0	9.7	6.5	0	1.6	4.8	0	1.6	9.5	0	1.6	4.8
<b>strong_intense_powerful</b>	0	3.2	4.8	14.5	19.4	12.9	4.8	7.9	9.5	6.3	7.9	14.3	12.7	12.7	9.5
<b>sweet</b>	28.6	28.6	34.9	6.5	9.7	8.1	7.9	27	14.3	17.5	20.6	14.3	19	12.7	11.1
<b>woody_roasted</b>	0	0	0	0	4.8	0	0	1.6	0	0	0	0	0	3.2	0