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5 **What is dominance? An exploration of the concept in TDS tests with trained assessors**
6 **and consumers**

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20 **Abstract**

21 TDS describes the evolution of the dominant sensory attributes during consumption.
22 Dominance can be assessed as the sensation that captures the attention, the most striking, or
23 the new sensation that pops up, but not necessarily the most intense. This wide definition
24 implies that individual assessors within a panel might assess dominance differently, and even
25 the same assessor could be using different strategies for determining the dominant attribute the
26 same product evaluation. In this context, the aim of the present work was to explore how trained
27 assessors and consumers conceptualize dominance and how the different interpretations and
28 definitions of dominance might influence results of a TDS test. Two studies were performed, one
29 study with a highly trained panel of 10 assessors and another study with 108 consumers.
30 Trained assessors evaluated three bread samples via TDS and their conceptualization of
31 dominance was explored through an immediate retrospective verbalization task. Consumers
32 evaluated the temporal perception of a commercial milk chocolate sample and answered a
33 series of open-ended questions. Results showed that dominance is a complex construct that is
34 not related to a single aspect of sensory perception, and that different conceptualizations of
35 dominance within a panel can hinder an accurate interpretation of results from TDS studies.
36 Various aspects of dominance are highlighted and discussed: how attributes are selected, which
37 are the drivers of transitions between dominant attributes, how the competitive effects of
38 attributes and modalities are manifested, how some phenomena like dumping or dithering could
39 happen at some stages and why. Practitioners are advised to ensure that their interpretation of
40 TDS data is made within the context of the dominance definition they instructed assessors to
41 use. Implications of the results for the application of TDS with trained assessors and consumers
42 are discussed.

43

44 **Keywords:** *temporal methods; TDS; sensory characterization; dominance; retrospective*
45 *verbalization*

47 1. Introduction

48 Temporal Dominance of Sensations (TDS), which describes the evolution of the
49 dominant sensory attributes during consumption, has become one of the most popular temporal
50 methods in sensory and consumer science (Cadena et al., 2014; Di Monaco, Su, Masi, &
51 Cavella, 2014). TDS is a multi-attribute method in which assessors are presented with a list of
52 sensory attributes and are asked to select the attribute perceived as dominant at each moment
53 of the evaluation (Pineau et al., 2003; 2009). This method is based on the concept of
54 dominance, which makes it conceptually different from all other sensory methods, such as time-
55 intensity (Meyners, 2010).

56 Dominance does not have a unique definition. Instead, several different definitions for
57 this complex construct can be found in the literature (Pineau & Schlich, 2014). Labbe et al.
58 (2009) and Albert, Salvador, Schlich, & Fiszman (2012) only considered intensity in their
59 definition, conceptualizing the dominant attribute as "*the most intense sensation*". Other studies
60 refer to the ability of an attribute to catch assessors' attention. Lenfant et al. (2009) defined the
61 dominant sensation as the one that "*triggers the most the attention at a point in time*", whereas
62 Bruzzone, Ares & Giménez (2013) defined it as "*the sensation catching the attention of the*
63 *assessors at a given time, not necessarily being the one with the highest intensity*". References
64 to marked changes in the sensory characteristics of products at a given time have also been
65 included in the definition of dominance. Pineau et al. (2009) and Rodrigues et al. (2016) referred
66 to the dominant attribute as "*the new sensation popping up, not necessarily the most intense*".
67 The majority of the most recent studies have referred to the "ability of sensory attributes to catch
68 assessors' attention" for defining dominance (Cadena et al., 2014; Di Monaco et al., 2014). In
69 this sense, the ISO standard for establishing a sensory profile (ISO, 2016) recommends that the
70 dominance sensation in TDS should be "*defined to the assessors as the sensation that catches*
71 *his/her attention at a given time, which does not mean that this sensation has to be very or the*
72 *most intense in the product*". Similarly, Pineau & Schlich (2014) have recommended that

73 dominance refers to the sensations that catch assessors' attention at a given time, explaining to
74 assessors that dominant sensations are perceived suddenly but are not necessarily the most
75 intense sensations. However, it is still not clear how assessors understand dominance or what
76 determines the attentional capture of sensory attributes during a TDS task (Di Monaco et al.,
77 2014).

78 In summary, three main aspects of sensory perception have been cited in the definition
79 of dominance: attentional capture, sensory changes during consumption, and attribute intensity.
80 Although changes during consumption and attribute intensity are expected to modulate the
81 attentional capture of sensory attributes, no study has explicitly investigated the relationship
82 between these three concepts. Which of the three definitions of dominance is used has
83 important implications for the interpretation of TDS data, as each definition refers to a different
84 aspect of sensory perception. Therefore, it is necessary to study how assessors conceptualize
85 dominance in order to accurately describe results from TDS.

86 Furthermore, different assessors within a panel may use different criteria for selecting
87 the dominant sensation, and even the same assessor evaluating different products might
88 change how they determine which attribute is dominant. These differences can lead to over-
89 dispersion in the TDS data. Heterogeneity in the conceptualization of dominance can hinder the
90 ability of TDS to provide a detailed description of how the sensory characteristics of products
91 change over time, particularly for complex products and/or when multiple sensory modalities are
92 simultaneously evaluated (Ares et al., 2015). In this sense, evidence of heterogeneity in how
93 assessors select the dominant attribute can be found in several studies: in several instances
94 maximum dominance rates were lower than 0.40, whereas in other cases, several attributes
95 have been reported to simultaneously show low and non-significant dominance rates (Labbe et
96 al., 2009; Lenfant et al., 2009; Meillon, Urbano, & Schlich, 2009; Teillet, Schlich, Urbano,
97 Cordelle, & Guichard, 2010; Saint-Eve et al., 2011). This suggests that in many circumstances

98 assessors tend to select different sensations as dominant and that less than 40% of the
99 assessors agree on which is the dominant sensation throughout the evaluation.

100 TDS has been used with both consumers and trained assessors for sensory
101 characterization of a wide range of products (Di Monaco et al., 2014). The conceptualization of
102 dominance may be influenced by training and therefore differences in how consumers and
103 trained assessors select the terms that catch their attention at each moment of the evaluation.
104 According to Meyners (2010), assessors trained in classical descriptive methods might base
105 their conceptualization of dominance on attribute intensity. In this sense, Meillon et al. (2009)
106 suggested not to over-train the sensory panel in order not to encourage assessors to select
107 attributes in the same order for all samples. In addition, Rodrigues et al. (2016) recently
108 reported differences in the temporal sensory profiles obtained using TDS with consumers and
109 trained assessors.

110 In this context, the aim of the present work was to explore how trained assessors and
111 consumers conceptualize dominance. This information is expected to contribute to a more
112 accurate interpretation of results from TDS.

113

114

115 **2. Materials and Methods**

116 The empirical work comprised two studies, one conducted with trained assessors and
117 the other conducted with consumers. In both studies, assessors were asked to complete a TDS
118 task with samples belonging to different product categories. After the task, qualitative
119 explorations were undertaken to better understand the motives that underlie the selection of the
120 attribute that caught each assessor's attention at each moment of the evaluations. Details on
121 these studies follow in the next two sections.

122

123 **2.1. Study 1: Dominance exploration with trained assessors**

124

125 **2.1.1. Trained assessors**

126 Study 1 was run at Nofima (The Food Research Institute) in Ås, Norway. The tests were
127 performed in a sensory laboratory designed according to guidelines in ISO 8589 (2007) with
128 separate booths and electronic data collection using EyeQuestion Software (Logic8 BV,
129 Netherlands). The panel at Nofima consists of 10 external assessors, hired solely as trained
130 assessors, some of them with more than 20 years of experience. They were selected and
131 trained according to recommendations in ISO 8586-1:2012 (ISO, 2012) and are regularly
132 trained, tested and controlled for their performance. The sensory panel has six years of
133 experience of using the TDS method with a range of different food products including liquids,
134 solids, and semi-solids. **Following recent recommendations, training of the panel for TDS was
135 focused on the identification of the attributes to improve selection of the dominant sensations
136 rather than on the concept of dominance itself (ISO, 2016). In addition, training sessions to
137 familiarize the assessors with the data collection procedure were conducted.**

138

139 **2.1.2 Sample selection and preparation**

140 In a pre-test, QDA and Temporal Dominance of Sensations (TDS) were performed on
141 eight Norwegian commercial bread products. Based on these results, three white and whole-
142 grain bread samples, representing a good spread of static and dynamic sensory profiles, were
143 selected for subsequent evaluation, using the same-trained panel. All bread products were
144 purchased early in the morning, sliced in the shop/store, put into plastic bags, and stored at
145 room temperature. Immediately before each session, bread slices were cut into 35-mm diameter
146 circles, then placed immediately into a plastic container with a lid identified by a 3-digit blinding
147 code. The size of the bread circles was determined based on pre-test feedback, with the
148 objective of allowing assessors to put the entire piece in their mouths for evaluation.

149

150 **2.1.3. Temporal dominance of sensations**

151 Attributes were selected by the panel for the temporal evaluation in an open discussion
152 with the panel leader in a preliminary session, and were chosen to enable the characterization
153 of samples, which from the pre-test were known to have particular perceptual differences. The
154 following 9 attributes comprised the TDS attribute list: acid, sweet, salty, bitter, juicy, coarse,
155 chew resistance, doughy, soft. Samples were fully randomized over assessor, product, and
156 replicate. Assessors were instructed to put the entire bread sample (35-mm diameter circles)
157 into the mouth and evaluate the most dominant attribute at all times, as *the sensation that*
158 *caught attention at a given time, not necessarily the most intense*. They were presented with the
159 9 flavour and texture attributes (listed above) on the computer screen. They simultaneously put
160 the bread sample in their mouths and clicked the “Start” button. At each moment they were free
161 to choose any attribute as dominant without restrictions; i.e., any particular attribute could be
162 dominant for as long or as often as deemed necessary by the assessor. The evaluation ended
163 at the time the assessor was ready to swallow, which the assessor indicated by clicking the
164 “Stop” button. Attributes were randomized between assessors and replicates but the same
165 assessor received always the same order for all products within each replicate. Attributes were
166 displayed in a radial pattern on the screen (Figure 1). Samples were evaluated in triplicate in the
167 TDS test used for selecting samples for the dominance exploration task.

168

169 **2.1.4. Dominance exploration: retrospective verbalization**

170 The qualitative exploration of the assessor conceptualization of dominance was
171 performed through an immediate retrospective verbalization task (Ericsson & Simon, 1993),
172 which was recorded as audio on a tablet device, by each assessor, immediately after the tasting
173 (voice recording). Protocol analysis techniques, like think aloud, concurrent verbalization and
174 retrospective verbalization, have been used by psychologists for decades to understand the
175 thought process behind a task, and more recently these techniques have been used in

176 marketing and consumer science (Sudman et al., 1996; Darker & French, 2009; Jaeger et al.
177 2013). Recorded verbalization data is similar to measurements like eye fixations, or sequences
178 of moves, in the way that they are related to the internal cognitive processes and to the
179 information attended to (Ericsson & Simon, 1993; Guan et al., 2006). How well this information
180 is retrieved depends on the interval between the acquisition and the recall, so it is important for
181 the verbal data to be captured as soon as the processes finalises, so there will still be
182 information stored in the short-term memory. Retrospective verbalization tasks have been
183 shown to provide a reliable account of what people attend to, their inferences and strategies in
184 completing complex tasks, with a low risk of introducing fabrications (Guan et al., 2006). To aid
185 the recall of the specific cognitive processes, subjects can be asked to regenerate it by redoing
186 the task, and use this information to explain the general procedure they may have used. The
187 verbal probe, or question asked to the subject, can be directed to a specific moment of the
188 process (Ericsson & Simon, 1993). In this case, two sessions of qualitative exploration through
189 retrospective verbalization were run with the panel, with different objectives. The two sessions
190 were held two weeks apart:

- 191 - Session 1 focused on the selection of and transitions between dominant attributes
- 192 - Session 2 focused on the exploration of competitive perceptions at each time slice

193 Both sessions were run with the same procedure. Assessors evaluated the sample as they
194 would normally do in a TDS task, and immediately received again the same sample to
195 regenerate their cognitive process by redoing the task and explaining their assessment
196 (retrospective verbalization). For each of the three bread samples, the retrospective
197 verbalization procedure consisted of three steps:

- 198 1) Assessors evaluated the sample via TDS as described above, through only one
199 evaluation (no replicates). The panel leader immediately printed the time sequence of
200 their individual evaluation and handed it to each of the assessors (see example in Figure
201 2).

202 2) Assessors re-tasted the same sample (redoing the task) looking at their individual plot
203 and focusing on the probe question. The probe question in session 1 was “Please
204 explain how you selected the dominant attribute and why you changed to a new
205 attribute”. The probe question in session 2 was “Please describe the competitive
206 perceptions at each time slot (the attributes that are perceived at the same time but you
207 haven’t selected as dominant)”.

208 3) Assessors immediately explained the general procedure they used (retrospective
209 verbalization of the cognitive process) by recording it as audio in a tablet device (voice
210 recording).

211 They repeated this procedure for the three bread samples in a monadic sequence, following a
212 random balanced rotation. Panellists did the retrospective verbalization individually and alone in
213 a sensory booth.

214 Insert Figure 2 about here

215

216 **2.2. Study 2: Dominance exploration with consumers**

217

218 **2.2.1. Participants**

219 A total of 108 consumers from Montevideo (Uruguay) participated in Study 2. They were
220 recruited from the consumer database of the research group who authored the study based on
221 their milk chocolate consumption, as well as their interest and availability to participate.
222 Participants (65% female) were 18 to 63 years old. Participants gave written informed consent
223 and received a small gift for their participation.

224

225 **2.3. Experimental procedure**

226 Consumers were asked to evaluate a commercial milk chocolate sample. They were
227 asked to review the attributes prior to the evaluation to facilitate the task of locating attributes

228 during the TDS evaluation. They were instructed that they had to select, from a list of terms, the
229 sensation that caught attention at a given time, not necessarily being the most intense.
230 Consumers had to click a “Start” button concurrently with taking a bite of sample, and to
231 immediately commence sample evaluation. The duration of the task was 60 s.

232 The list included 10 terms involving both flavour and texture attributes: bitter, brittle,
233 chocolate flavour, hard, melting, off-flavour, soft, sticks to teeth, sweet, vanilla. Terms were
234 selected based on results of previous consumer studies (Ares et al., 2017) and pilot work with a
235 small group of consumers to check understanding of the terms. To avoid list order bias, the
236 order of the attributes was balanced between assessors following Williams' Latin square design.
237 No definition of the attributes was given to consumers.

238 After the evaluation of all samples was completed, consumers were asked to type their
239 responses to the following open-ended questions to explore their conceptualization of
240 dominance:

- 241 i) Why did the attributes you selected catch your attention during the test?
- 242 ii) Did you perceive any other sensations simultaneously with the sensation that
243 caught your attention? If yes, why did you not select them?
- 244 iii) What made you change your selection of attributes during the task?

245 Testing took place in standard sensory booths that were designed in accordance with
246 ISO 8589 (ISO, 2007), under artificial daylight and temperature control (22 °C). Data collection
247 was carried out using Compusense Cloud 7.8 (Compusense Inc., Guelph, Canada).

248

249 **2.3. Data analysis**

250

251 **2.3.1 TDS curves**

252 The TDS curves for the study conducted with the trained assessor panel were obtained
253 by plotting the dominance rate of each of the sensations at different points of the eating period,

254 for each sample, across the panel (Pineau et al., 2009). The data from each subject were
255 standardized according to individual mastication durations (Lenfant et al., 2009), with the first
256 and last timepoints corresponding to when the assessor clicked “Start” and “Stop”, respectively.

257

258 **2.3.2. Dominance exploration with the trained panel**

259 The trained panel described their sensations in Norwegian. Recordings were transcribed
260 and translated; two researchers checked the translations. Translated transcriptions of the
261 immediate retrospective verbalization task were then qualitatively analysed, independently, by
262 two researchers with previous experience in content analysis. Afterwards, the researchers met
263 to agree on the interpretation of the data and overall conclusions of the study. They followed
264 good practices of coding protocols, identifying and organizing utterance segments by type, and
265 relevant sentences and ideas were organized in topics for discussion. The objective of this part
266 of the study, however, was not to calculate percentages of citation of the different categories
267 because of the low number of subjects in a trained panel (n=10), but rather to qualitatively
268 discuss the main procedures used by the assessors when evaluating dominance in the TDS
269 task.

270

271 **2.3.3. Dominance exploration with consumers**

272 Consumer responses were analyzed using inductive coding (Krippendorff, 2004). This
273 process includes open coding, creating categories and abstraction. Responses were merged
274 into mutually exclusive by two researchers with previous experience in content analysis. After
275 the individual classification of each researcher, a meeting was held to select the final categories
276 by consensus. The percentage of consumers giving responses within each category was
277 determined.

278

279 **3. Results**

280 In the following sections, results are presented by type of assessor who completed the
281 task. It is beyond the scope of the paper to present or discuss the TDS curves for all the
282 products that were evaluated. These curves are only included to interpret the qualitative
283 information provided by the trained assessors. Interested readers may contact the authors for
284 further details.

285

286 **3.1. Dominance exploration with the trained panel: Retrospective verbalization task**

287 Figure 3 displays the dynamic profiles of the three selected samples to perform the
288 qualitative exploration of the concept of dominance with the trained panel. The objective of
289 having samples that were very different in sensory profiles was accomplished; the diversity in
290 flavour and texture was aimed in order to generate the richest possible information in the
291 qualitative step. The samples selected were a white bread (a), a half-coarse bread with seeds
292 (b) and an extra coarse bread (c).

293

294 Insert Fig 3 about here

295

296 Selected phrases of the feedback by individual assessors are used in this section to
297 exemplify the main outcomes of the qualitative exploration and to discuss various aspects of the
298 implications of dominance evaluation within a TDS test.

299

300 **3.1.1 Heterogeneity of the conceptualization**

301 Heterogeneity in the conceptualization of dominance was found. Most aspects of the
302 definition of dominance utilised in previous works were highlighted by the panel: attentional
303 capture, sensory changes, and attribute intensity were all mentioned, for all samples.

304 In line with the definition of dominance as the sensation that “triggers the most the
305 attention” (Lenfant et al., 2009; Bruzzone, Ares & Giménez, 2013), many comments by the

306 panel referred to the attentional capture of sensory attributes. Some sensations were more
307 attended to, while others remained in the background: *“The first thing that strikes me the most is*
308 *its softness, but it’s also very juicy and sweet”*; *“In the background I can also notice saltiness*
309 *and sweet and wheat flour taste, but the texture is what’s dominating”*; *“Coarse. The acidity*
310 *lurks in the background the whole time, as well as the chewing resistance”*.

311 The perception of the dominant attribute as “the new sensation popping up” (Pineau et
312 al., 2009; Rodrigues et al., 2016) was widely mentioned: *“Suddenly there’s a feeling that it*
313 *becomes very juicy”*; *“It then becomes juicy, but keeps its acidity”* (this assessor chose the
314 attribute Juicy as dominant); *“Eventually it becomes sweet and sourdough-ish while keeping its*
315 *tenacity”* (this assessor chose Sweet); *“there’s a saltiness that pops up”*.

316 Trained assessors also referred to the dominant attribute as “the most intense
317 sensation” (as in Labbe et al., 2009; Albert et al., 2012): *“Very soft. Doesn’t actually taste a lot”*;
318 *“it becomes very juicy”*; *“Relatively good chewing resistance with a very sweet taste”* (Sweet
319 was selected as dominant by this assessor); *“it had a lot of chewing resistance, but the*
320 *coarseness was stronger”*.

321

322 **3.1.2 Drivers of the transitions between attributes**

323 In general, qualitative data showed that most transitions between dominant attributes
324 were driven by “big”, noticeable perceptual changes due to new sensations popping-up,
325 sensations fading away, and events like biting through seeds, as exemplified by the following
326 comments: *“Immediately, there’s a lot of taste at once. Acidic with a lot of taste of grains”*;
327 *“Suddenly there’s a feeling that it becomes very juicy”*; *“Saltiness that pops-up and catches your*
328 *attention before ending up as pretty bitter”*; *“Nutty when you bite through the whole grains”*;
329 *“After you’ve chewed so much that the feeling of softness and acidic taste disappears, a salty*
330 *taste appears”*; *“Then it just disappears and there’re no feelings of texture left and the saltiness*
331 *becomes apparent”*; *“When this stops there’s an acidic and salty taste that appears”*.

332

333 3.1.3 The role of oral processing in the evaluation of dominance

334 From the analysis of the qualitative data, it became apparent that texture and flavour
335 might be competing in a TDS test as modalities rather than as specific, single attributes.
336 Examples described by the trained panel for the three samples are given below, with underlined
337 text (emphasis ours) highlighting the most important ideas:

338 *“It’s soft immediately when entering the mouth, but you chew past that fast and it*
339 *becomes sticky around the teeth, also with a doughy feeling. Then it just disappears and there*
340 *are no feelings of texture left and the saltiness becomes apparent... That lasts until you’re left*
341 *with only juiciness. It dissolves very fast”.*

342 *“Starts out with a lot of chewing resistance, but early on you start chewing at the grains*
343 *so the word ‘coarse’ springs to mind immediately as soon as you chew some of those hard bits.*
344 *As long as they’re there, that (coarseness) is what’s dominating. Then it’s the salty taste that*
345 *dominates when you’ve chewed past most of the coarseness. Then it’s basically the texture*
346 *taking over again, there’re no taste attributes apparent enough, except the saltiness, so it’s just*
347 *how it feels in the mouth left – that it’s doughy and then juicy at the end”.*

348 *“A very noticeable chewing resistance when you put it in your mouth, then there’s not a*
349 *lot happening before it goes from having chewing resistance to becoming sticky and doughy in*
350 *the mouth. The chewing resistance and the doughiness is what’s dominating above all taste*
351 *related attributes before eventually the bitterness come at the end”.*

352 This competition of sensory modalities can be described as “first texture, then flavour”,
353 and can be seen clearly in the TDS curves for all samples (Figure 3). This effect could be a
354 result of the type of sample or product category, as bread is naturally complex in texture and not
355 particularly intense in terms of flavour as a category. However, both samples b and c could be
356 considered “flavoursome” breads. This effect might on the other hand be arising from the natural

357 in mouth processing of a solid food, which has first to be broken down to being able to be
358 swallowed.

359

360 **3.1.4 Dithering and dumping effects**

361 Both dithering (characterized by uncertainty and indecisive behaviour) and dumping
362 effects (inflation of an attribute due to response restriction) (Lawless & Heymann, 2010) were
363 evident from the qualitative results for all samples throughout the test. The limitation to only one
364 dominant attribute could produce dithering, and the limitation of attribute availability might
365 produce dumping. In addition, in follow-up discussions with the trained assessors, they stated
366 experiencing frustration when there is only one attribute that can be chosen and when the one
367 they look for is not available, because of the impossibility to describe the actual perception.
368 Some examples below extracted from the qualitative exploration show the cognitive processes
369 they follow when they experience attribute restriction:

370 *“I’ve set it to salt, but at the same time it’s also really soft. Went over to become doughy,*
371 *but when I started to look for flavour attributes they were not available, like a taste of drawer,*
372 *claying and insipid. I just therefore put it as doughy the rest of the time.”* In this case, the
373 assessor did not find the flavour attributes she was looking for because the relevant attributes
374 were not available in the list. Thus, because of this dumping phenomenon and hesitation
375 (dithering) she opted to leave *doughy* selected as dominant until the end. Consequently,
376 *doughy* was indicated to be dominant for longer than it was actually the dominant attribute.

377 *“A bread with a lot of stuff going on at once. A bit hard to decide which attribute to put as*
378 *dominant. A lot of taste and texture. I think it’s mostly a taste of sourdough, but I can’t get that*
379 *across anywhere, but since it’s also pretty coarse, I’ve set that as dominant most of the time.”* In
380 this case, the assessor was overwhelmed by the complexity of the perception and could not
381 decide (dithered) before selecting the dominant attribute. This phenomenon was triggered by
382 the absence of some of the attributes she was looking for from the attribute list. Therefore, the

383 assessor chose an attribute she did perceive, although it was not necessarily the dominant one,
384 and did so for a long period of time.

385 *“Immediately very juicy and spongy, but there’s also a lot of taste at once, but it’s hard to*
386 *place in the circle. Can’t really find where to put it. I think it’s rye grains, but maybe a bit salty,*
387 *but the only taste I’ve set it to is bitter.”* In this case, the assessor dithered before selecting the
388 dominant attribute; although some attributes that were perceived (salty, bitter) were available,
389 and she decided to select bitter for the whole duration (dumping).

390 *“My experience with this method is that if you perceive a taste very strongly that’s not in*
391 *the list, you can only choose a taste (that is there) and it’ll seem present for longer than it*
392 *realistically is if there were more attributes to choose from.”* This last example summarizes part
393 of the phenomenon in one of the assessor’s own words.

394

395 **3.2. Dominance exploration with consumers**

396 *Figure 4 shows the TDS curve of the chocolate sample evaluated by consumers. As*
397 *shown, four attributes were significantly dominant throughout the evaluation: hard, brittle,*
398 *chocolate, flavour, sweet and sticks to teeth. Except for hard, the maximum dominance rates of*
399 *the attributes were close to 20%, which suggests heterogeneity in how consumers identified the*
400 *attribute that caught their attention was found.*

401 *Responses to the open-ended question provided additional evidence of the diversity of*
402 *factors underlying consumer conceptualization of dominance.* As shown in Table 1, when
403 consumers were asked about the motives underlying selection of the dominant attribute, they
404 referred to different aspects of sensory perception, most of which have been included in the
405 definition of dominance. Attribute intensity was the most frequent response: 34% of the
406 consumers indicated that the sensation that caught their attention was the most intense.
407 Consumers also referred to the sensation that caught their attention as the most striking
408 sensation or the sensation that best described what they felt while consuming the product.

409 Changes in sensory perception and attributes that “popped up” were also mentioned as relevant
410 motives for selecting an attribute as dominant, as exemplified in the following comment: “*I*
411 *selected the terms as the sensations I perceived while consuming the chocolate changed*”.

412 Furthermore, some consumers explained why sensations caught their attention based
413 on their expectations and hedonic reaction towards the product (Table 1). Some of the
414 consumers stated that sensations caught their attention because the sensations did not fit their
415 expectations based on their previous experiences with the product category, as shown in the
416 following statements: “*It caught my attention because of the comparison with other chocolates*
417 *I’ve tried before*” and “*Because I felt different sensations compared to what I usually perceive*
418 *when eating chocolate*”. Other consumers indicated that they had selected the attributes they
419 liked or disliked about the product: “*Because I did not like its hardness*” and “*Because I liked*
420 *how it melted in my mouth*”.

421 When consumers were asked if they perceived other sensations simultaneously with the
422 one that caught their attention, 72% gave an affirmative answer. The main reason for not
423 selecting the sensations that were simultaneously perceived was that the non-dominant attribute
424 had a lower intensity compared to the sensation that caught their attention (Table 1). However,
425 some of the consumers (21%) indicated that they did not select these secondary attributes
426 because the test only allowed them to select one characteristic at a time and therefore they had
427 to choose only one of those characteristics as the attribute that caught their attention: “*I did not*
428 *select them because I could only select one term at each time*”. Other consumers just indicated
429 that they did not select other sensations because they did not catch their attention, because
430 they did not suddenly appear, or because they did not describe why they liked or disliked the
431 product (Table 1).

432 Finally, consumers were asked to explain why they changed their selection of dominant
433 attributes during the TDS task. As shown in Table 1, the most frequent response was related to

434 changes in the characteristics of the product during mastication, as well as changes in attribute
435 intensity during consumption.

436

437 Insert Table 1 around here

438

439 **4. Discussion**

440 The concept of dominance of sensory attributes is a key differentiating feature of the
441 TDS method. Understanding the meaning of this complex concept is necessary for an accurate
442 interpretation of results from TDS. However, several different definitions can be found in the
443 literature (for a review, see Di Monaco et al., 2014). The definition of dominance has important
444 implications for how results are interpreted, and researchers must ensure that their analysis and
445 interpretation are made within the context of the dominance definition used.

446 Most recent studies have conceptualized the dominant attribute as the sensory
447 characteristic that catches assessors' attention at a given time (e.g. Ares et al., 2016; Pineau &
448 Schlich, 2014; Thomas, Visalli, Cordelle, & Schlich, 2015), in agreement with the ISO standard
449 (ISO, 2016). However, it is still not clear how assessors select the attributes that catch their
450 attention at a given time. In the present study, two qualitative studies were conducted to
451 understand how dominance is interpreted in practise and what determines the attentional
452 capture of sensory attributes for trained assessors and consumers.

453 Heterogeneity in how assessors selected the dominant attribute was found in both the
454 trained panel study and the consumer panel study in the present paper, suggesting that when
455 dominance is associated with attentional capture, this concept is not one thing but many
456 different things. When assessors were asked to explain why they selected the attribute that
457 caught their attention, most aspects of the definitions of dominance used in previous studies
458 were highlighted by both the trained assessors and consumers (Di Monaco et al., 2014).

459 Trained assessors mainly referred to the dominant attribute as the one that caught their
460 attention, highlighting that both attribute intensity and sudden changes in the sensory profile
461 were relevant aspects of dominance, as highlighted in the definition of dominance used by
462 several authors (Albert et al., 2012; Labbe et al., 2009; Pineau et al., 2009; Rodrigues et al.,
463 2016). In the specific case of consumers, results suggested that intensity was the main aspect
464 of sensory perception involved in the assessment of dominance, followed by changes during
465 consumption and comparison with expectations and previous consumption experiences.

466 Attribute transitions were mostly driven by “big” changes in perception, both for trained
467 assessors and for consumers. Assessors seem to change from one dominant attribute to
468 another when the perception of the selected attribute fades and/or when a new sensory
469 characteristic pops up. In the specific case of trained assessors, selection of the dominant
470 attribute during the evaluation of bread samples seemed to be determined by oral processing:
471 assessors tended to choose texture attributes first, followed by taste attributes. Miller & Teates
472 (1986) postulated that in animals, somatosensory information from oral movements and sensory
473 perception information provided feedback linked to metabolic events, and used to recall how
474 much of a food must be eaten to achieve satiety, as linked to the chewing process. The link of
475 palatability and appetite provides an adaptive, evolutionary advantage (Hyde and Witherly,
476 1993), so it is not surprising that oral processing and temporal sensory perception would be
477 related intimately. Recent studies on oral processing of solid foods (Witt & Stokkes, 2015)
478 discuss the underlying physics of getting a food into a bolus, including how the temporal aspects
479 of the dominant physical processes relate to the dominant textural properties. They propose a
480 model determined by the food–saliva system, describing the two processes of decreasing food
481 particle size and increasing salivary content until getting a swallowable bolus. From a food
482 physics perspective, there will be three dominating stages: fracture mechanics, particle-saliva-
483 oral interface mechanics, and bolus rheology. These stages will be intertwined with textural
484 perception of hardness/crunchiness in the first stage, dryness/roughness in the second stage,

485 and stickiness/cohesiveness in the third stage. In the present study, there is no fracture involved
486 in this bread category, but the evolution of the other textural attributes goes very much in line
487 with that model. Witt & Stokkes did not include flavour in their model for development of a
488 swallowable bolus, but it makes sense that during the oral processing stage driven by the
489 particle-saliva-oral interface will be when the flavour perception becomes more important. Along
490 the same lines, Devezeaux de Lavergne et al (2015) found for semi-solid gels a similar
491 succession of appearance of dominant sensations in time for all samples, correlated to various
492 fracture properties of gels. They linked the succession of appearance of dominant sensations to
493 the influence of the QDA attribute order assessment and did not suggest oral processing
494 implications, but the succession of appearance of dominant sensations described in this study
495 could have resulted from the oral processing stages. Indeed, it could be interesting for future
496 studies to look at the effects of oral processing steps in TDS evaluation across different product
497 categories.

498 Hedonics and previous experience with the product category seemed to be relevant in
499 consumers' conceptualization of dominance. According to consumer responses to the open-
500 ended question, many times the dominant attribute was a sensation that did not fit their
501 expectations, was surprising, or was liked or disliked. This suggests that selection of the
502 dominant attribute for consumers may also be related to their hedonic reaction to the products,
503 which can lead to heterogeneity in their responses. In this sense, Ares et al. (2017) has recently
504 reported that maximum dominance rates tend to be lower for those samples in which
505 heterogeneity in consumer hedonic responses are found.

506 Heterogeneity in assessor conceptualization of dominance may lead to high dispersion
507 of TDS data, low dominance rates, and consequently few significantly dominant attributes and
508 lack of ability to identify significant differences among samples. Evidence of heterogeneity in
509 assessor conceptualization of dominance has been observed in several studies in which TDS
510 curves show several attributes with similar dominance rates, several of which do not reach

511 dominance (Labbe et al., 2009; Lenfant et al., 2009; Meillon et al., 2009; Teillet et al. 2010;
512 Saint-Eve et al., 2011). This reinforces the argument of Ares et al. (2016) regarding the fact that,
513 at the aggregate level, TDS may miss relevant information about the dynamics of relevant
514 sensory characteristics during consumption. In addition, using a broad and complex definition of
515 dominance can make it difficult to interpret results from TDS tasks as it would be difficult to
516 determine if a sensory attribute is dominant due to its high intensity, due to changes in the
517 product during consumption, or perhaps because it is different from the product that assessors
518 consume regularly.

519 Results from the present work showed that dumping and dithering biases are
520 widespread in TDS tests conducted with both trained assessors and consumers. These biases
521 are common in sensory profiling (Lawless & Heymann, 2010). In static descriptive analysis, they
522 can be avoided with a good selection of attributes (no restriction of relevant ones) and a good
523 training. Dumping has been described before in time-intensity tests by Bonnans & Noble (1993)
524 and in multiple-time intensity tests (Clark & Lawless, 1994) due to the restriction in the number
525 of attributes available during each evaluation. Dithering and dumping seem to be interrelated in
526 TDS tasks due to the limitation of attributes in the list, the need to select only one dominant
527 attribute at a time (which does not happen in multiple time intensity or descriptive analysis), and
528 the time pressure to which assessors are subjected. Thus, it seems that these effects would
529 play a more important role in TDS as compared to other descriptive methods. Therefore,
530 although the noise caused by these two biases is expected to decrease with an increase in the
531 number of evaluations, it should be taken into account that they still can lead to a relevant loss
532 of information regarding the dynamics of the sensory characteristics of samples, particularly
533 during the evaluation of complex products in which several sensory attributes are
534 simultaneously perceived. Therefore, if practitioners aim at obtaining a detailed description of
535 how the sensory properties of products change during consumption, TDS might not be the best
536 methodological choice, as highlighted previously by Ares et al. (2015).

537 In addition, it is important to highlight that dithering and dumping might increase if
538 assessors are asked to evaluate taste and texture in the same TDS task because fewer terms
539 are available per modality. This raises concerns about simultaneous evaluation of different
540 modalities in TDS tasks, as previously argued by Di Monaco et al. (2014). Therefore, if
541 information about the dynamics of different sensory modalities during consumption is of interest,
542 practitioners could consider conducting separate TDS evaluations for each modality, as
543 proposed by Agudelo, Varela, & Fiszman (2015) with trained assessors. This methodological
544 decision may have different implications when working with trained panels or consumers.
545 Trained panels use technical words, longer lists of attributes, and are better at isolating and
546 focusing on a particular sensory modality. Trying to cover two modalities while keeping a short
547 list may restrict word choice on both modalities. If the objective is to understand how flavours
548 and texture interact and how flavours are released during oral processing, a decision should be
549 made whether to collect data in a single TDS task, or do it in two separate tasks and try to tie
550 together their data *a posteriori*. However, if understanding consumer perception is the objective,
551 it could be very reasonable to ask consumers about their total experience covering flavour and
552 texture. In this case, the terms on the attribute list could be less technical and most often
553 included fewer but more general words. Consumers will also evaluate products in a more
554 natural way and therefore noticeability of or competition between particular textures and flavours
555 might be of interest. If the experimenter chooses to run the experiment twice (flavour and
556 texture separate) it has to be pointed out that trying to combine TDS timelines from different
557 evaluations is not a straightforward procedure. In addition, it doubles the number of samples,
558 introducing fatigue to the tasters.

559 In closing this section, it is important to highlight that sensory analysis conducted with
560 trained assessors generally aims at obtaining objective sensory information, with as little
561 subjectivity as possible. However, TDS tasks with trained assessors involve a much stronger
562 aspect of subjectivity due to the wideness of the concept of dominance, unless this concept is

563 clearly defined as one unique concept they could agree on and measure accordingly. In this
564 sense, it is important to stress that TDS has been claimed to require almost no training and that
565 extensive training has not been recommended in TDS (Meillon et al., 2009; Pineau et al., 2009).
566 According to Schlich (2017), trained assessors may look for learned sequences of attributes
567 while evaluating the products. For this reason, training in TDS is mainly focused on the
568 identification of sensory attributes and the method itself (ISO, 2016). Results from the present
569 work suggest that the conceptualization of dominance as the attribute that catches assessors'
570 attention may give rise to large individual differences, as it is not feasible to train people in what
571 catches their attention. Therefore, in order to obtain an objective description of the dynamics of
572 the sensory characteristics of products, practitioners are advised to focus on a specific aspect of
573 dominance.

574 From this perspective, TDS may be more appropriate for consumers than for trained
575 assessors. The use of consumers for TDS tasks might be more natural than considering a small
576 group of trained assessors that in spite of receiving a particular definition of dominance do not
577 use the same criteria to evaluate dominance in practice. When working with consumers one can
578 obtain a more representative idea about what consumers emphasize as dominant and how this
579 affect their product perception. However, it should be taken into account that consumer
580 preferences may influence the conceptualization of dominance and increase the level of noise in
581 the data. For this reason, dominance rates are expected to be low when large heterogeneity in
582 consumer preference patterns exists, as recently reported by Ares et al. (2017). Thus,
583 practitioners are advised to not exclusively focus on aggregate TDS data but consider other
584 data analysis approaches based on individual data (Meyners, 2016).

585

586

587 **5. Conclusions**

588 Dominance is a complex construct that is not related to a single aspect of sensory
589 perception. Results from the present work show that defining the dominant attribute as the
590 characteristic that catches attention gives rise to a wide range of interpretations, which can
591 result in heterogeneity in the responses and, consequently, information loss in TDS curves. The
592 definition of dominance is then critical and knowing the underlying dimensions of the concept of
593 dominance is key for data interpretation.

594 Although assessors can be trained to identify sensory attributes and familiarised with
595 TDS, training them on the how to select the attribute that catches their attention seems not
596 feasible. **In the authors' opinion**, when working with trained assessors, contrary to recent
597 recommendations, it may be better not to define the dominant attribute as the attribute that
598 *“triggers the most the attention (catching the attention) at a point in time”*. Instead, it may be
599 more appropriate to clarify which aspect of sensory perception assessors should attend to for
600 selecting the dominant attribute: attribute intensity (e.g., “Select the most intense attribute at all
601 times”) or changes in the sensory profile of products (e.g., “Select any sensation that you
602 perceive to be undergoing big changes”). This type of definition may reduce individual
603 differences and provide a more accurate and objective description of the dynamics of the
604 sensory characteristics of products throughout consumption.

605 Results from the present work also raise concerns about the inclusion of terms related to
606 different modalities in TDS studies with trained assessors. Simultaneous evaluation of different
607 sensory modalities may cause dithering and dumping effects, leading to a relevant loss of
608 information about the dynamics of the sensory characteristics of products during consumption.
609 Further research should be conducted in order to make recommendations to practitioners
610 regarding how the inclusion of attributes related to sensory modalities influence results from
611 TDS tests.

612 When working with consumers, if the objective of the study is to describe the dynamics
613 of the sensory characteristics of products during consumption, the influence of preference

614 patterns on the attentional capture of attributes should be taken into account, as some
615 consumers tend to select the attributes they liked/disliked or those sensory characteristics that
616 do not fit with their expectations. In the authors' opinion, TDS with consumers may be more
617 appropriate to highlight the sensory characteristics that are relevant for consumers when
618 consuming a product. TDS seems to be a useful tool to understand how consumers perceive
619 products, even with the noise of the divergent conceptualizations of dominance. In this sense,
620 practitioners should be aware that sensory and hedonic expectations, as well as preference
621 patterns, influence dominance. For this reason, low dominance rates are expected when
622 heterogeneity in consumer preference exists and therefore, average TDS curves from
623 consumers may not accurately describe how the sensory characteristics of products evolve
624 during product consumption. Further research is still necessary to confirm that the dominant
625 attributes are in fact good predictors of consumer hedonic reaction to products.

626

627

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635

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730 **Figure captions**

731

732 **Figure 1.** Example of the radial attribute display for TDS with the trained panel, in the data
733 collection software (Eye Question). Attributes are in Norwegian as used by the panel. In the
734 example, the assessor has started the evaluation and has selected “*saftig*” (juicy) as dominant
735 sensation.

736

737 **Figure 2.** Example of the time sequence an individual TDS evaluation that was handed to each
738 assessor prior to the immediate retrospective verbalization task.

739

740 **Figure 3.** TDS dynamic profiles for three bread samples, which were used to perform the
741 qualitative exploration of the concept of dominance with the trained panel: a white bread (a), a
742 half-coarse bread with seeds (b), and an extra coarse bread (c). **Only the names of the**
743 **attributes that were significantly dominant are shown.**

744

745 **Figure 4.** TDS dynamic profile for the chocolate sample evaluated by consumers. **Only the**
746 **names of the attributes that were significantly dominant are shown.**

747

748 **Tables**

749

750 **Table 1.** Mention of the categories identified for each of the open-ended questions after the
751 TDS task in the consumer study.

752

Question	Categories	Consumers (%)
i) Why did the attributes you selected catch your attention during the test?	The most intense sensation	34
	The most striking sensation	20
	Sensations that “popped up”	19
	Sensations that did not fit previous expectations	15
	Liked/disliked sensations	11
	Common sensations in the product	1
ii) Did you perceive any other sensations simultaneously with the sensation that caught your attention? Why did you not select them?	No	28
	Yes...	
	but they were less intense	32
	but the test only allowed me to select one, so I had to choose	21
	but they did not catch attention	13
	but they lasted less than the one I selected	2
	but they did not suddenly appear	2
	but they were not relevant for describing liked/disliked aspects of the product	2
iii) What made you change your selection of attributes during the task?	Changes in the product during mastication	76
	Changes in attribute intensity	20
	Sudden changes	3
	The appearance of sensations I disliked	1

753

Figure 1

[Click here to download high resolution image](#)

Trykk på **START** i det du tar hele prøve **292** i munnen.
Velg så hvilken egenskap som **dominerer** til enhver tid.
Når produktet er klar til å svelges, trykk **STOPP** og spytt ut prøven.

The image shows a control panel with several buttons. At the top, there are two buttons: 'Tyggemotstand' (white) and 'Saftig' (blue). Below these are four buttons: 'Bitter' (white), 'Salt' (white), 'Syrlig' (white), and 'Grov' (white). In the center is a red button labeled 'Stopp'. Below that are three more buttons: 'Myk' (white), 'Søt' (white), and 'Deigete' (white). At the bottom left is a blue button labeled 'Neste'.

Assessor 1

Sample 325

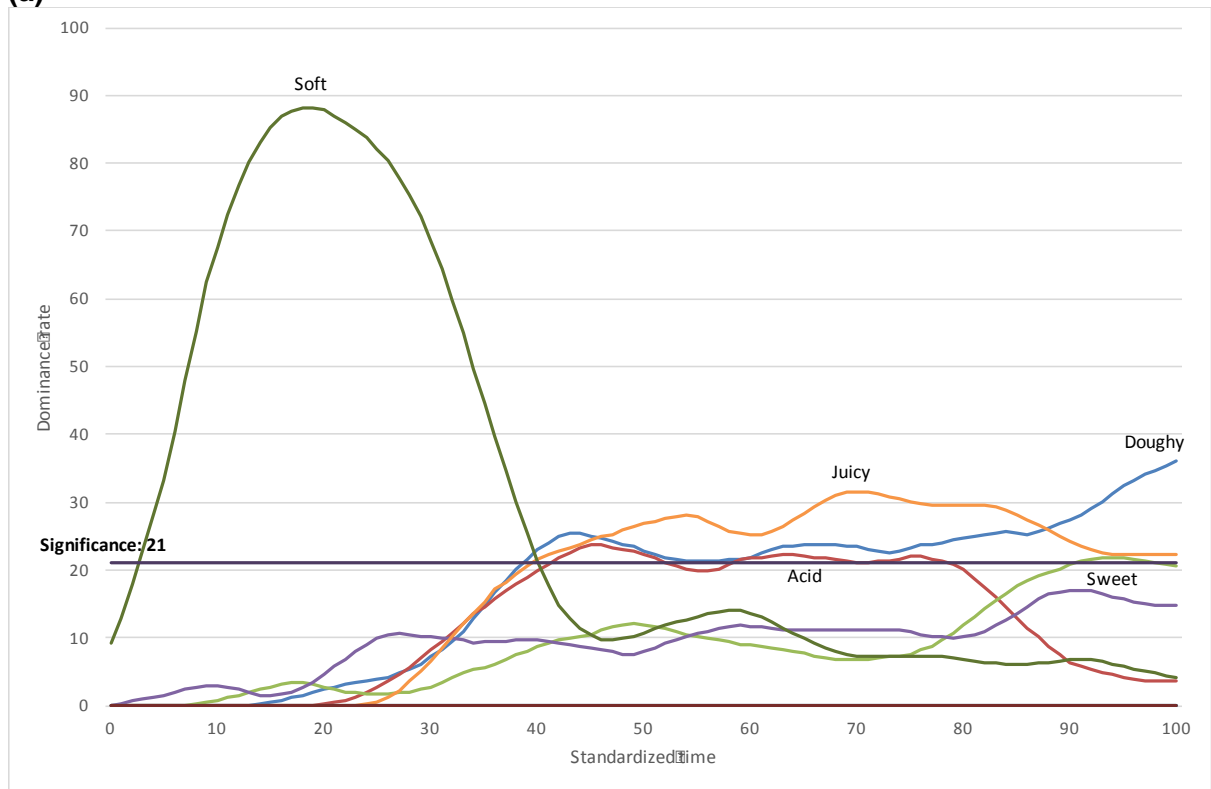
START

STOP

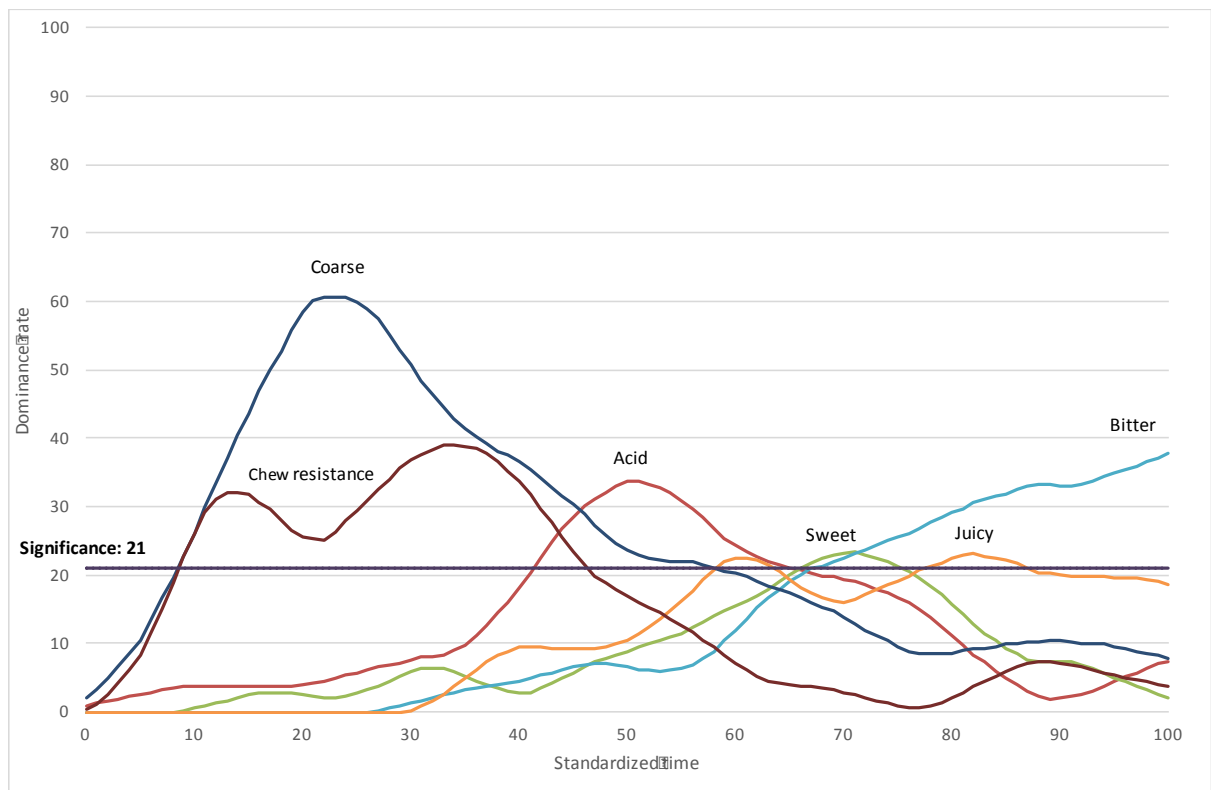


Figure 3

(a)



(b)



(c)

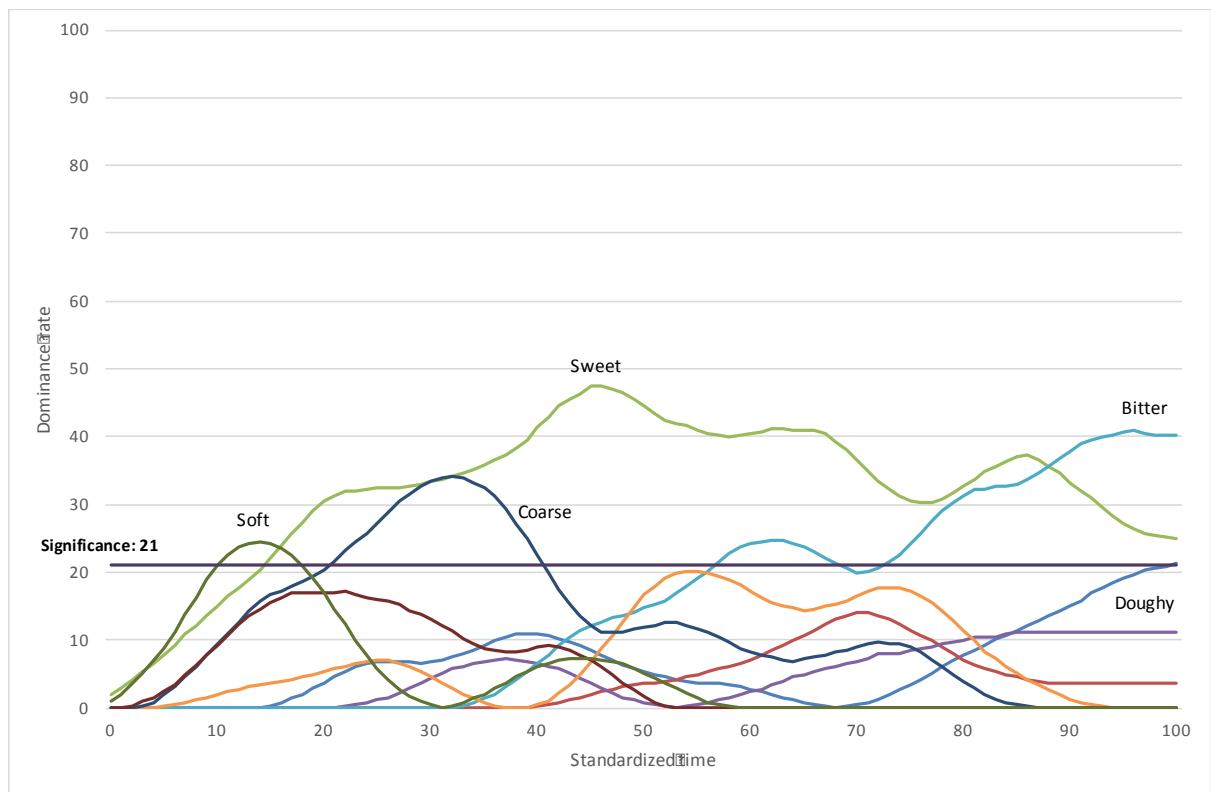


Figure 4

