

# Block protocol for conventional profiling to sensory characterize plant protein isolates

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# 1 TITLE

2 Block protocol for conventional profiling to sensory characterize plant protein isolates

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### 12 1. INTRODUCTION

13 Over the last decade, the food industry has been searching for alternatives to animal proteins as more 14 consumers are making dietary choices based on health, ethical, or environmental criteria. In this context, pea 15 (Pisum sativum L.) protein isolates are becoming increasingly common in new plant-based foods, enhancing 16 the sustainability of food systems (Pelzer et al., 2012; Siddique et al., 2012). Pea proteins have desirable functional properties (e.g., emulsification, foaming, and whipping) (Gharsallaoui et al., 2009); they also have 17 low allergenicity and high nutritional value (Chel-Guerrero et al., 2007; Gharsallaoui et al., 2009). If many 18 19 articles deal about their physico-chemical characteristics, little deal about their sensory characteristics 20 reflecting difficulties to sensory describe them (Roland et al. 2017).

Like other pulse plant proteins, pea proteins have a distinct flavor. Sensory characterizations have highlighted the existence of three highly persistent notes: bitterness, astringency, and beaniness (Bott and Chambers, 2006; Humiski and Aluko, 2007). Beaniness corresponds to a complex flavor perception that is associated with bean products: consumers perceive such diverse notes as musty/earthy, musty/dusty, sour, starchy, powdery, green pea, nutty, and brown (Bott and Chambers, 2006). Such notes are rooted in the complex composition of the

aroma compounds found in pulses (Murat et al., 2013). In mouth, pea proteins are also often described as astringent, which has been defined as "the complex of sensations due to shrinking, drawing, or puckering of the epithelium as a result of exposure to substances such as alums or tannins" by the American Society for Testing Materials (ASTM, 1991). Finally, pea proteins are often perceived as bitter, which could result from the interaction of bitter compounds (e.g., amino acids, phenolics) with the TAS2R family of receptors, which are found on the apical membranes of taste receptor cells (Maehashi et al., 2008; Meyerhof et al., 2010).

32 Consequently, the distinct and persistent flavor of pea proteins limits their use as food ingredients (Lam et al., 33 2018) and challenges their sensory evaluation. In sensory evaluation of foods, descriptive analysis such as 34 classical profiling is conventionally employed (Lawless and Heymann, 2010). However, in classical profiling, 35 the multidimensional nature of beaniness can be difficult for panelists to precisely describe and quantify. As a 36 result, there is an increased probability of omitting a sensory dimension (Torres-Penaranda et al., 2001). In 37 addition, the prolonged persistence of bitter and astringent notes can lead to physiological adaptation and sensory fatigue (Kallithraka et al., 1997). These same difficulties occur when pea proteins are part of food 38 39 matrices, where composition, texture, and structure play an essential role in shaping sensory properties (Kühn 40 et al. 2009; Guichard et al., 2002). Perception could also be affected by cognitive interactions (i.e., 41 neurophysiological interactions) between taste qualities (e.g., bitterness, saltiness, sweetness; Keast and 42 Breslin, 2003). These cognitive interactions may act differently for individuals depending on their cultural background, food use, food consumption habits, and physiology (Lawrence et al., 2009). These interactions 43 44 occur when people eat products in natural context, however if we are interested in understanding the sensory 45 mechanisms and to relate them to specific compounds in the food, it may be interesting to limit these cognitive interactions. 46

47 Several alternatives to the classical sensory profiling protocol have already been described in literature to deal 48 with these issues. To limit interactions between sapid and flavor perceptions, some researchers have suggested 49 that nose clips could be employed to allow panelists to focus on sapid perceptions (Abegaz et al., 2004; 50 Murphy and Cain, 1979; O'Mahony, 1991; Schoumacker et al., 2017). In descriptive analysis, to cope with 51 complex food and to limit the probability of omitting a dimension, some protocols allow each panelist to add 52 descriptors to a pre-established list of attributes as with the Mixed profiling (Coulon-Leroy et al., 2017). As 53 food presentation schemes can impact how memory is activated, other researchers have recommended 54 adapting how samples are presented (monadically, comparatively, or accompanied by a reference) 55 (Mazzucchelli and Guinard, 1999; McBride, 2007; Saint-Eve et al., 2006). Using a stable and known reference for product evaluation could be interesting. For example, Polarized Sensory Positioning proposes to compare 56 and indirectly describe a set of products to three known reference products (Teillet, et al., 2010). The use of 57 references is also used by the method of Pivot Profile (Thuillier et al., 2005), which is based on a free 58 59 expression of the difference between a tested product and an identified pivot product. For both methods, the 60 choice of the reference product is critical to produce meaningful descriptions.

61 In addition, pronounced variability in sensitivity to bitterness has been observed in the general population and 62 among panelists (Hansen et al., 2006); furthermore, past research has shown that panelists who are less 63 sensitive to bitterness are less able to discriminate among foods (Dinehart et al., 2006). Consequently, when 64 carrying out sensory assessments, it is necessary to characterize panelists' sensitivity to bitterness. For example, the 6-n-Propylthiouracil (PROP) test can be used. Indeed, past work has found that PROP status 65 66 could be a proxy for overall oral responsiveness, which means that high PROP tasters could potentially display greater overall sensitivity to sensory properties (Carney et al., 2018). This hypothesis is based on research that 67 has found links between sensitivity to PROP bitterness and sensitivity to i) other basic taste sensations (Fischer 68 69 et al., 2015; Hayes et al., 2008; Prescott and Swain-Campbell, 2000; Webb et al., 2015); ii) chemesthetic 70 sensations (pungency associated with capsaicin and other oral irritants) (Prescott and Swain-Campbell, 2000; 71 Yang et al., 2014); and iii) tactile sensations (astringency associated with alum) (Bajec and Pickering, 2008). 72 Dinehart and colleagues found that people with greater PROP sensitivity gave higher bitterness scores to 73 vegetables (Dinehart et al., 2006). As a result, differences among panelists in bitterness sensitivity could 74 greatly influence sensory perceptions of foods containing pea proteins. In summary, the complex sensory 75 properties of pea proteins require an improved sensory profiling protocol if we wish to better and more 76 extensively characterize food products containing pea proteins and understand the mechanisms that lead to 77 sensory perceptions.

78 The aim of this study was to propose a relevant protocol for the evaluation and the characterization of pea 79 protein-based samples. Based on this past research, we adapted a classical protocol to evaluate 80 pea-protein-based foods. To decrease the effects of sensation saturation and sensory fatigue, we limited sample number and employed a strict palate-cleansing protocol. To deal with the complex and multidimensional 81 82 perception of beaniness, we asked panelists to evaluate attributes by blocks. In addition, panelists were 83 extensively trained to recognize different attributes, and we employed a reference sample to evoke these sensory memories during the experiment. Finally, to limit cognitive interactions between taste and flavor, and 84 to dissociate cognitive interactions from chemical interactions, panelists wore nose clips during the evaluation 85 86 of sapid perceptions. In this study, we compared how panelists evaluated solutions of pea protein isolates 87 using both the classical protocol and the adapted protocol called here block protocol.

# 88 2. MATERIALS AND METHODS

89 2.1 Samples preparation

Six commercial pea protein isolates (representing different batches and suppliers) were used in this study.
They were presented in the form of solutions (P1 to P6). No further information on the isolates will be given
for reasons of confidentiality.

We prepared 4% (w/w) pea protein solutions: the isolates were mixed in water (Evian, France) for 1 min and
then allowed to soak for 30 min. The solutions were then mixed by hand before being served to the panelists.

95 The samples were stored at 4°C before serving. They were served at 20°C (room temperature) in transparent
96 cups (29.5 mL) bearing three-digit codes.

97 2.2. Experimental conditions

We recruited 17 panelists (13 women and 4 men) based on their interest in participating in a long-term study. They were grouped on two sub-groups: 9 panelists (8 women and 1 man, mean age = 20 years) and 8 panelists (5 women and 3 men, mean age = 26 years). These groups were formed according to the availability of panelists. They had no prior experience with pea products or sensory evaluation methods. They were not informed of the precise aim of the experiment. They gave their free and informed consent to participate in the study and received compensation for their participation. They were asked not to eat, drink, or smoke for at

least 1 h prior to any experiments or training sessions. All sensory profiling was carried out in individual
booths under white light (samples had similar color) in an air-conditioned room (20°C).

#### 106 2.3. Palate-cleansing protocol

To reduce sensation build-up, three main strategies have been used: limiting sample number, increasing waiting time between samples, and more effectively cleansing the oral mucosa between samples (Courregelongue et al., 1999). Among these possibilities, the following palate-cleansing protocol was used between samples during our formal experiments: panelists had to consume an apple slice, drink water, and wait 40 seconds.

112 2.34. Characterization of panelist PROP status

We assessed the PROP taster status of the panelists using the three-solution test, with sodium chloride as the 113 standard (Tepper et al., 2001). Taste intensity ratings were collected for three solutions of suprathreshold 6-n-114 115 Propylthiouracil (Sigma-Aldrich, USA) (0.032, 0.32, and 3.2 mM) and of sodium chloride (NaCl, Sigma-116 Aldrich, USA) (0.01, 0.1, 1.0 M); the solvent was water (Evian, France). The panelists first assessed the three 117 sodium chloride solutions and then the three PROP solutions; the order of presentation in three-solution tests 118 does not produce systematic differences in taste ratings. The Labeled Magnitude Scale (LMS) was used for 119 evaluating the samples (Tepper et al., 2001). For each solution type, the order in which different solutions 120 were presented was balanced across panelists. Between solutions, panelists rinsed their mouths with the palate-121 cleansing. The panelists assessed each solution twice.

122 2.4<del>5</del>. Attribute selection and panelist training

Panelists were asked to fill out a check-all-that-apply (CATA) survey. It contained 30 attributes, and it was possible for panelists to add more. For our final list, we selected attributes that were cited more than 20% of the time and that allowed significant discrimination among sample types. We also wished to limit attribute number to avoid panelist fatigue. The eleven attributes that we retained were salty, bitter, astringent, mouthfeel, granularity, pea, broth, nuts, almond, potato, and grains. For the evaluation of textured food matrices, the granularity attribute was not relevant to be used. 129 We then trained all the panelists to assess these attributes using external references and an unstructured scale ranging from 0 and 10 (Table 1). Training took place over 8 sessions that lasted 45 min. Afterward, panelist 130 131 performance was evaluated and confirmed. The panel performance was assessed for the entire panel (subgroup 1 and subgroup 2) using an ANOVA model with three factors (sample, panelist, repetition) and their 132 interactions. The sample effect indicates the discrimination of products by panelists (p < 0.05). Interactions 133 were also used to determine whether panelists used the intensity scale between repetitions in a similar way 134 135 (panelist \* repetition), whether there was agreement among panelists (product \* panelist) and whether panelists generated similar values between repetitions (product \* repetition). Panelist performance was also evaluated 136 for panelist discrimination, agreement and repeatability. 137

138 2.56. General experimental set-up

Nine panelists (9/25) were taught to use classical protocol, and eight others (8/25) were taught to use block protocol. They were then asked to evaluate the solutions P1 to P6. The panelists were unaware of sample identity, and they were given two replicates of each sample type. After this first round of evaluation, the panelists were taught the profiling protocol they had not yet used, and they were asked to repeat the evaluation process. So in total 17 panelists (17/25) evaluated products with both block and classical protocol. This repeated measures approach to sensory profiling allowed us to account for potential order and learning effects.

145 2.67. Sensory profiling methods

146 Two protocols were used: classical protocol and block protocol. In both cases, panelists were asked to evaluate 147 the intensity of a sample's sensory attributes using an unstructured scale ranging from 0 to 10. To account for 148 order and carry-over effects, sample order was balanced across panelists using a Latin square (Williams 149 design). Panelists were given two replicates of each sample. The palate-cleansing protocol described above 150 was used between samples.

When panelists employed the classical protocol, samples were presented monadically in sequence (Fig. 1):panelists evaluated all eleven attributes (printed on the same survey page) at once for each sample.

When panelists employed the block protocol, attributes were evaluated in blocks (Fig. 1). Prior to the experiment, the attribute blocks were defined and discussed with the panelists. The first attribute block focused

155 on taste perception and mouthfeel (attributes of block 1: salty, bitter, astringent, mouthfeel, and granularity), 156 for which panelists wore nose clips. The next two attribute blocks focused on olfactory perception (attributes 157 of block 2: pea, broth, nuts, almond; attributes of block 3: potato, grains and other), and panelists did not wear nose clips during the evaluation. For each block, samples were presented monadically in sequence: panelists 158 evaluated all the attributes in the block (printed on the same survey page) for each sample. The samples order 159 was the same for the three blocks for one subject (but different between subjects). In addition, the first sample 160 161 (P1) in each session, for the three blocks, was also the reference used to limit drift between sessions. This 162 reference was available in large quantities and was stored under highly stable conditions.

163 2.78. Data analysis

164 All the analyses were performed using XLStat (Addinsoft, 2017, Paris, France) and R (R Core Team, 2017). 165 For analyses of an inferential nature, we used  $\alpha = 0.05$  to determine statistical significance.

Based on the results of the PROP test, we defined three groups of panelists. In the low PROP taster (LPT) group were panelists who had rated sodium chloride as having a more intense taste than PROP. Panelists who gave similar ratings to sodium chloride and PROP were in the medium PROP taster (MPT) group. Those who had rated PROP as having a more intense taste than sodium chloride were in the high PROP taster (HPT) group. Differences among groups were analyzed using repeated-measures analysis of variance (ANOVA) and post-hoc comparisons (Newman-Keuls method).

172 To analyze the sensory profiling results, in a classical way, we carried out three-way ANOVAs. There were 173 two sets of models: models using the classical protocol data and models using the block protocol data. Within each set, there was one model focused on the results for a single attribute. For all the models, sample type, 174 replicate, and panelist identity were the fixed effects, and all first-order interactions were included. When the 175 176 fixed effects were significant, we carried out post-hoc comparisons (Newman-Keuls method). We also performed additional three-way ANOVAs and Newman-Keuls tests to assess the effect of PROP status on the 177 intensity scores for the 11 attributes: sample type, replicate, PROP status and panelist identity (nested factor 178 179 with PROP status) were the fixed effects, and all first-order interactions were included. To visually explore 180 differences in the results obtained using classical versus block protocol, we carried out multiple factor analysis 181 (MFA) (centered by group; Pearson type); the data from both protocols were averaged across replicates and182 panelists.

183 3. RESULTS

184 3.1. Assessing panelist performance

185 We examined how well panelists performed (reproducibility and homogeneity) when using classical versus 186 block protocol to evaluate attribute intensity. Table 2 presents the results from the three-way ANOVAs that 187 used the scoring data for each attribute from each of the protocols. The interaction between replicate and 188 sample type were not significant (except in the case of granularity as evaluated with classical protocol). 189 Replicate was significant for both protocols for all the attributes and the interaction between panelist and 190 replicate was not significant for potato, nuts, broth, grains and bitter for the classical protocol and, granularity 191 for the block protocol. But the F values for these factors are low compared to the F values for the effects 192 produced. Nevertheless, these effects indicated a low level of repeatability of the panel and ask to be 193 circumspect for the following analysis. The interaction between panelist and sample type was significant for 194 seven attributes and one attribute for the block and the classical protocols, respectively. Such interactions are 195 common when sensory attributes are evaluated using unstructural scales and are difficult to control even when 196 panelists have undergone extensive training (Lawless and Malone, 1986; Jourjon et al., 2005). Nevertheless, 197 the block protocol seems to enhance differences between products and panelists. These results nonetheless suggest that the panelists generally came up with repeatable and homogeneous scores, even if there was some 198 199 disagreement for some attributes.

200 3.2. Comparison of the classical protocol and block protocol results

In the three-way ANOVAs, sample type was significant, revealing that there were differences in how the different pea protein solutions were perceived (Table 2). When the block protocol was used, panelists discriminated among the six sample types for all the attributes; for the classical protocol, the same was true for eight of the attributes (except pea, grains and astringent). For the block protocol, the greatest degree of discrimination was observed with the attributes nuts and mouthfeel (F = 21.61 and F=21.14); for the classical protocol, it was with granularity (F=10.04). For the block protocol, there was some degree of discrimination

207 displayed in granularity, pea, and almond (resp. F=8.67, F=9.19, F=8.26) as well with grains and astringent 208 (resp. F=4.54, F=4.10), although F-values were weaker in the latter case. In contrast, with classical protocol, 209 panelists did not discriminate among the sample types for the attributes astringent, grains, and pea. 210 Consequently, the block protocol allowed a greater degree of discrimination among a larger number of attributes. Table 3 presents the results of the Newman-Keuls groups associated for the evaluation of pea 211 protein isolates for significant attributes with the classical and the block protocols. Overall products are ranked 212 213 in the same way. Nevertheless there is a higher number of different groups with the block protocol for the 214 attributes bitter, astringent, mouthfeel, pea, broth and grains (respectively from 2 to 4, and 1 to 3 groups).

215 The results of the MFA are shown in Figure 2. The RV coefficient was 0.778, which means that there There 216 was a good correlation between the results obtained with the two protocols (RV coefficient = 0.778) (Josse et 217 al., 2008). The first two axes accounted for a large proportion of the variance (81.01%) in the sensory profiles. 218 The loadings of maps for the attributes showed that evaluations of granularity were well correlated between 219 the two protocols, as were evaluations of broth, salty, mouthfeel, bitter, nuts, and almond. The only attribute 220 for which this was not the case, was potato. This is because of higher potato intensity scores when panelists used block protocol, especially for P1 (5.31 for block profiling vs. 2.68 for classical profiling). This result 221 222 means that scores of potato intensity were different when panelists used classical versus block protocol. It may be that, with the classical protocol, it was easier to confuse the potato attribute with other attributes; in 223 224 contrast, block protocol might have limited such confusion. Along the first axis (52.95% of variance 225 explained), sample types were mainly differentiated based on the attributes nuts, mouthfeel, almond, and 226 granularity. Along the second axis (28.05% of variance explained), sample types were mainly differentiated 227 based on the attributes salty and potato. The sample types evaluated with classical protocol are mostly 228 distributed along the first axis, which means that panelists mainly used a single dimension when differentiating 229 among sample types. In contrast, the sample types evaluated with block protocol are distributed along axes 1 230 and 2, which means that panelists used two dimensions in the discrimination process. Overall, this finding indicates that there was a greater degree of discrimination among sample types when block protocol was 231 232 employed.

For both protocols, panelists had the possibility to complete their descriptions with another attribute in 'Other'. However, with both protocols, this attribute has been used only rarely and never in a consensual way. These results do not allow us to conclude on the usefulness of such an attribute.

236 3.3. PROP status and its relationship with the block protocol results

Among the 17 individuals who evaluated pea protein isolates in solution with both protocols, 7 were assigned to the HPT group (PROP intensity > sodium chloride intensity) and 5 were assigned to the LPT group (PROP intensity < sodium chloride intensity). The 5 panelists who did not perceive a difference between PROP and sodium chloride were assigned to MPT group.

241 We used the block protocol data and the classical protocol data for the P1-P6 solutions to examine whether 242 panelist PROP status influenced attribute evaluation (Table 4). The ANOVA results show that PROP status 243 affected the panelists' evaluation of 9 of the 11 attributes (all except mouthfeel and granularity) for block 244 protocol and 9 of the 11 attributes (all except mouthfeel and pea) for classical. Table 5 presents the results 245 from the Newman-Keuls post-hoc comparisons. With block protocol, in contrast to the HPT and MPT groups, the LPT group perceived all the attributes as less intense (all except mouthfeel and granularity which are not 246 significant). With classical protocol, LPT group perceived the products as less intense in astringent, 247 granularity and aroma attributes (except pea attribute). The differences between the two protocols therefore 248 249 depend on the attributes. Nevertheless, for bitter attribute, block protocol allow the expression of a greater difference between PROP status populations. 250

# 4. DISCUSSION

We found that classical and block protocols yielded correlated results. However, the block protocol allowed better discrimination among sample types. These differences were likely due to the differences in the presentation schemes, which activated different cognitive processes. In past research, monadic presentation has been found to be faster and less tiring than comparative presentation (Mazzucchelli and Guinard, 1999); however, comparative presentation allows panelists to detect smaller differences among foods and to make more accurate decisions about these relative differences (McBride, 2007; Saint-Eve et al., 2006). Here, our classical protocol employed a monadic presentation scheme, which means that panelists based their attribute evaluations on their memory of the references from the training period. They thus had to activate both their long-term and short-term memory. In contrast, in our block protocol, the presentation scheme combined both monadic and comparative elements. Consequently, the panelists could base their attribute evaluations on both their memories from the training period as well as on the reference sample, which was the first sample in the sequence (Hastie and Park, 1986). As a result, they might have needed to rely less on their long term-memory than when using the classical protocol.

The differences in the results obtained with the two protocols could also be rooted in bias. For example, during sensory evaluation, one of a food's attributes can strongly influence or bias the perception of the food's other attributes (halo effect) (Thorndike, 1920), or, in contrast, the absence of a potentially salient attribute from a food can affect how the food's other attributes are perceived (dumping effect) (Clark and Lawless, 1994). By having panelists evaluate attributes in groups, block protocol may reduce correlations among attributes and thus limit halo and dumping effects. Such factors could explain the distribution patterns along the first and second axes in the MFA (Fig. 2).

Here, we asked panelists to evaluate sapid and texture attributes with nose clips. If nose-clip evaluation does not mimic what happens when people taste the products in real life, it allows to dissociate chemical interactions from cognitive interactions in order to study the relationships between sensory data and instrumental data to move towards an understanding of the mechanisms of sensory perceptions (Abegaz et al., 2004).

In term of practicality, the block protocol takes more time than the classical protocol for products evaluation (about 20 min versus 15 min). Although using the nose clip for only one of the attributes blocks requires to panelists to put on and remove it during the evaluation, panelists found it easier to evaluate perceptions than classical protocol in particular due to the focus on a smaller number of attributes. In addition, the use of the reference, which makes sample preparation more cumbersome, was greatly appreciated by the panelists to help them to rate the products.

In summary, with this explorative study these products, block protocol is more efficient (better repeatability and discrimination) than classical protocol, and its use when evaluating foods with complex, multidimensional

sensory properties, such as foods incorporating pea protein isolates would be interesting to consider.
Nevertheless, due to the high presence of the replicate effect, particularly in the classical protocol, and to the
low number of evaluated products, as well as the limited number of subjects used in the panels, results have
yet to be confirmed by other studies.

This research has also improved our knowledge of how pea proteins are perceived. Plant proteins are often 289 described as "beany," a multidimensional and ambiguous descriptor. In our study, we decided against using 290 291 the term beany. Instead, we parsed out its multiple components and expressed them via other terms. Indeed, in 292 the literature, the definition of beany varies across consumers and food types. For example, lupin flour has 293 been described as having beany/green, mushroom/soil, floral, meaty, nutty, woody/green, sweet, and baked 294 attributes (Kaczmarska et al., 2018), and pea and soybean have been described as having beany, green, fresh, 295 and grassy attributes (Troszyńska et al., 2007). As a result, the use of beany as a descriptor is sometimes 296 avoided (Lawrence et al., 2016). For example, one study allowed cooked peas to only be described with the 297 attributes pea, cooked vegetable, earthy, brothy, grainy, and hay like (Malcolmson et al., 2014).

298 In our study, pea protein solutions could be described using attributes such as potato, pea, grains, broth, 299 almond, and nuts. This definition of pea flavor (in particular the following attributes: green/pea, grain/starchy, 300 nuts, and broth) is consistent with the definition developed by Vara-Ubol, Bott, and Chambers (Bott and 301 Chambers, 2006; Vara-Ubol et al., 2004), where beany is a combination of musty/earthy, musty/dusty, and one 302 or more of the characteristic attributes green pea pod, nutty, brown, sour, starchy, and powdery. However, 303 there are some differences in the beaniness of pea proteins (as illustrated in our results) and the beaniness of 304 proteins in soybeans, green peas, or lupin flour. More specifically, the attributes musty/dusty and 305 earthy/mushroomy are not associated with pea proteins.

Another aspect of our study is that we found a relationship between panelist PROP status and evaluations of pea protein solutions. The percentage of HPTs and LPTs that we identified among our panelists generally concurs with what has been reported in the literature. However, it is important to note that there is pronounced variability among populations worldwide (India: 26% HPT and 42% LPT; West Africa: 3% LPT; China: 6%– 23% LPT; North America [Caucasians]: 30% LPT ( Deshaware and Singhal, 2017; Guo and Reed, 2001). Here, we found that PROP status affected evaluations of bitterness (as also shown by Dinehart et al., 2006) as

312 well as evaluations of other sapid and flavor attributes. In particular, LPTs seemed to have a harder time 313 discriminating among sample types for a number of attributes; the only attribute for which there was evidence 314 of discrimination was a texture attribute, which suggests that mechanisms underlying texture perception are very different from those underlying chemical perception. However, some researchers have been questioning 315 whether PROP status is a global indicator of taste function given that the PROP test only measures sensitivity 316 to one bitter compound (Lim et al., 2008; Webb et al., 2015). That said, certain studies have shown that, 317 318 compared to LPTs, MPTs and HPTs do perceive a variety of compounds with greater intensity (Fischer et al., 2015; Hayes et al., 2008). Therefore, to improve the quality of food descriptions and discrimination, sensory 319 studies might want to strictly employ panelists who are HPT or MPT. Alternatively, researchers could control 320 321 for panelist PROP status when carrying out the analyses.

# 322 5. CONCLUSIONS

323 In this study, we drew upon classical sensory protocol to develop a block protocol in which attributes are evaluated in groups. Panelists evaluated samples that were presented monadically and sequentially; for each 324 evaluation sequence, the first sample in the series was the reference. This protocol made it easier to evaluate 325 326 samples with strong persistent attributes, such as bitterness or astringency, and multidimensional attributes, 327 such as beaniness. The use of a reference sample helped limit drift between sessions. The block protocol made 328 it possible for panelists to provide a more complete sensory characterization of the samples, which included a 329 large number of attributes. In this study, the use of nose clips limited interactions between taste and flavor with 330 a view to dissociate cognitive interactions from chemical interactions. We also assessed the PROP status of 331 our panelists, which allowed us to better understand each panelist's evaluations. Furthermore, our results 332 suggest that PROP status could help researchers select panelists based on sensory sensitivity. In closing, our overall findings should improve the characterization and formulation of innovative products based on pea 333 334 proteins. Nevertheless, these results have yet to be confirmed for its use when evaluating other types of 335 products. In particular, foods with complex, multidimensional sensory properties, such as foods incorporating 336 pea protein isolates would be interesting to consider.

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340 REFERENCES

- Abegaz, E. G., Tandon, K. S., Scott, J. W., Baldwin, E. A., & Shewfelt, R. L. (2004). Partitioning taste from
- 342 flavourtic flavor notes of fresh tomato (Lycopersicon esculentum, Mill) to develop predictive models
- 343 as a function of volatile and nonvolatile components. *Postharvest Biology and Technology*, *34*(3),

344 227–235.

- ASTM. (1991). Standard terminology relating to sensory evaluation of materials and products. *American Society for Testing Materials*, 1–3.
- Bajec, M. R., & Pickering, G. J. (2008). Thermal taste, PROP responsiveness, and perception of oral
  sensations. *Physiology & Behavior*, 95(4), 581–590.
- Bott, L., & Chambers, E. (2006). Sensory characteristics of combinations of chemicals potentially associated
  with beany flavour in foods. *Journal of Sensory Studies*, *21*(3), 308–321.
- 351 Carney, E. M., Stein, W. M., Reigh, N. A., Gater, F. M., Bakke, A. J., Hayes, J. E., & Keller, K. L. (2018).
- Increasing flavor variety with herbs and spices improves relative vegetable intake in children who are
   propylthiouracil (PROP) tasters relative to nontasters. *Physiology & Behavior*, *188*, 48–57.
- Chel-Guerrero, L., Scilingo, A. A., Gallegos Tintoré, S., Dávila, G., & Añón, M. C. (2007). Physicochemical
  and structural characterization of Lima Bean (Phaseolus lunatus) globulins. *LWT Food Science and Technology*, 40(9), 1537–1544.
- Clark, C. C., & Lawless, H. T. (1994). Limiting response alternatives in time-intensity scaling: an examination
  of the halo-dumping effect. *Chemical Senses*, *19*(6), 583–594.
- Coulon-Leroy, C., Symoneaux, R., Lawrence, G., Mehinagic, E., & Maitre, I. (2017). Mixed Profiling: A new
   tool of sensory analysis in a professional context. Application to wines. *Food Quality and Preference*,
   57, 8–16.
- Courregelongue, S., Schlich, P., & Noble, A. C. (1999). Using repeated ingestion to determine the effect of
   sweetness, viscosity and oiliness on temporal perception of soymilk astringency. *Food Quality and Preference*, 10(4), 273–279.

- Deshaware, S., & Singhal, R. (2017). Genetic variation in bitter taste receptor gene TAS2R38, PROP taster
   status and their association with body mass index and food preferences in Indian population. *Gene*,
   627, 363–368.
- Dinehart, M. E., Hayes, J. E., Bartoshuk, L. M., Lanier, S. L., & Duffy, V. B. (2006). Bitter taste markers
  explain variability in vegetable sweetness, bitterness, and intake. *Physiology & Behavior*, 87(2), 304–
  313.
- Fischer, M. E., Cruickshanks, K. J., Pankow, J. S., Pankratz, N., Schubert, C. R., Huang, G.H., Klein, B. E. K.,
  Klein, R., & Pinto, A. (2015). The Associations between 6-n-Propylthiouracil (PROP) intensity and
  taste intensities differ by *TAS2R38* Haplotype. *Journal of Nutrigenetics and Nutrigenomics*, 7(3), 143–
- **374** 152.
- Gharsallaoui, A., Cases, E., Chambin, O., & Saurel, R. (2009). Interfacial and emulsifying characteristics of
  acid-treated pea protein. *Food Biophysics*, 4(4), 273–280.
- Guichard, E. (2002). Interactions between flavor compounds and food ingredients and their Influence on flavor
  perception. *Food Reviews International* 18(1):49–70.
- Guo, S.W., & Reed, D. R. (2001). The genetics of phenylthiocarbamide perception. *Annals of Human Biology*,
  28(2), 111–142.
- Hansen, J. L., Reed, D. R., Wright, M., & Breslin, P. A. (2006). Heritability and genetic covariation of
  sensitivity to PROP, SOA, Quinine HCl, and Caffeine. *Chemical Senses*, *31*(5), 403–413.
- Hastie, R., & Park, B. (1986). The relationship between memory and judgment depends on whether the
  judgment task is memory-based or on-line. *Psychological Review*, *93*(3), 258–268.
- Hayes, J. E., Bartoshuk, L. M., Kidd, J. R., & Duffy, V. B. (2008). Supertasting and PROP bitterness depends
  on more than the TAS2R38 gene. *Chemical Senses*, *33*(3), 255–265.
- Humiski, L. M., & Aluko, R. E. (2007). Physicochemical and bitterness properties of enzymatic pea protein
  hydrolysates. *Journal of Food Science*, 72(8), 605–611.
- Josse, J., Pagès, J., & Husson, F. (2008). Testing the significance of the RV coefficient. *Computational Statistics & Data Analysis*, 53(1), 82–91.
- Jourjon, F., Symoneaux, R., Thibault, C., & Reveillere, M. (2005). Comparison of different scaling techniques
   for sensory analysis of wine. *OENO One*, 39(1), 23.

- Kaczmarska, K.T., Chandra-Hioe, M. V., Frank, D., & Arcot, J. (2018). Flavour characteristics of lupin and
   soybean after germination and effect of fermentation on lupin flavour. *LWT- Food Science and Technology*, 87, 225–33.
- Kallithraka, S., Bakker, J., & Clifford, M. N. (1997). Evaluation of bitterness and astringency of (+)-catechin
  and (-) epicatechin in red wine and in model solution. *Journal of Sensory Studies*, 12(1), 25–37.
- Keast, R. S., & Breslin, P. A. (2003). An overview of binary taste–taste interactions. *Food Quality and Preference*, *14*(2), 111–124.
- Kühn, J., Delahunty, C. M., Considine, T., & Singh, H. (2009). In-mouth flavour release from milk proteins. *International Dairy Journal*, *19*(5), 307–13.
- Lam, A. C. Y., Can Karaca, A., Tyler, R. T., & Nickerson, M. T. (2018). Pea protein isolates: Structure,
  extraction, and functionality. *Food Reviews International*, *34*(2), 126–147.
- Lawless, H. T., & Malone, G. J. (1986). Comparison of rating scales: sensitivity, replicates and relative
   measurement. *Journal of Sensory Studies*, 1(2), 155–74.
- 406 Lawless, H. & Heymann, H. (2010). Sensory Evaluation of Food Science: Principles and Practices. *2nd ed.*407 *New York: Springer.*
- Lawrence, G., Salles, C., Septier, C., Busch, J., & Thomas-Danguin, T. (2009). Odour–taste interactions: a
  way to enhance saltiness in low-salt content solutions. *Food Quality and Preference*, 20(3), 241–48.
- Lawrence, S. E., Lopetcharat, K., & Drake, M. A. (2016). Preference mapping of soymilk with different U.S.
  consumers: preference mapping of soymilk. *Journal of Food Science*, *81*(2), 463–76.
- Lim, J., Urban, L., & Green, B. G. (2008). Measures of individual differences in taste and creaminess
  perception. *Chemical Senses*, *33*(6), 493–501.
- Maehashi, K., Matano, M., Wang, H., Vo, L. A., Yamamoto, Y., & Huang, L. (2008). Bitter peptides activate
  hTAS2Rs, the human bitter receptors. *Biochemical and Biophysical Research Communications*, *365*(4), 851–855.
- 417 Malcolmson, L., Frohlich, P., Boux, G., Bellido, A. S., Boye, J., & Warkentin, T. D. (2014). Flavour and
- 418 Flavour Properties of Saskatchewan Grown Field Peas (Pisum Sativum L.). *Canadian Journal of*
- 419 *Plant Science*, *94*(8), 1419–26.

- Mazzucchelli, R., & Guinard, J. X. (1999). Comparative of monadic and simultaneous sample presentation
  modes in a descriptive analysis of milk chocolate. *Journal of Sensory Studies*, *14*(2), 235–248.
- 422 McBride, R. L. (2007). Hedonic rating of food: single or side-by-side sample presentation? *International*423 *Journal of Food Science & Technology*, 21(3), 355–363.
- Meyerhof, W., Batram, C., Kuhn, C., Brockhoff, A., Chudoba, E., Bufe, B., & Behrens, M. (2010). The
  molecular receptive ranges of human TAS2R bitter taste receptors. *Chemical Senses*, *35*(2), 157–170.
- Murat, C., Bard, M. H., Dhalleine, C., & Cayot, N. (2013). Characterization of odour active compounds along
  extraction process from pea flour to pea protein extract. *Food Research International*, 53(1), 31–41.
- Murphy, C., & Cain, W. (1979). Taste and olfaction: independence vs interaction I. *Physiology & Behavior*,
  24, 601–605
- 430 O'Mahony, M. (1991). Taste perception, food quality and consumer acceptance. *Journal of Food Quality*,
  431 14(1), 9–31.
- Pelzer, E., Bazot, M., Makowski, D., Corre-Hellou, G., Naudin, C., Al Rifaï, M., & Jeuffroy, M. H. (2012).
  Pea–wheat intercrops in low-input conditions combine high economic performances and low
  environmental impacts. *European Journal of Agronomy*, *40*, 39–53.
- Prescott, J., & Swain-Campbell, N. (2000). Responses to repeated oral irritation by apsaicin, Cinnamaldehyde
  and Ethanol in PROP tasters and non-tasters. *Chemical Senses*, 25(3), 239–246.
- Roland, W. S. U., Pouvreau, L., Curran, J., Van de Velde, F., & De Kok, P. M. T. (2017). Flavor Aspects of
  Pulse Ingredients. *Cereal Chemistry Journal*, 94(1), 58–65.
- 439 Saint-Eve, A., Lévy, C., Martin, N., & Souchon, I. (2006). Influence of Proteins on the Perception of Flavored
  440 Stirred Yogurts. *Journal of Dairy Science*, 89(3), 922–933.
- Schoumacker, R., Martin, C., Thomas-Danguin, T., Guichard, E., Le Quéré, J. L., & Labouré, H. (2017). Fat
  perception in cottage cheese: The contribution of flavour and tasting temperature. *Food Quality and Preference*, 56, 241–246.
- 444 Siddique, K. H. M., Johansen, C., Turner, N. C., Jeuffroy, M. H., Hashem, A., Sakar, D., & Alghamdi, S. S.
- 445 (2012). Innovations in agronomy for food legumes. A review. Agronomy for Sustainable
- 446 *Development*, *32*(1), 45–64.

- Teillet, E., Schlich, P., Urbano, C., Cordelle, S., & Guichard, E. (2010). Sensory methodologies and the taste
  of water. *Food Quality and Preference*, *21*, 967–976.
- Tepper, B. J., Christensen, C. M., & Cao, J. (2001). Development of brief methods to classify individuals by
  PROP taster status. *Physiology & Behavior*, *73*(4), 571–577.
- Thorndike, E. L. (1920). A constant error in psychological ratings. *Journal of Applied Psychology*, 4(1), 25–
  29.
- Thuillier, B., Valentin, D., Marchal, R., & Dacremont, C. (2005). Pivot© profile: A new descriptive method
  based on free description. *Food Quality and Preference*, *42*, 66–77.
- Torres-Penaranda, A. V., & Reitmeier, C. A. (2001). Sensory descriptive analysis of soymilk. *Journal of Food Science*, 66(2), 352–56.
- Troszyńska, A., Szymkiewicz, A., & Wołejszo, A. (2007). The effects of germination on the sensory quality
  and immunoreactive properties of pea (Pisum Sativum L.) and Soybean (Glycine max). *Journal of Food Quality*, *30*(6), 1083–1100.
- Vara-Ubol, S., Chambers, E., & Chambers, D. H. (2004). Sensory characteristics of chemical compounds
  potentially associated with beany flavour in foods. *Journal of Sensory Studies*, *19*(1), 15–26.
- Webb, J., Bolhuis, D. P., Cicerale, S., Hayes, J. E., & Keast, R. (2015). The relationships between common
  measurements of taste function. *Chemosensory Perception*, 8(1), 11–18.
- Yang, Q., Hollowood, T., & Hort, J. (2014). Phenotypic variation in oronasal perception and the relative
  effects of PROP and Thermal Taster Status. *Food Quality and Preference*, *38*, 83–91.
- Yousseef, M., Lafarge, C., Valentin, D., Lubbers, S., & Husson, F. (2016). Fermentation of cow milk and/or
  pea milk mixtures by different starter cultures: Physico-chemical and sensorial properties. *LWT Food Science and Technology*, 69, 430–437.
- 469
- Table 1: Definition of the sensory attributes evaluated by the panelists for the pea-protein-based sample types.

Attributes	Attributes in French	Definition
Salty	Salé	A fundamental taste - sodium chloride is a typical example
Bitter	Amer	The fundamental taste associated with a caffeine solution

		A sensation of drying out, roughening, and/or					
Astringent	Astringent	puckering that is felt in the mouth, like when					
		consuming red wine or unripe fruit					
Mouthfool	Engissour	The way a food feels in the mouth in relation to its					
Moutifieer	Epaisseur	viscosity					
Granularity	Granulosité	The presence of grains or granules in a food					
Pea	Pois	The flavor characteristic of beans and bean-based foods					
Broth	Bouillon	The flavor associated with boiled meat, soup, or stock					
Nuto	Noir	The flavor associated with nuts, like walnuts or					
Inuts	ΝΟΙΧ	hazelnuts					
Almond	Amande	The flavor associated with almonds					
Potato	Pomme de terre	The flavor associated with cooked potato					
Grains	Céréales The flavor associated with grains						

Table 2: Results of the three-way ANOVAs examining panelist performance and comparing the two protocols during the experiment where attribute intensity for pea protein solutions was evaluated using the classical protocol (CP) and the block protocol (BP) (degrees of freedom: 118; residual degrees of freedom: 85). Significant p-values are in bold ( $\alpha = 0.05$ ).

	Sample type		Panelist ID		Replicate		Sample *	Panelist	Sample* Replicate		Panelist* Replicate	
	F	Pvalue	F	Pvalue	F	Pvalue	F	Pvalue	F	Pvalue	F	Pvalue
Almond-BP	8.26	<0.01	0.76	0.39	15.31	<0.01	1.86	<0.01	0.68	0.64	3.17	<0.01
Almond-CP	4.35	<0.01	1.03	0.31	13.84	<0.01	1.27	0.15	1.01	0.42	2.42	0.01
Astringent-BP	4.10	<0.01	6.54	0.01	6.86	<0.01	1.13	0.29	1.64	0.16	2.46	<0.01
Astringent-CP	2.16	0.07	2.77	0.10	9.73	<0.01	1.12	0.30	2.33	0.05	3.41	<0.01
Bitter-BP	13.29	<0.01	15.19	<0.01	14.34	<0.01	1.34	0.10	1.15	0.34	2.91	<0.01
Bitter-CP	5.62	<0.01	1.06	0.31	11.50	<0.01	0.79	0.85	0.87	0.50	1.22	0.27
Broth-BP	12.44	<0.01	1.83	0.18	13.56	<0.01	1.41	0.06	1.46	0.21	3.65	<0.01
Broth-CP	6.98	<0.01	7.26	0.01	4.70	<0.01	0.93	0.64	1.76	0.13	1.71	0.06
Grains-BP	4.54	<0.01	11.96	<0.01	16.14	<0.01	1.57	0.02	1.62	0.16	3.14	<0.01
Grains-CP	1.84	0.11	1.05	0.31	7.02	<0.01	0.98	0.53	1.35	0.25	1.29	0.22
Granularity-BP	8.67	<0.01	0.13	0.72	8.81	<0.01	1.39	0.07	0.62	0.69	1.38	0.17
Granularity-CP	10.04	<0.01	3.77	0.06	6.97	<0.01	1.69	0.01	2.85	0.02	3.81	<0.01
Mouthfeel-BP	21.14	<0.01	22.52	<0.01	10.72	<0.01	1.68	0.01	0.52	0.76	2.19	0.01
Mouthfeel-CP	5.37	<0.01	4.34	0.04	13.81	<0.01	1.29	0.13	1.88	0.11	5.11	<0.01
Nuts-BP	21.61	<0.01	21.64	<0.01	5.35	<0.01	2.50	<0.01	0.93	0.47	3.08	<0.01
Nuts-CP	7.69	<0.01	0.70	0.41	6.23	<0.01	1.26	0.15	2.34	0.05	1.38	0.17
Pea-BP	9.19	<0.01	5.15	0.03	8.11	<0.01	2.76	<0.01	2.38	0.05	1.93	0.03
Pea-CP	1.62	0.17	1.60	0.21	6.16	<0.01	1.30	0.12	1.91	0.10	1.97	0.03
Potato-BP	11.89	<0.01	0.05	0.83	13.16	<0.01	2.19	<0.01	0.99	0.43	5.22	<0.01
Potato-CP	6.71	<0.01	1.12	0.29	8.37	<0.01	1.29	0.13	2.29	0.05	1.66	0.07
Salty-BP	16.69	<0.01	0.38	0.54	14.22	<0.01	2.24	<0.01	1.69	0.15	3.39	<0.01
Salty-CP	7.49	<0.01	0.00	0.95	15.99	<0.01	1.11	0.32	0.72	0.61	4.14	<0.01

<sup>477</sup> Table 3: Results from the Newman-Keuls post-hoc comparisons for the evaluation of pea protein isolates in

<sup>478</sup> water solutions by different protocol. (CP) Classical protocol. (BP) Block protocol. Nb\_group number of

<sup>479</sup> Newman-Keuls group. Significant differences between groups are indicated by differences in letters.

	Salty	Bitter	Astringent	Mouthfeel	Granularity	Pea	Broth	Nuts	Almond	Potato	Grains
P1-BP	a	a	а	a	ab	a	b	a	a	а	а
P1-CP	abc	а	а	a	с	а	b	а	ab	b	а
P2-BP	b	ab	ab	b	bc	bc	с	а	а	b	ab
P2-CP	bc	ab	а	a	с	а	b	ab	а	b	а
P3-BP	a	с	ab	cd	a	b	а	b	b	а	b
P3-CP	a	b	а	с	ab	а	а	с	b	а	а
P4-BP	b	с	b	d	ab	bc	bc	b	а	b	ab
P4-CP	с	b	а	bc	a	а	b	bc	ab	ab	а
P5-BP	b	bc	b	d	a	с	bc	b	b	b	b
P5-CP	с	ab	а	abc	bc	а	ab	ab	b	b	а
P6-BP	b	с	b	bc	с	ab	bc	а	а	b	ab
P6-CP	ab	ab	а	ab	с	а	b	bc	а	b	а
Nb_group-BP	2	3	2	4	3	3	3	3	2	2	2
Nb group-CP	3	2	1	3	3	1	2	3	2	2	1

481 Table 4: Effects of panelist PROP status on the evaluation of the attribute intensities of pea protein solutions

482 from the results from the ANOVAs (degrees of freedom: 34; residual degrees of freedom: 169). Significant p-

483 values are in bold ( $\alpha = 0.05$ ). (CP) Classical protocol. (BP) Block protocol.

	Panelist [PROP]		Sample type		PROP status		Replicate		Replicat	e* PROP	PROP * Sample	
	F	Pvalue	F	Pvalue	F	Pvalue	F	Pvalue	F	Pvalue	F	Pvalue
Almond-BP	9.50	<0.01	5.37	<0.01	12.45	<0.01	0.39	0.53	1.55	0.21	1.03	0.42
Almond-CP	12.21	<0.01	4.08	<0.01	12.32	<0.01	0.16	0.69	6.06	<0.01	1.77	0.07
Astringent-BP	3.74	<0.01	3.24	0.01	19.51	<0.01	4.83	0.03	2.27	0.11	0.78	0.65
Astringent-CP	5.20	<0.01	1.52	0.19	21.66	<0.01	1.66	0.20	1.47	0.23	0.42	0.93
Bitter-BP	11.99	<0.01	10.74	<0.01	8.79	<0.01	12.46	<0.01	5.31	0.01	1.41	0.18
Bitter-CP	13.16	<0.01	5.75	<0.01	6.91	<0.01	1.09	0.30	0.19	0.83	1.08	0.38
Broth-BP	5.08	<0.01	8.21	<0.01	39.35	<0.01	0.63	0.43	3.06	0.05	0.35	0.96
Broth-CP	4.46	<0.01	7.00	<0.01	5.32	0.01	8.11	<0.01	1.10	0.34	1.34	0.21
Grains-BP	11.61	< 0.01	3.09	0.01	14.29	<0.01	11.61	<0.01	4.57	0.01	1.74	0.08
Grains-CP	7.03	<0.01	1.63	0.16	4.35	0.01	0.98	0.32	1.19	0.31	0.61	0.80
Granularity-BP	8.01	<0.01	7.07	<0.01	3.04	0.05	0.04	0.84	0.32	0.73	1.18	0.30
Granularity-CP	4.28	<0.01	6.23	<0.01	8.60	<0.01	0.75	0.39	10.88	<0.01	0.99	0.46
Mouthfeel-BP	9.16	<0.01	14.79	<0.01	0.52	0.59	17.48	<0.01	0.84	0.43	1.96	0.04
Mouthfeel-CP	11.23	<0.01	3.60	<0.01	2.76	0.07	2.13	0.15	10.00	<0.01	1.29	0.24
Nuts-BP	2.42	< 0.01	11.54	<0.01	8.18	<0.01	13.97	<0.01	1.28	0.28	2.42	0.01
Nuts-CP	4.54	<0.01	6.98	<0.01	10.73	<0.01	0.39	0.53	0.79	0.45	1.28	0.24
Pea-BP	2.80	<0.01	4.64	<0.01	15.97	<0.01	2.80	0.10	0.01	0.99	1.97	0.04
Pea-CP	5.57	<0.01	0.89	0.49	2.21	0.11	1.63	0.20	1.05	0.35	1.74	0.08
Potato-BP	3.90	<0.01	6.02	<0.01	28.99	<0.01	0.08	0.78	3.92	0.02	0.70	0.72
Potato-CP	6.27	<0.01	5.06	<0.01	11.99	<0.01	1.71	0.19	2.77	0.07	1.04	0.42
Salty-BP	8.12	<0.01	9.88	<0.01	10.06	<0.01	0.37	0.55	0.97	0.38	1.82	0.06
Salty-CP	13.26	< 0.01	5.60	< 0.01	4.56	0.01	0.18	0.67	2.86	0.06	0.71	0.71

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Table 5: Results from the Newman-Keuls post-hoc comparisons, where HPT = high PROP taster group, MPT
= medium PROP taster group, and LPT = low Prop taster group. (CP) Classical protocol. (BP) Block protocol.
Nb\_group number of Newman-Keuls group. Significant differences between groups are indicated by
differences in letters.

# Salty Bitter Astringent Mouthfeel Granularity Pea Broth Nuts Almond Potato Grains

HPT - BP	а	а	a	а	а	а	b	a	b	а	а
HPT - CP	а	а	a	а	a	а	a	а	а	а	а
MPT - BP	а	а	а	а	а	а	a	a	а	a	а
MPT - CP	а	а	b	а	а	а	ab	ab	ab	a	ab
LPT - BP	b	b	b	а	а	b	с	b	b	b	b
LPT - CP	а	а	с	а	b	а	b	b	b	b	b
Nb_group-BP	2	2	2	1	1	2	3	2	2	2	2
Nb group-CP	1	1	3	1	2	1	2	2	2	2	2

- 492 Fig. 1: Schematic representation of the profiling protocols used in this study. (a) Classical protocol. (b) Block
- 493 protocol.



Fig. 2: Results of the multiple factor analysis comparing the sensory evaluations of pea protein solutions by
classical (CP) versus block protocol (BP) (RV coefficient: 0.778) (8/11 attributes which are significant for
both methods). (a) Correlation map of the variables along the first two axes. (b) Observations and projected
points along the first two axes.

