**The role of the dynamic sensory perception in the reformulation of shakes. Use of
TDS for studying the effect of milk, fiber and flavor addition**

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17 **Abstract**

18 Various factors need to be taken into account when reformulating a food or beverage. The food
19 components, not only macronutrients but also minor ingredients such as flavoring agents, could
20 affect the perception of the sensory sensations, importantly their dynamic aspects, as rising and
21 duration, which are not normally considered. The novelty of the present approach is the study of
22 the effects of the addition of several ingredients (fiber, extra milk powder, and strawberry
23 flavoring) on the dynamic perception of a food item (strawberry shakes) using the Temporal
24 Dominance of Sensations (TDS) technique. The occurrence and duration of the key sensory
25 sensations (*Acid, Natural strawberry flavor, Thick, Sweet, Candy strawberry flavor, and Milk flavor*)
26 extracted from the TDS curves were analyzed and linked to the composition factors and liking and
27 expectations of satiety scores. For example, the addition of flavoring increased the liking scores
28 (increments ranging from 0.3 to 1.1) that was linked to the attenuation of *Acid* sensation; and the
29 addition of extra milk powder increased the expectation of satiety scores (increments ranging
30 from 0.5 to 0.7) that was linked to the perception of early *Thick* sensation in the mouth. In general,
31 the more complex sensory profiles the higher liking and expectations of satiety.

32

33 **Practical application**

34 The present work is a case study on how temporal sensory methods can contribute important
35 information on the actual perception of food during consumption. Depending on the ingredients
36 added these sensory properties appear at different times and with different dominance during
37 evaluation affecting liking or fullness expectations. In consequence, the temporal sensory
38 properties should be taken into account when designing or reformulating food.

39

40 **1. Introduction**

41 Reformulating existing foods might be one of the most effective ways to obtain healthier food
42 products. Food reformulation might be defined as reformulating existing foods to remove, reduce,
43 or add certain food components while maintaining sensory characteristics such as flavor and
44 texture. It is simple to say but difficult to achieve, since most of these modifications could (and
45 normally do) modify the sensory profile of the reformulated product, regarding both flavor and
46 texture sensations.

47 In general, one of the goals of researchers is to avoid any reduction in the acceptability of the
48 reformulated products (Ünal and Akalin 2013) compared to the regular item but (normally)
49 changes in dynamic perceptions, i.e. arising and duration of the different key sensory sensations
50 are not analyzed; these changes can modify the food perception as a whole. To date very little
51 research has been done on sensory interaction taking into account the temporal component
52 (Charles and others 2017). Conventional descriptive sensory techniques require judges to make
53 single-point evaluations; in many cases, this might imply some loss of vital information because
54 the process of food consumption is not static (Di Monaco and others 2014). Different temporal
55 methodologies have been developed over the last decades, such as Time Intensity and more
56 recently, Temporal Dominance of Sensations (TDS). TDS is a method that allows sensory
57 perceptions to be followed during consumption of a food or beverage. It involves selection and
58 continuous updating of the dominant sensation, and provides sequential data to characterize
59 products (Castura and Li 2016) in a dynamic way.

60 In the present study, strawberry milkshakes were reformulated by adding extra milk and fiber (a
61 combination of inulin and oligofructose); in addition, a strawberry flavor was used to study its
62 effect on the temporal sensory profile. TDS combined with acceptance tests can provide important
63 information regarding the sensations that are key for products' quality as reported by Castura and

64 Li (2016) for flavored fresh cheeses, and Bouteille and others (2013) on yoghurts. Bemfeito and
65 others (2016), who studied different Minas cheese established that TDS analysis can provide
66 important information on the peculiarities of each product.

67 A large body of research has shown that protein-enriched foods may enhance nutritional value
68 and filling sensations (Morell and Fiszman 2017; Chungchunlam and others 2017; Bowen and
69 others 2006). On the other hand, dietary fiber has outstanding health promotion functions;
70 important constituents of dietary fiber are oligosaccharides (prebiotic effect) and bioactive
71 compounds (antioxidant effect) which enhance its beneficial effects in the body (Macagnan and
72 others 2016; Viscione 2013); particularly fiber enrichment of beverages has attracted more
73 attention in recent years due to the appearance of new soluble fiber ingredients (Mudgil and Barak,
74 2016). Soluble fibers such as inulin and oligofructose are increasingly used in new food product
75 development. Both inulin and oligofructose are ingredients which offer a useful combination that
76 may significantly change the sensory characteristics (Franck 2002), and both have been shown to
77 be effective prebiotics (Kolida and others 2002). Soluble fibers have been used in dairy foods for
78 the development of functional products: Cruz and others (2013) added oligofructose into yogurt,
79 Balthazar and others (2017) studied the effects of inulin and oligosaccharides addition to sheep
80 milk ice cream, and Belsito and others (2017) evaluated the addition of galactooligosaccharides to
81 processed cheese. These soluble fibers are added as functional food ingredients that have
82 prebiotic effects but also have an important impact on the sweetness, texture and mouthfeel of
83 dairy products (Balthazar and others 2017).

84 A crucial challenge when developing beverages with enhanced nutritional value is the extent to
85 which the physical product can actually live up to the anticipated enhancement of fullness feelings
86 (van Kleef and others 2012). Reformulation should therefore pursue sensory characteristics, not
87 only so that the new products will appeal more to consumers but also so that they will elicit higher

88 expectations of satiety which may help people control their energy intake and weight. Food
89 contributes satiating power by a number of mediating processes that can be classified as sensory,
90 cognitive, postingestive, and postabsorptive. These processes that result from the effects of food
91 on physiological, and biochemical mechanism have collectively been referred to as the Satiety
92 Cascade. The Satiety Cascade shows that satiation and satiety are initially affected by sensory and
93 cognitive factors, including expectations about what is to be consumed, the taste, texture and
94 smell of the food or drink and any associations with previous experience that arise (Fizman and
95 Tarrega 2017). These beliefs are important in appetite regulation, since some pieces of evidence
96 have emerged which suggest that satiety expectations can influence the actual post-consumption
97 experience of satiety (Cassady and others 2012; Wilkinson and others 2012).

98 In the present study, the addition of a strawberry flavoring was also investigated. A number of
99 studies investigated how changes in flavor can modulate the perception of other sensory
100 sensations and liking; however, how these changes affect the elicitation of expectations of satiety
101 has scarcely been studied. Consequently, the aims of the present work were to study: (a) how
102 enrichment with soluble fibers and protein affects the dynamic perception profiles of a
103 strawberry-and-milk-based shake; and (b) how the addition of a strawberry flavoring agent further
104 affects these profiles. The relationship between the changes in the formulation and the dynamic
105 perception of sensations, consumer liking and the expectation of satiety of the product was
106 investigated.

107

108 2. Materials & Methods

109 2.1 Sample composition and preparation

110 Three batches of strawberry milkshake were prepared: a control formulation (sample CON), a
111 fiber-enriched formulation (sample FIB), and a protein-enriched formulation (sample PRO). Sample

112 CON was made of two parts of natural strawberry purée provided by Fruselva (Barcelona, Spain)
113 and one part of mineral water (Bezoya, Segovia Spain) (v/v), to which skimmed milk powder (6 g/
114 100 mL, La Asturiana, Spain) and a commercial intense artificial sweetener (0.2 g/100 mL sodium
115 cyclamate plus sodium saccharin, Hacendado, Spain) were added.

116 For sample FIB, 3 g of fiber were added per 100 mL of sample CON. The fiber was a 5:3 w/w
117 mixture of inulin and oligofructose (Frutafit CLR and Frutalose OFP, respectively; Sensus,
118 Roosendaal, The Netherlands). The proportion had been taking from a previous study (Cassani and
119 others 2017). For sample PRO, the skimmed milk powder was increased to 18 g/ 100mL to achieve
120 6 g of protein per 100 mL of milkshake.

121 All three strawberry milkshake batches (CON, FIB, and PRO) were divided into two parts and 0.5
122 mL/ 100 mL of artificial strawberry flavoring (10569A, Lucta, Barcelona, Spain) was added to one
123 part, giving samples CON+Flav, FIB+Flav, and PRO+Flav, respectively. The samples were all
124 prepared and kept under refrigeration on the day before testing.

125

126 2.2 Temporal Dominance of Sensations (TDS)

127 Sixteen participants (14 women and 2 men) who had previous experience in sensory descriptive
128 evaluation and TDS technique were recruited from the IATA staff.

129 Three preliminary sessions were conducted. In the first session, the participants had to list all the
130 in-mouth sensations they felt while tasting the six samples (CON, FIB, PRO, CON+Flav, FIB+Flav,
131 and PRO+Flav). The sensations obtained were related to flavor and texture. Sixteen terms were
132 generated. In the second session, the most relevant sensations for characterizing the samples and
133 the common vocabulary to describe them were reached by consensus among the participants
134 (Table 1). The six sensations selected were Sweet, Acid, Natural strawberry flavor, Candy
135 strawberry flavor, Milk flavor, and Thick. In the third session, the participants were introduced to

136 the concept of the dominance of a sensation at a given time during the consumption of a food
137 product. They were able to understand the sequential appearance of sensations and dominant
138 concepts, and performed simulated TDS runs with several strawberry milkshake samples in order
139 to get used to the computer program and methodology.

140 Subsequently, TDS evaluation of the samples was performed in duplicate on different days. The
141 participants were instructed to drink the sample (15 mL of milkshake served at 10 °C in a small
142 plastic cup) in a single sip and simultaneously start the software by clicking on the “Start” button.
143 Immediately, they selected which of the sensations displayed on the screen was dominant by
144 clicking on it. Each time the participants felt a change in perception and that a new sensation
145 appeared as the dominant one, they clicked the button corresponding to the new dominant
146 sensation. Participants were told they did not have to use all the sensations in the list and were
147 free to select any sensation several times. The evaluation continued until the participants had
148 swallowed the sample completely and perceived no new sensations, at which point they clicked
149 the “Stop” button. Each participant’s individual evaluation time for each sample was calculated as
150 the mean evaluation time for the two replicates. The two straight lines in the TDS graphs (Figure 1)
151 show the “chance level” (the dominance rate that an sensation could have by chance) and the
152 “significance level” (the minimum value for the dominance rate to be considered significant). Data
153 collection was performed using a computerized system: Fizz® (Biosystemes, Courtenon, France).

154

155 2.3 Assessments of liking and expected satiety

156 Liking and expected satiety were assessed by 99 consumers recruited from staff and students of
157 IATA (69 women and 30 men, aged between 19 and 57 years). The six strawberry milkshake were
158 coded with 3-digit numbers. After tasting 1 sip each sample, the consumers were asked to rate
159 their liking of the samples on a nine-point hedonic scale ranging from 1 (“dislike extremely”) to 9

160 (“like extremely”). Afterwards, they were asked to rate how satiating each milkshake was on a 7-
161 point scale ranging from 1 (“It would fill me very little”) to 7 (“It would fill me a lot”). They
162 performed this task after being asked the following question: “Imagine drinking a whole glass of
163 this milkshake. Please taste it. How full do you think it would make you feel?” (a 200-mL capacity
164 plastic glass was presented to the participants for size estimation purposes).

165 The evaluations were carried out in a standardized test room (ISO, 2007). The samples (20 nL)
166 were served in white small plastic cups (30 mL capacity) with random three-digit codes, and were
167 presented monadically following a balanced design. Mineral water was provided for the
168 consumers to rinse their mouths between samples. Data acquisition was carried out with
169 Compusense Five® software (Compusense Inc., Guelph, Ont., Canada)

170 All experiments were performed in compliance with the national legislation, and according to the
171 institutional frame-work and practices established by the CSIC Ethics Committee. All participants
172 received written information about the study before giving their informed consent.

173

174 2.4 Statistical analysis

175 To study the arousal and duration of each of the six sensations studied over the time of evaluation
176 across the participants TDS curves were constructed for each sample. For this analysis, the
177 dominant sensations chosen and the times when each of them began and finished were collected
178 for each participant run. As the duration of the TDS evaluation (until swallowing was complete and
179 no more sensations were perceived) was different from one participant to another, the data were
180 normalized by adjusting them according to each participant's consumption time (left-right
181 standardization). Finally, the TDS curves were computed according to the method described by
182 Pineau and others (2009).

183 To study the effect of the addition of flavoring and composition on the overall liking and expected
184 satiating capacity scores a mixed ANOVA was performed, taking into account the type of
185 formulation (CON, FIB and PRO), the addition (or not) of the flavoring (Flav), and their interaction,
186 as fixed factors, and the consumers as the random factor. Tukey's HSD tests were used to analyze
187 significant differences between the samples. XLStat version 2016 software (Addinsoft, France) was
188 used for all the analyses.

189

190 3. Results & Discussion

191 3.1 Temporal Dominance of Sensations

192 The mean values of the time of evaluation ranged from 20.7 to 21.7 s that were not significantly
193 different ($p < 0.05$) across samples. Figure 1 shows the TDS curves corresponding to the 6 milkshake
194 samples.

195 ***Insert Figure 1 around here***

196 Sample CON. Two major sensations dominated over the CON evaluation time. The TDS curve for
197 this sample shows that *Acid* was a significantly dominant sensation both at the beginning and
198 towards the end of the evaluation, and also exceeded the chance level throughout the evaluation
199 time. Santos Gonçalves and others (2017) also found *Acid* as the dominant sensation throughout
200 the TDS evaluation of strawberry pulp subjected to pasteurization and different freezing methods,
201 but in their case no sugar or intense sweetener were added to the samples. The other significant
202 sensation in the present sample was *Natural strawberry flavor*, which also dominated during
203 almost the entire evaluation time, alternating with *Acid*, especially over the first half of the time.
204 *Sweet*, *Thick*, and *Candy strawberry flavor* made a timid (but over the chance limit) appearance at
205 the beginning of the last third of the consumption time.

206 Fiber-enriched sample (FIB). In this sample, *Acid* and *Natural strawberry flavor* also dominated the
207 evaluation time, although at lower dominance rate values than in sample CON. It seemed that the
208 addition of soluble fiber had attenuated the perception of these two sensations. The dominance of
209 the *Natural strawberry flavor* in the second half of the evaluation time appeared more significantly
210 in this sample than in sample CON. The *Milk flavor* dominance rate was over the chance level
211 during almost all the evaluation time and *Thick* also presented values over the chance level,
212 especially during the first third of the evaluation time. Villegas and others (2010) reported that
213 different levels of inulin could vary the physicochemical and sensory properties of vanilla-flavored
214 beverages, mainly as regards sweetness and thickness. In the present case, it was obvious that the
215 addition of soluble fiber modified the perceptual profiles: *Milk flavor* increased its dominance rate,
216 exceeding the chance level, probably due to the perception of a more dominant *Thick* sensation.
217 From this point of view, inulin has been shown to improve texture sensations considerably
218 (creaminess, mouthfeel and smoothness) when used to replace fat in low-fat yogurts (Kip and
219 others 2006; Modzelewska-Kapitula and Klebukowska 2009). According to Alimi and others (2013),
220 inulin addition levels of around 5 g/ 100 g contribute a creamy texture and create a mouthfeel that
221 can be used to reinforce the mouthfeel lost as a consequence of sugar or fat reduction.

222 Protein-enriched sample (PRO). This sample presented a completely different temporal profile
223 from those described for samples CON and FIB. The *Milk flavor* sensation dominated significantly
224 throughout the whole evaluation period, while *Thick* dominated at the beginning and during the
225 central evaluation time, and presented dominance rate values that were over the chance level for
226 the entire period. The skimmed milk powder added for protein enrichment logically contributed to
227 enhancing the thickness and, of course, the *Milk flavor*, which dominated more than other flavor
228 notes such as *Acid* or *Natural strawberry flavor*. A *Sweet* sensation was the only sensation that
229 also presented dominance rate values exceeding the chance level (although not at the significance

230 level) over several periods during the evaluation. As in the case of soluble fiber addition (sample
231 FIB), the addition of milk powder to sample PRO changed its temporal flavor profile. At this point it
232 is important to remember that the TDS method is not a matter of intensity but of dominance of
233 the sensations.

234 Control with flavoring (sample CON+Flav). Adding the strawberry flavoring agent to the CON
235 sample formulation induced some changes in its sensory profile. *Natural strawberry flavor* was no
236 longer significantly dominant at any instant of the evaluation time, although its dominance rate
237 value exceeded the chance level, as did *Candy strawberry flavor*. This implies that consumers
238 selected one strawberry flavor or the other interchangeably. With respect to *Acid*, this sensation
239 continued to be dominant, to a lesser extent, at the beginning of the evaluation time, but had a
240 higher dominance rate at the end of the evaluation than in sample CON. Therefore, the addition of
241 the flavoring had an important impact throughout the consumption period, allowing a lower
242 dominance of the perception of acid notes at the beginning of the evaluation, and the occurrence
243 of *Candy strawberry flavor* dominance over *Natural strawberry flavor*, resulting in a more complex
244 profile. The occurrence of *Sweet*, *Milk flavor* and *Thick* sensation dominance did not change due to
245 the addition of flavoring. Working with binary basic taste mixtures, Kawasaki and others (2015)
246 found that the dominance rate and duration time of one basic taste modality are significantly
247 affected by a coexisting taste modality, and its details depend on the combination of modalities.
248 This may suggest sensory competition between two taste modalities based on several factors that
249 occur during taste mixture consumption.

250 Fiber-enriched sample with flavoring (FIB+Flav). The addition of flavoring to the FIB sample again
251 attenuated the dominance of *Acid* throughout the evaluation time, as in the case of the CON
252 samples. *Candy strawberry flavor* presented higher dominance rate values, exceeding the chance
253 level for almost the whole evaluation time, and even reaching a significant dominance around the

first third and first half of the consumption period. *Sweet*, *Thick* and *Milk flavor* sensations also exceeded the chance level at several points in the evaluation time, with higher dominance rate values than those found for sample FIB, which again shows that the addition of flavoring can produce a much more complex dynamic profile of sensations. In this case, the addition of both soluble fiber and flavoring resulted in a complete dimming of the *Natural strawberry flavor*, which remained below the chance level throughout the evaluation period.

Protein-enriched sample with flavoring (PRO+Flav). The addition of flavoring to sample PRO induced very interesting changes in the temporal sensory profile. As in sample PRO, PRO+Flav presented a dominance of *Thick* at the beginning and during the central evaluation time, remaining over the chance limit through to 70% of the evaluation time, whereas *Milk flavor* lost its salience and was significantly dominant only at the end of the evaluation time (from 80% onward). PRO+Flav was the only sample in which the *Sweet* sensation was perceived as significantly dominant, appearing from 15% to 50% of the evaluation period and then again from 65% until the end. *Acid* remained below the chance level over the whole evaluation time (as in sample PRO), and both *Natural strawberry flavor* and *Candy strawberry flavor* also had very low dominance rates.

3.2 Consumer liking assessment

Figure 2 shows the mean liking scores. ANOVA showed that formulation ($p < 0.001$), flavor (< 0.001), and their interaction ($p = 0.037$) had significant effects on liking scores.

In the samples with no addition of flavoring, the order of the liking scores was as follows: FIB > CON > PRO. Compared to the control (CON), the mean liking score for sample FIB was significantly higher, and that for sample PRO significantly lower. This trend indicated that consumers preferred an intermediate perception between the dominance of the *Acid/Natural*

278 *strawberry flavor* and *Milk/Thick* pairs of sensations. Sample FIB showed lower dominance of the
279 former pair and higher dominance of the latter, compared to CON. As commented above, the
280 addition of soluble fiber seemed somewhat to increase the perception of *Milk flavor* and *Thick*
281 (both sensations exceeded the chance level during some periods of time), and probably
282 contributed a flavor profile without the sharp, salient sensation occurrence found in samples CON
283 and PRO.

284 ***Insert Figure 2 around here***

285 The same trend in liking scores was found for the samples with added flavoring:
286 FIB+Flav>CON+Flav>PRO+Flav. In this case, only sample FIB+Flav showed a significantly higher
287 liking value than sample PRO+Flav. The significant interaction found by the ANOVA indicated that
288 the effect of the flavoring depended on the formulation. Although the liking scores for each
289 individual sample increased with the addition of flavoring, the only one that increased its liking
290 score significantly, compared with its counterpart without flavoring, was sample PRO+Flav.

291 Looking at the TDS curves (Figure 1), adding the flavoring to samples CON and PRO lowered the
292 dominance of the above-mentioned pairs of highly dominant sensations (*Acid/Natural strawberry*
293 and *Milk/Thick*, respectively), indicating that consumers preferred samples with more complex but
294 flatter sensory profiles, where a number of flavor notes could be perceived without any salient
295 dominance. It is worth noting that the addition of flavoring did not increase the dominance of any
296 strawberry flavor but did decrease the dominance of other sensations, the only exception being
297 the *Acid* final taste in both CON samples.

298 The highest liking scores corresponded to the FIB and FIB+Flav samples, where the addition of
299 soluble fiber, inulin and oligofructose increased the liking scores compared to CON. In accordance
300 with these findings, a review by Nair and others (2010) found that when inulin was added at low
301 concentrations to plain unsweetened yogurt in a consumer study, the sample containing inulin

was preferred over those without inulin, because of its slightly sweet flavor and creamier appearance. In addition, oligofrutosaccharides have been shown to mask the aftertaste of aspartame and acesulfame K, as well as providing a well-rounded flavor profile (Weidmann and Jager 1997).

It is very well known that conventional static sensory techniques (like Quantitative Descriptive Analysis) provide very detailed, consistent and reproducible results (Varela and other, 2014); however, in the present study, the temporal dimension of the sensory perception using the TDS dynamic technique contributed new insight that would be key to new product development. It has been shown that subtle changes in product formulation had an effect on the arousal and duration of the key product sensory sensations.

3.3 Evaluation of consumer expectations of satiety

Figure 2 shows the mean expected satiety scores. ANOVA showed that formulation ($p < 0.001$) and flavor (< 0.001) both had significant effects on expected satiety values, although the effect of their interaction was not significant ($p = 0.56$).

In order to test if the expectation of satiety measures changed over the course of all 6 samples the effect of the order of presentation of samples was analyzed and no significant effect was found.

The type of formulation significantly affected the expected satiety scoring, in the following order:

PRO>FIB>CON and PRO+Flav>FIB+Flav>CON+Flav (Figure 2). Both PRO samples (with and without flavoring) presented significantly higher expected satiety than the corresponding CON samples.

Satiety expectations come mainly from previous eating experiences and the degree of satiety occurring after the ingestion of similar food items (Brunstrom and others 2008). In the literature it

is widely reported that thickness increases expected satiety. For example, McCrickerd, Chambers,

Brunstrom and Yeomans (2014) demonstrated that varying the viscosity of drinks, using thickening

agents, modified the expected satiation and satiety ratings even when the perceived differences in thickness were relatively subtle. Thus, it is not surprising that both the PRO samples, which were perceived as dominantly thick (Figure 1), scored the highest expected satiety values, since the consumers would associate their perception of these samples with known metabolic consequences.

Incorporating the flavoring agent into each of the basic samples (CON+Flav, FIB+Flav, and PRO+Flav) increased the expected satiety compared to the corresponding basic formulation. The expected satiety of sample FIB was not significantly different from that of sample CON, but the addition of flavoring increased the expected satiety of sample FIB+Flav, which achieved a significantly higher value than sample CON (Figure 2).

The composition of sample PRO is nearer to that of commercial strawberry milkshakes, which are normally milk-based and artificially thickened. One possible explanation is that consumers found these beverages more familiar, which is also related to increases in expected satiety. Conversely, samples CON and FIB contained less milk and were perceived as thinner.

In the same way, Yeomans and Boakes (2016) found that odors that had been paired with a thick/creamy sensation in the mouth increased both expected satiety and expected satiation, and predicted that the presence of odors which generate an expectation that a product will be more filling could also act to enhance satiety. In the present study, as commercial strawberry milkshakes normally contain an added artificial strawberry flavor, it could be well possible that the odor/ taste of the flavoring may have transferred higher expected satiety to all the flavored samples.

Combination of temporal techniques and hedonics suggests further future research on the preferences of the consumers regarding the order of arousal and dominance of certain sensory sensations over consumption time. In particular, these temporal studies could aid industry to

349 develop functional food products with enhanced expectations of satiety; one important goal
350 would be to construct “ideal” temporal curves for the key attributes linked to those expectations.

351

352 . **Conclusions**

353 The present study has highlighted that in the reformulation of beverages for enhanced nutritional
354 and filling properties, not only changes in composition but also small additions of flavoring may
355 have important consequences for the final product. Both the dynamics of the dominance of key
356 sensory features and liking may be modified and this, in turn, may affect the perception of
357 expectations of the food product satiety.

358 Specifically, this study has shown that additions of soluble fiber, protein, and flavoring brought
359 about significant changes in the dynamic sensory profile of strawberry shakes. The addition of
360 fiber attenuated the dominance of the *Acid/Natural strawberry flavor* pair in the control sample,
361 whereas the addition of protein created a completely new dynamic sensory profile dominated by
362 *Thick* and *Milk flavor*. The addition of flavoring produced more complex but flatter profiles in
363 general in all the samples. From this point of view, TDS provided a holistic view of the sensory
364 impact on consumption of the samples, which might influence the consumers’ judgements.

365 Liking scores also proved to be dependent on composition, as they were higher for samples with
366 soluble fiber. The addition of flavoring had a similar effect, creating more complex profiles without
367 salient dominant sensations. As anticipated, expected satiety was strongly linked to perceived
368 thickness in both of the samples that contained higher levels of milk protein.

369

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382

383 **Author Contributions**

384 A. Tarrega, S. Fiszman and M.R. Moreira designed the study and interpreted the results. B.
385 Tomadori collected test data and drafted the manuscript.

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387

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490 Table 1. Description of the sensory sensations evaluated by temporal dominance of sensations

Sensation	Description
<i>Acid</i>	Basic taste of acidity
<i>Sweet</i>	Basic taste of sweetness
<i>Natural strawberry flavor</i>	Flavor found in fresh strawberries
<i>Candy strawberry flavor</i>	Flavor as found in strawberry candies
<i>Milk flavor</i>	Flavor found in milk
<i>Thick</i>	Heavy consistency in the mouth

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 494 Figure 1. TDS curves obtained for the different strawberry milkshakes. (---) Acid; (···) Natural
 495 strawberry flavor; (—) Milk flavor; (—) Thick; (—) Candy strawberry flavor; and (—) Sweet.
 496 Straight lines: (---) significance level; (—) chance level.

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501 Figure 2. Mean values (n=99) of liking and expected satiety scores for the different shake
502 formulations. Different lowercase letters indicate significant differences in liking ($p<0.05$) between
503 samples; different bold letters indicate significant differences in expectation of satiety ($p<0.05$)
504 between samples. CON: control formulation; FIB: fiber-enriched formulation; PRO: protein-
505 enriched formulation; Flav: Strawberry flavoring agent.

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