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## A sensory- and consumer-based approach to optimize cheese enrichment with grape skin powder

### This is the author's manuscript

*Original Citation:*

*Availability:*

This version is available <http://hdl.handle.net/2318/1636994> since 2022-04-02T10:50:05Z

*Published version:*

DOI:<http://dx.doi.org/10.3168/jds.2015-9922>

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(Article begins on next page)



## A sensory- and consumer based approach to optimize cheese enrichment with grape skin powders

Journal:	<i>Journal of Dairy Science</i>
Manuscript ID:	JDS-15-9922.R2
Article Type:	Research
Date Submitted by the Author:	n/a
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Key Words:	soft cheese, grape skin powder, free-choice profile, consumer acceptability

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1 A sensory- and consumer based approach to optimize cheese enrichment with grape skin powders

2 Torri

3 **Summary.** A sensory- and consumer based approach to optimize cheese enrichment conditions was  
4 proposed. Innovative cheeses developed by adding grape skin powders (GSP) from winemaking process to  
5 cow's milk curd were described by cheese taster experts and evaluated by consumers for their  
6 acceptability. Even though cheese is not an optimal vehicle for GSP enrichment, the adopted approach  
7 clearly identified the effect of the addition of the GSP on the sensory properties of cheese, pointed out  
8 which sensory features were detrimental for the product acceptability and allowed to obtain suitable  
9 information to optimize the ingredient use and the process conditions.

For Peer Review

10  
11 **SENSORY APPROACH FOR CHEESE OPTIMIZATION**12  
13 **A sensory- and consumer based approach to optimize cheese enrichment with grape skin powders**14  
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22 0172-45850023  
24 **ABSTRACT**25 The present study aimed to present a sensory- and consumer based approach to optimize cheese  
26 enrichment with grape skin powders (GSP). The combined sensory evaluation approach, involving a  
27 descriptive and an affective test respectively, was applied to evaluate the effect of the addition of grape  
28 skin powders from two grape varieties (*Barbera* and *Chardonnay*) at different levels (0.8, 1.6 and 2.4% w  
29 powder/w curd) on the sensory properties and consumer acceptability of innovative soft cow's milk  
30 cheeses. The experimental plan envisaged seven products, six fortified prototypes (B0.8, B1.6, B2.4, C0.8,  
31 C1.6, and C2.4) and a control sample, having 1 week ripening. By means of a Free Choice Profile, 21  
32 cheese experts described the sensory properties of prototypes. A Central Location Test with 90 consumers  
33 was subsequently conducted to assess the acceptability of samples. The GSP enrichment strongly affected  
34 the sensory properties of innovative products, mainly considering the appearance and the texture. Fortified  
35 samples were typically described with a marbling aspect (violet or brown as function of the grape variety)  
36 and with an increased granularity, sourness, saltiness and astringency. The fortification also contributed

37 certain vegetable sensations perceived at low intensity (grassy, cereal, nuts), and some potential negative  
38 sensations (earthy, animal, winy, varnish). The white color, the homogenous dough, the compact and  
39 elastic texture and the presence of lactic flavors resulted the positive drivers of preference. On the contrary,  
40 the marbling aspect, granularity, sandiness, sourness, saltiness and astringency negatively affected the  
41 cheese acceptability for amounts of powder exceeding 0.8% and 1.6% for the *Barbera* and *Chardonnay*  
42 prototypes, respectively. Therefore, the amount of powder resulted a critical parameter for liking of  
43 fortified cheeses and a discriminant between the two varieties. Reducing the GSP particle size and  
44 improving the GSP dispersion in the curd would reduce the impact of powder addition on sensory  
45 properties, thereby encouraging the use of these polyphenol-based fortifiers in cheeses. The proposed  
46 approach allowed the identification of sensory properties critical for product acceptability by consumers  
47 thus helping the optimization of both fortifier characteristics and new cheese production and composition.

48  
49 **Key Words:** consumer acceptability, free-choice profile, soft cheese, grape skin powder

50

51

## INTRODUCTION

52 Consumers are increasingly aware that food directly contributes to their health (Mollet and Rowland,  
53 2002), and the dairy market plays an active role in health and wellness (Brockman and Beeren, 2011). The  
54 use of functional ingredients represents one of the most important trends in dairy product technological  
55 innovation. Dairy product enrichment can include (1) fortification with micro-ingredients (isolated and  
56 purified high-value compounds) to enhance the nutritional value of the food or (2) addition of macro-  
57 ingredients (complex ingredients, composed by a mixture of components). Within the first category,  
58 several examples are available (Bermúdez-Aguirre and Barbosa-Cánovas, 2011; Rinaldoni et al., 2014;  
59 Stratulatet al., 2014). Recently, winery by-products, such as the grape pomace, were added as macro-  
60 ingredients to several foods to obtain novel functional food products enriched in terms of polyphenols and  
61 dietary fiber (Mildner-Szkudlarz et al., 2013; Yu and Ahmenda, 2013).

62 Several biological activities are reported for dietary fiber and polyphenols from grape pomace, and  
63 advantages from their use in dairy production processes, as well as in product quality, have been envisaged

64 (Zhuet al., 2014). Environmental sustainability (Augustin et al., 2013) and contributions to managing waste  
65 (Fontana et al., 2013) are similarly important factors encouraging the use of non-dairy products as  
66 ingredients in the dairy industry. To authors' knowledge, among dairy products grape pomace has been  
67 uniquely used to fortify yogurt (Karaaslanet al., 2011; Codaet al., 2012) and salad dressing (Tseng and  
68 Zhao, 2013).

69 Beside the wide literature focusing on the advantages associated to the use of grape pomace as a food  
70 ingredient (Zhu et al., 2014; Yu and Ahmedna, 2013), there is a lack of information considering the  
71 sensory impact of this ingredient on food prototypes. Generally, the use of ingredients obtained by vegetal  
72 by-products to fortify or enrich foods contributes unpleasant sensations, which result detrimental for the  
73 overall quality (Braghieri et al., 2014; Ajila et al., 2010) and the acceptability (Rinaldoni et al., 2014; Marti  
74 et al., 2014) of food products. A limited number of studies took into account the effect of fortification with  
75 grape pomace on product sensory properties (Torri et al., 2015) and on its acceptability by consumers  
76 (Sant'Anna et al., 2014; Lavelli et al., 2014).

77 Health benefit belief from functional foods emerges as the strongest positive determinant of consumer  
78 willingness to compromise on taste (Verbeke, 2006). Moreover, considering the appeal of nutrition and  
79 health claims, significant interaction effects were found between claim type and the product concept,  
80 indicating that consumers differently react to the carrier product, functional ingredient and claims as  
81 function of the product concept (Verbeke et al., 2009).

82 Thus, implementing healthy properties without taking into account taste modifications and consumer  
83 response to the new fortified food appears a highly speculative and risky strategic option (Verbeke, 2006).

84 This aspect deserves even more attention in the case of fortification/enrichment of familiar food. In fact,  
85 the more a consumer is familiar with the product the more a deviation from the expected sensory properties  
86 will negatively affect the consumer's response (Mildner-Szkudlarz et al., 2013). Based on these  
87 considerations, and given the importance of developing successful product for the food industry, it seems  
88 extremely important to include a consumer-based approach in product innovation and optimization process,  
89 in order to investigate the effect of the fortification/enrichment on acceptability and to increase the success  
90 probability of new products.

91 In the present study, a sensory- and consumer based approach to optimize cheese enrichment/fortification  
92 conditions was proposed and applied to an innovative cow's milk soft cheese developed by incorporating  
93 the grape skin powders (GSP) obtained from two grape varieties (*Barbera*, a red grape variety, and  
94 *Chardonnay*, a white grape variety) into the curd. The sensory- and consumer-based approach presented (1)  
95 evaluates the effect of enrichment conditions (type and concentration of added ingredient) on cheese  
96 sensory properties and (2) identifies the sensory drivers of the acceptability of the enriched soft cheeses  
97 developed in this study.

98

99

## MATERIALS AND METHODS

### *Products*

101 ***Grape Skin Powders.*** Grape pomace from non-fermented white *Vitis vinifera* cv *Chardonnay* was  
102 provided by the Fontanafredda winemaking factory (Serralunga d'Alba, Cuneo, Italy) while that from  
103 fermented red *Vitis vinifera* cv *Barbera* was provided by the Clarea winemaking factory (Chiomonte,  
104 Torino, Italy). The skins were mechanically separated, vacuum packaged and stored at -20 °C prior to  
105 being dried in an oven (Memmert, UFE 550, Schwabach, Germany) at 54 °C for 48 h and then ground with  
106 a Retsch ZM200 grinder (Retsch GmbH, Haan, Germany) to obtain grape skin powder (GSP) with a  
107 particle size of less than 250 µm.

108 ***Cheese Samples.*** Raw cow's milk (protein 3.5%, fat 3.6%, lactose 5.1%) was provided from a local  
109 farm, pasteurized at 72°C for 15 sec then added of calcium chloride (0.1% v/v) and mesophilic starter  
110 bacteria Lyofast MOSO60D (Clerici-Sacco, Cadorago, CO, I). Coagulation was performed at 38-40 °C  
111 with cow rennet (chimosine:pepsine 20:80; Clerici, Milan, Italy). After 30-40 min of resting, the curd was  
112 cut two times and left to stand for 10 min at 37°C. Ripening was performed at 6 ± 1°C for 6 days. During  
113 ripening, each cheese was manually dry-salted. The obtained soft cheeses were fresh products similar to  
114 Robiola and considered as control sample (STD). Six samples of enriched cow's milk soft cheese were  
115 developed by incorporating GSP from *Barbera* (B) and *Chardonnay* (C) into the curd during the  
116 cheesemaking process. Three different percentages of powders (0.8, 1.6 and 2.4% w powder/w curd) were  
117 added directly to the curd before shaping and manually mixed. A preliminary production test showed that it

118 is not possible to obtain a cheese with a powder percentage higher than 2.5%, since cheeses were not able  
119 to maintain their shape. The enriched samples were codified as B0.8, B1.6, B2.4, C0.8, C1.6, and C2.4. In  
120 total, the study envisaged seven cheese samples. At the end of ripening, the obtained cheeses ( $250 \pm 10$  g)  
121 were cut in slices ( $5 \times 3 \times 1.5$  cm) at room temperature ( $20 \pm 1$  °C) approximately 20 minutes prior to each  
122 sensory evaluation. Slices were placed in transparent plastic cups (38 ml) and hermetically sealed with a  
123 clear plastic lid. Samples were identified with three digit codes, served in randomized and balanced order  
124 among subjects and evaluated at room temperature ( $20 \pm 1$  °C).

125

## 126 **Methods**

127 **Free Choice Profile.** A group of 21 expert cheese tasters voluntarily participated in one session of the  
128 Free Choice Profile. Assessors (M=13, F=8; aged from 24 to 70, mean age=55) were selected from among  
129 the tasters of the Italian National Cheese Taster Association (ONAF, Organizzazione Nazionale  
130 Assaggiatori Formaggio) and declared a cheese consumption greater than 3 times a week. The session  
131 lasted 120 minutes. Sensory analysts briefed the experts on the methodology and the tasting procedure. The  
132 Free Choice Profile session was divided in two parts separated by a 15-minute break. In the first part, a  
133 vocabulary describing the sensory characteristics of prototypes was developed. The procedure required the  
134 assessors to observe, smell and taste samples and describe the sensory characteristics of prototypes  
135 considering appearance, odor, taste, flavor, and texture freely using their own terms. Panelists were  
136 encouraged to use associative and cognitive terms, rather than quantitative or affective ones (such as good,  
137 bad, or intense). Next, the panelists were asked to select from their own list of self-elicited attributes those,  
138 which they considered the most discriminative among samples. Each assessor freely selected the number of  
139 attributes to use. In the second part, a new set of the same samples was served (with different codes and in  
140 a different order) and assessors were asked to taste the samples and rate the intensity of sensations  
141 described by the attributes they selected using a 9-point scale (1=extremely weak, 9=extremely intense).  
142 Thus, in agreement with literature (Guardia et al., 2010; Vit et al., 2011), assessors tasted each sample  
143 twice evaluating the intensity of the descriptors once. The sample codes and presentation order were  
144 randomized across assessors in the two parts of the session. Instructions required the assessors to rinse their



145 mouths with still water before the beginning of the test. After each sample, subjects rinsed their mouths  
146 with water, had plain crackers for 30 s and finally rinsed their mouths with water for a further 30 s.  
147 Subjects took a 1 min break between sample evaluations.

148 **Consumer Test.** A Central Location Test (CLT) with 90 consumers (M=43, F=47; aged from 18 to 70,  
149 mean age=43) was performed during the “Cheese 2013” International Cheese Exhibition (Bra, Cuneo,  
150 Italy). Consumers voluntarily participated in the sensory test. Demographic information (age: 18-35, 36-55,  
151 56-70; gender: M, F; nationality: Italian, non-Italian), socio-economic information (educational level:  
152 primary, high school, college, bachelor, other advanced degrees; occupational status: student, worker,  
153 retired, unemployed) and frequency of cheese consumption (once or less a week, 2-3 times a week, 4-5  
154 times a week, once a day, more than once a day) were collected. Participants received individual trays with  
155 the seven cheese samples and rinsed their mouths with still water before beginning the evaluation.  
156 Participants tasted the samples according to the tray presentation order and in blind conditions, without any  
157 information about the innovativeness of the cheeses in order to avoid a potential effect of the information  
158 on liking scores. Participants rated their liking for appearance, odor, taste, flavor, texture and overall liking  
159 using a 9-point hedonic scale (1=extremely dislike, 9=extremely like) (Peryam and Pilgrim, 1957). Cheese  
160 prototypes were served in a randomized and balanced order. The subjects followed the same rinsing  
161 procedure adopted in FCP.

162

### 163 **Data Analysis**

164 **Free Choice Profile.** Data collected using the Free Choice Profile were submitted to Generalized  
165 Procrustes Analysis (GPA) to obtain a consensus map (Gower, 1975) by using the software Senstools v.  
166 1.2x (OP&P Product Research BV, Utrecht, Netherlands). To estimate the significance of the GPA results,  
167 a Permutation Test was carried out (500 permutations were conducted on the raw matrix) and the total  
168 accounted variance of first dimensions was considered.

169 **Consumer Test.** The effect of the amount of GSP on liking in terms of appearance, odor, taste, flavor,  
170 texture and overall liking was assessed using a 2-way ANOVA mixed model with interactions (fixed  
171 factor: GSP amount, 3 levels 0.8, 1.6, 2.4%; random factors: subjects). The effect of grape variety on

172 liking in terms of appearance, odor, taste, flavor, texture and overall liking was assessed using a 2-way  
173 ANOVA mixed model with interactions (fixed factor: grape variety, 2 levels *Barbera*, *Chardonnay*;  
174 random factors: subjects). A 2-way ANOVA mixed model with interactions was used to estimate the effect  
175 of the product on the overall liking and on liking in all sensory modalities (fixed factor: product, 7 levels;  
176 random factors: subjects). A Partial Least Square Regression (PLS) was performed for exploratory  
177 purposes, considering the sensory data from FCP as the X data set and the overall liking of 90 consumers  
178 as the Y data set. To select the most discriminating attributes, those with a loading equal to or greater than  
179 0.7 (absolute value) on the GPA consensus map for the first two principal Dimensions (Dim1 and/or Dim2)  
180 were selected to create the matrix. The PLS was performed using The Unscrambler X software, vers. 10.3  
181 (Camo Software AS, Norway). ANOVA analyses were conducted using SYSTAT software, version 13.1  
182 (Systat Software Inc, San José, USA).

183

184

## RESULTS

### *Cheese Sensory Properties*

186 Experts elicited 64 terms in total. The number of elicited attributes per subject ranged from a minimum of  
187 four to a maximum of 17 attributes. The average number of attributes elicited by experts was eight, in  
188 agreement with findings in the literature (Guàrdia et al., 2010). The initial list of attributes was reduced to  
189 achieve a unique list that comprehensively and accurately described the product space; redundant and/or  
190 less-cited terms were grouped on a semantic basis and/or eliminated. The final list consisted of 54  
191 descriptors classified according to sensory modality: appearance (7), aroma (11), taste and mouthfeel  
192 sensations (6), flavor (17) and texture (13) (Table 1). Analysis of occurrences showed that the most  
193 frequently elicited descriptors (cited by at least one third of experts at least 7 times) were: marbling brown,  
194 white, odor and flavor of lactic, odor and flavor of yogurt, bitter, sour and gummy.

195 Appearance resulted a key sensory modality for sample discrimination with a relatively low number of  
196 descriptors (7) and a relatively high number of occurrences (31). New prototypes were generally described  
197 by using terms related to the marbling aspect (marbling, brown marbling, violet marbling, homogeneous

198 marbling), homogenous dough, white color and by the presence of holes. The control sample was described  
199 as having a white color, in contrast to the fortified samples.

200 Taste and mouthfeel were described using four attributes for fundamental tastes (sour, bitter, sweet, salty)  
201 and the tactile sensation of astringency with 35 occurrences in total. Sourness was the most used taste,  
202 elicited by 11 out of 21 judges. Secondly, bitter and salty tastes were elicited seven and six times,  
203 respectively, both showing higher intensity scores in the enriched samples compared to the reference  
204 standard. Judges elicited astringency only three times. For two assessors this attribute had high loading  
205 values on the Dim2, but it was perceived in a contrasting way by judges.

206 Considering the olfactory sensations, judges used a high number of attributes to describe odor and flavor  
207 (11 and 17 terms, respectively). Among these descriptors, several terms described vegetable sensations  
208 (cereal, grassy, fruity, citric, nuts, vanilla), while other terms were not related to food and tended to have a  
209 negative connotation (earthy, varnish, ammonia, acetone, animal, metallic, winy). However, a low number  
210 of judges elicited odor and flavor sensations, and most of the sensations in this sensory modality occurred  
211 fewer than three times. The odor and flavor of lactic and the odor and flavor of yogurt were the only  
212 attributes with a number of occurrences equal to or higher than seven. These two sensations typically  
213 characterized the perception of cheese.

214 Texture was extremely important in discriminating among samples, showing the highest number of  
215 occurrences (41). Judges mainly used the attributes: gummy, adhesive, elastic and granular, with the last  
216 one clearly characterizing the enriched samples. The attributes sandy, creamy and compact had low  
217 occurrences but showed high loading values on the consensus map.

218 The experts' individual configurations were submitted to GPA. The Permutation Test indicated a  
219 probability of less than 0.05% that the consensus generated in the study could have arisen by chance. The  
220 consensus space obtained from GPA and applied to individual configuration is depicted in Fig. 1. The total  
221 variance explained by the first two dimensions accounted for 39 and 15% on Dim1 and Dim2, respectively.  
222 Samples were clearly discriminated according to the percentage of GSP along the Dim1. The reference  
223 sample was positively correlated to Dim1 and is highly correlated to white color, homogenous dough,  
224 gumminess, sweet, bitter and lactic sensations. Judges also detected an animal flavor in this sample.

225 Fortified samples tend to move on the left side of Dim1 as a function of their GSP content. In general,  
226 sourness, saltiness and bitterness tended to increase as a function of the amount of GSP added,  
227 independently from the grape variety.

228 The grape variety showed a significant effect on sensory properties along the Dim2. In particular, all  
229 samples containing *Barbera* GSP were on the lower part of the map, while samples with *Chardonnay* GSP  
230 spread in the upper quadrant of the map. The grape variety affects the prototype color and marbling  
231 descriptors (marbling, marbling violet, marbling brown) along Dim1. In particular, B2.4 and B1.6 were  
232 closely associated with intense violet marbling and samples C2.4 and C1.6 had a brown marbling  
233 appearance.

234 Grape variety also influenced the relative differences among samples fortified with increasing amounts of  
235 the same GSP. The perceived differences between C1.6 and C2.4 were greater than those detected between  
236 B1.6 and B2.4, as shown by the relative distance between samples on the map; specifically, the perceived  
237 difference was higher between C1.6 and C2.4 than between B1.6 and B2.4. It is possible to assume that the  
238 higher color intensity perceived in cheese prepared with 1.6 and 2.4% of *Barbera* GSP with respect to B0.8  
239 tend to suppress the perception of other sensory differences between this pair of samples. C0.8 and B0.8  
240 were shown to be quite similar in terms of appearance and texture, with B0.8 being associated with  
241 granularity and crumbliness sensations, while C0.8 was described as more gummy and having a clearer  
242 color. Samples C1.6 and C2.4 were positively correlated to the Dim2 and were primarily described as  
243 sandy, creamy, sour, bitter and astringent.

244

### 245 *Cheese Liking*

246 Results from the 2-way mixed ANOVA model did not reveal a significant effect ( $F=0.921$ ;  $p=0.34$ ) of the  
247 grape variety on the overall liking expressed by all 90 consumers ( $B=5.0\pm 0.1$ ;  $C=5.1\pm 0.1$ ). A significant  
248 effect of the GSP percentage on the overall liking was found ( $F=9.10$ ;  $p<0.01$ ). In particular, the overall  
249 liking significantly decreased with the increase of GSP: prototypes with the lowest percentage of GSP  
250 (0.8%) obtained the highest overall liking scores ( $5.3\pm 0.1$ ), while the prototypes with 2.4% of GSP were  
251 the least preferred ( $4.8\pm 0.1$ ). A significant effect of product ( $p<0.001$ ) was found on liking as expressed by

252 90 consumers considering the appearance, odor, taste, flavor, texture and overall liking (Table 2). The  
253 reference sample was the most liked according to scores relevant to all the sensory modalities. The addition  
254 of GSP to the cheese induced a significant decrease in liking ratings ( $p < 0.05$ ).

255 Accordingly to the overall liking ratings, all fortified samples ranged from 4.7 to 5.5 (Tab. 2). In particular,  
256 C0.8, B0.8 and C1.6 obtained the highest average scores, C2.4 received the lowest mean value with no  
257 significant differences from samples B0.8 and B1.6. C0.8, C1.6 and B0.8 showed the highest mean scores  
258 for the appearance. Barbera samples fortified with 1.6 and 2.4% of GSP tended to be the least preferred  
259 samples in terms of the appearance. Results showed only slight differences among samples in liking for the  
260 aroma. Samples containing the lowest and intermediate GSP amount (B0.8, B1.6, C0.8, and C1.6) tended  
261 to be preferred than B2.4 and C2.4 in terms of taste and flavor. Considering the texture, C0.8 had the  
262 highest score, with the mean rate not significantly different from B0.8 and C1.6. Samples with the highest  
263 amount of GSP (B2.4, and C2.4) had the lowest texture ratings, with a mean rate not significantly different  
264 from B0.8 and B1.6.

265

#### 266 *Relationship between Sensory Properties and Hedonic Responses*

267 The map obtained by the PLS regression performed for exploratory purposes shows the relationship  
268 between the hedonic responses of 90 consumers and the sensory properties of the samples (Fig. 2). The  
269 map indicates consumers' clear preference for the reference sample, as shown by the high concentration of  
270 consumers positioned on the right part of the map. The sensory properties characterizing the standard  
271 tended to be the positive drivers of the overall liking, particularly the white color, the homogenous dough,  
272 the compact and elastic texture and the presence of lactic flavors. On the contrary, all sensations perceived  
273 at high intensity in samples with a high amount of GSP appeared to be negative drivers of overall liking,  
274 particularly for attributes describing the marbling appearance (violet and brown), the intense sourness and  
275 the perception of granularity and sandiness, together with some odors and flavors (varnish, earthy, citric).

276 In general, the analysis of the preferences suggests the importance of reducing the sandiness and granular  
277 sensations associated with the less liked cheeses to match consumers' preferences, as well as to reduce the  
278 perceived intensity of sourness.

279 Results showed an inverse relationship between the amount of GSP added and the acceptability of  
280 prototypes. In general, GSP addition clearly induced lower consumer liking for prototypes. This effect was  
281 more evident in B than C samples. In fact, liking strongly decreased as the amount of B GSP increased  
282 from 0.8 to 1.6%, whereas only a slight change in liking occurred for the same range of GSP variation in  
283 the C samples. Grape variety clearly affects consumer preference for fortified prototypes. In particular, a  
284 visual inspection of PLS regression plot shows that consumers tended to be almost equally distributed  
285 along the Dim2 between the upper and lower quadrants of the map. This finding suggested the presence of  
286 two distinct groups of subjects. One group, composed of the consumers located in the upper right quadrant,  
287 preferred the samples prepared with the white grape variety (*Chardonnay*). The other group, located in the  
288 lower right quadrant, tended to prefer samples prepared with the red grape variety (*Barbera*). Results  
289 confirmed this finding, by computing the mean overall liking ratings of the two separate groups (the first  
290 positioned in the right upper quadrant, the second in the lower right quadrant). Both groups preferred the  
291 standard sample but among the fortified samples, the former segment preferred samples C1.6 ( $6.3\pm 0.2$ ) and  
292 C0.8 ( $5.5\pm 0.3$ ), while the latter group preferred the cheese B0.8 ( $5.7\pm 0.2$ ).

## 294 DISCUSSION

### 295 *Effect of the Addition of Grape Skin Powder on Cheese Sensory Properties*

296 Considering the frequency of the occurrence of sensory attributes used in FCP, the most frequent attributes  
297 mentioned by experts were related to taste (sourness elicited by 11 out of 21 experts) and appearance,  
298 particularly the marbling aspect (16 elicitations in total considering marbling, violet marbling, brown  
299 marbling and homogenous marbling). These results confirm the importance of the visual inspection in the  
300 description and appreciation of food products (Dinnella et al., 2014). Authors partially explained this result  
301 by recalling that generally, visual attributes are easier to describe than the olfactory and gustative  
302 sensations because vision and hearing are an inborn mechanism, whereas the other senses rely largely on  
303 learning (Köster, 2003).

304 The visual inspection of the consensus map obtained from the GPA clearly showed the strong effect of  
305 GSP fortification on the sensory properties of the new developed prototypes. Considering the appearance,

306 the high amount of colored phenol compounds contained in red grape skins from *Barbera* and released  
307 from the GSP into the cheese induced a violet and brown marbling, a color that was not present in the  
308 reference sample. Other studies showed an analogous effect on food color induced by the use of phenol  
309 based winery by-products in biscuits (Mildner-Szkudlarz et al., 2013; Pasqualone et al., 2014). Moreover,  
310 the addition of GSP strongly affected the cheese texture. In particular, the granularity sensation perceived  
311 in the soft cheese was probably due the particle size of GSP used, which was under 250  $\mu\text{m}$ . This particle  
312 size is above the perception threshold, estimated approximately 25  $\mu\text{m}$  (Hinton et al., 1970), and hard and  
313 irregular particles can produce gritty sensations, even at the lower size of 10  $\mu\text{m}$  (Utz, 1986). In agreement  
314 with our findings, the addition of solid particles in a food matrix increased the sensation of roughness and  
315 significantly decreased the ratings of a number of texture attributes, such as smooth, creamy, fatty and  
316 slippery (Engelen et al., 2005). Considering soft model systems containing solid particles, larger particle  
317 sizes and higher concentrations reduced creaminess (Kilcast and Clegg, 2002). Moreover, both the  
318 concentration and the particles size influenced grittiness (Imai et al., 1997), as well as the shape and surface  
319 of particles (Tyle, 1993; Engelen et al., 2005). Thus, a finer and rounded-shaped particle size for GSP  
320 could help to reduce the perceived sensation of granularity, which was one of sensory properties  
321 responsible for decreasing overall liking in the cheese prototypes. In agreement with data from the  
322 literature, GSP from both grape varieties contributes a sour taste and peculiar vegetable orto- and retro-  
323 olfactory sensations such as grassy, winy, fruity, citric, cereal, nut, toasted, and spicy (Pasqualone et al.,  
324 2014).

325

### 326 ***Effect of the Grape Skin Powder Addition on Consumers' Preference***

327 In studies about food acceptability, a critical question is, "To what extent the variation in perceived sensory  
328 characteristics influences consumer response?" (Bayarri et al., 2011). In certain cases, sensory differences  
329 among products do not affect the acceptability (Costell et al., 2010), while in other cases, the sensory  
330 properties strongly influence liking (Murray and Delahunty, 2000).

331 In the present study, the addition of GSP significantly affected the acceptability of the newly developed  
332 samples, inducing a decrease in the liking ratings for all considered sensory modalities ( $p < 0.05$ ). This

333 result is in complete agreement with Sant'Anna and collaborators (Sant'Anna et al., 2014), who recently  
334 reported a decrease in the liking for aroma, aftertaste, flavor and appearance in fettuccine pasta fortified  
335 with grape marc powder. Consumers' familiarity with conventional unfortified food (such as commercially  
336 available fettuccini pasta or soft cheese) and clear expectations about their sensory properties probably  
337 accounts for the low acceptability found for fortified versions of food (Wardle and Cooke, 2008;  
338 Sant'Anna et al., 2014). It is noteworthy that the level of familiarity with a food strongly influences its  
339 acceptability by consumers,

340 In agreement with our findings, Rinaldoni and colleagues (2014) also reported that the spreadable cheese-  
341 like product supplemented with the lowest degree of soybean proteins had the best hedonic performance in  
342 terms of overall liking. These results clearly show that the functionalization of products obtained by the  
343 addition of a powdery ingredient (i.e., powder) could negatively affect consumer liking; consequently, the  
344 amount of the added material is a crucial parameter when developing new prototypes. Moreover, the  
345 amount of powder which can be added without lowering liking below the level of acceptability depended  
346 on the considered matrix to which the powder is added. Our study indicated that in soft cow's cheeses,  
347 while the small amount of 0.8% was already the critical acceptability threshold in the case of cheeses  
348 prepared with *Barbera* GSP, consumers tolerated an amount of 1.6% of *Chardonnay* GSP in cheese  
349 without further negative effects on sample acceptability. It could be hypothesized that the violet marbling  
350 of *Barbera* samples appeared more unusual to consumers, who then became less inclined to compromise  
351 on flavor compared to those consumers who preferred the *Chardonnay* samples enriched at 0.8 and 1.6%.  
352 Because the difference between the two grape varieties was evident mainly considering the color of the  
353 marbling aspect, the color resulted the main sensory properties discriminating between the two blocks of  
354 samples. Similarly, a recent study (Braghieri et al., 2014) on the acceptability of Scamorza cheeses  
355 enriched with peptidolytic adjunct showed higher values of overall liking for standard samples compared to  
356 enriched samples. In some cases, the fortification of cheese with health related compounds did not play a  
357 significant role for the liking of color expressed by consumers (Bermúdez-Aguirre and Barbosa-Cánovas,  
358 2011). However, color influenced consumers' acceptability of low-fat cheeses with added annatto colorant  
359 (Wadhvani, and McMahon, 2012). Similarly, in the present study, the deviation from the white color



360 characterizing the reference sample compared to the marbling aspect of the enriched samples negatively  
361 impacted the latter's acceptability. Presumably, consumers perceived the intense violet and brown marbling  
362 characterizing samples with the highest amount of GSP (B2.4 and C2.4) as overly strange or not  
363 appropriate for a fresh cheese.

364

365

## CONCLUSIONS

366 Collecting sensory information allows to develop new fortified/enriched products with an increased  
367 probability to meet the consumers' acceptance, factor which could not be neglected especially when  
368 dealing with food products very familiar to consumers, such as in the case of cheese. This study showed the  
369 feasibility of developing soft cow's milk cheese enriched with grape skin powders (GSP). However, the  
370 amount of GSP added to cheeses resulted a critical parameter for the acceptability of innovative prototypes.  
371 To obtain satisfactory results in terms of consumers' hedonic responses, no more than 0.8% should be  
372 added to samples prepared with the red grape variety *Barbera*, while the threshold for samples prepared  
373 with the white grape variety *Chardonnay* should not exceed 1.6%. The fortification with GSP strongly  
374 influenced the sensory properties of new prototypes, particularly considering the texture and the  
375 appearance. High amounts of GSP were generally associated with an increase in the perceived marbling  
376 aspect, granularity, sandiness, sourness, saltiness and astringency. All samples were described as having a  
377 lactic flavor, but fortification generally added certain vegetable sensations (grassy, cereal, nuts) in  
378 combination with other sensations sometimes perceived as possible defects (earthy, animal, winy, varnish).  
379 For the fortification, the amount of GSP added played the main role in modifying the sensory properties of  
380 soft cheeses; however, also the grape variety was important for the color modifications, with the *Barbera*  
381 and *Chardonnay* samples being described with a violet and brown marbling aspect, respectively. This  
382 differentiation of the prototypes based on the grape variety tended to discriminate consumers into two  
383 groups with opposite preferences for violet and brown colored cheeses. Therefore, in our study, the grape  
384 variety (intended as a modifier of the product appearance, particularly in terms of color) represented an  
385 opportunity to differentiate cheeses. In future, a marketing strategy aiming to inform consumers about the  
386 addition powder from *Barbera* and *Chardonnay* GSP to cheeses could be developed and represent a good

387 opportunity to differentiate prototypes suitable to satisfy the needs of different consumer segments with  
388 opposing preferences. However, the optimization of the prototype is suitable, however, particularly  
389 considering (1) the reduction of the GSP particle size, possibly beyond the perception threshold, and (2) the  
390 improvement of the dispersion of GSP in the milk curd.

391 In conclusion, even probably cheese is not a good vehicle for fortification with GSP, the sensory- and  
392 consumer based adopted approach allowed us (1) to identify the effect of the addition of the GSP on the  
393 sensory properties of soft cheese, (2) to point out which sensory properties were detrimental for the product  
394 acceptability by consumers and (3) to obtain information to optimize the ingredient characteristics and the  
395 process conditions.

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#### ACKNOWLEDGMENTS

398 This research was supported by AGER (contract number 2010-2222). The authors thank the Fontanafredda  
399 and Clare winemaking factories for providing the grape pomace used in this study and the 21 assessors of  
400 the Italian National Cheese Taster Association (ONAF, Organizzazione Nazionale Assaggiatori  
401 Formaggio) for their participation in the Free Choice Profile evaluation.

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For Peer Review

504 **Table 1.** Descriptors used by experts divided on sensory modalities, number of occurrences of each  
 505 descriptor in the data set and number of occurrences of each construct.

Sensory Modality	Descriptor	Occurrences	O/SM <sup>1</sup>	Dim1 (39%)		Dim2 (15%)	
				+	-	+	-
Appearance	holes	5		0	0	0	0
	homogeneous_dough	2		1	0	0	0
	homogeneous_marbling	2		0	2	0	0
	marbling	3	31	0	3	0	0
	marbling_brown	7		0	6	0	0
	marbling_violet	4		0	2	0	0
	white	8		5	0	0	0
Odor	o-cereal	2		0	0	0	0
	o-citric	1		0	1	0	0
	o-cream	1		0	1	0	0
	o-earthy	1		0	1	0	0
	o-fruity	2		0	0	0	0
	o-grassy	1	30	0	0	0	0
	o-lactic	7		1	1	0	0
	o-nuts	2		0	0	0	0
	o-varnish	1		0	1	0	0
	o-winy	4		0	0	0	0
	o-yogurt	8		0	1	0	0
Taste and mouthfeel	bitter	7		1	1	1	0
	salty	6		0	3	0	0
	sour	11	36	0	5	1	0
	spicy	3		0	0	0	0
	sweet	5		2	1	0	0
	astringent	3		0	0	1	1
Flavor	f-acetic	1		0	0	0	0
	f-acetone	1		0	0	0	0
	f-ammonia	1		0	0	0	0
	f-animal	1		1	0	0	0
	f-citric	2		0	1	0	0
	f-cream	3		0	0	0	0
	f-earthy	1		0	1	0	0
	f-grassy	1		0	0	0	0
	f-lactic	8	35	1	0	0	0
	f-floury	2		0	0	0	0
	f-metallic	1		0	0	0	0
	f-nuts	2		0	1	0	0
	f-toasted	2		0	0	0	0
	f-vanilla	1		0	0	0	0
	f-winy	1		0	0	0	0
	f-yogurt	7		0	0	1	0
	f-overall intensity	1		0	0	0	0
Texture	adhesive	5		1	0	0	0
	compact	3		1	0	1	0
	creamy	2		0	0	2	0
	crumbly	1		0	0	0	1
	doughy	4		0	1	0	0
	elastic	5		1	0	0	0
	granular	5	41	0	2	0	1
	gummy	8		2	0	0	0
	sandy	3		0	0	2	0
	soft	1		0	1	0	0
	soluble	2		0	1	0	0
	sticky	1		0	0	0	0
	watery	1		0	0	0	0
<b>Total</b>	<b>54</b>	<b>173</b>	<b>173</b>	<b>17</b>	<b>37</b>	<b>9</b>	<b>3</b>

506  
 507 <sup>1</sup>O/SM = number of occurrences per sensory modality.  
 508 Descriptors with a vector loading  $\leq 0.7$  or  $\geq 0.7$  on the first two dimensions (Dim) of GPA have been  
 509 included.  
 510 A descriptor can have a loading on more than one axis.



511 **Table 2.** Overall liking and liking for appearance, odor, taste, flavor and texture of the cheese  
 512 samples expressed by 90 consumers.  
 513

Liking	Samples <sup>1</sup>							SEM	F	P
	B0.8	B1.6	B2.4	C0.8	C1.6	C2.4	STD			
appearance	4.9 <sup>bcd</sup>	4.6 <sup>de</sup>	4.3 <sup>e</sup>	5.3 <sup>b</sup>	5.1 <sup>bc</sup>	4.8 <sup>cd</sup>	7.1 <sup>a</sup>	0.18	36.34	<0.001
odor	5.5 <sup>b</sup>	5.4 <sup>bc</sup>	5.1 <sup>bc</sup>	5.4 <sup>b</sup>	5.4 <sup>bc</sup>	5.0 <sup>c</sup>	6.3 <sup>a</sup>	0.16	10.32	<0.001
taste	5.4 <sup>bc</sup>	5.1 <sup>bcd</sup>	4.8 <sup>d</sup>	5.4 <sup>b</sup>	5.1 <sup>bcd</sup>	5.0 <sup>cd</sup>	6.3 <sup>a</sup>	0.17	10.98	<0.001
flavor	5.3 <sup>bc</sup>	5.1 <sup>bc</sup>	5.0 <sup>c</sup>	5.4 <sup>b</sup>	5.1 <sup>bc</sup>	4.9 <sup>c</sup>	6.4 <sup>a</sup>	0.17	13.32	<0.001
texture	5.3 <sup>bcd</sup>	5.2 <sup>cd</sup>	5.0 <sup>d</sup>	5.6 <sup>b</sup>	5.6 <sup>bc</sup>	5.2 <sup>cd</sup>	6.5 <sup>a</sup>	0.17	12.85	<0.001
overall	5.2 <sup>bc</sup>	5.0 <sup>cde</sup>	4.8 <sup>de</sup>	5.5 <sup>b</sup>	5.2 <sup>bcd</sup>	4.7 <sup>e</sup>	6.4 <sup>a</sup>	0.17	3.97	<0.001

514

515 <sup>1</sup>Samples: B = *Barbera* grape variety, C = *Chardonnay* grape variety; 0.8 = 0.8 w grape skin  
 516 powders/w curd, 1.6 = 1.6 w grape skin powders/w curd, 2.4 w grape skin powders/w curd; STD =  
 517 control, not fortified.

518

519 SEM: standard error of the mean

520

521 Table shows results from 2-way mixed ANOVA models (fixed factor: product; random factor:  
 522 subject, interaction product/subject).

523

524 Different letters within a row indicate significant differences ( $p < 0.05$ ) between mean values.

525 Fisher's Least Significance Difference post hoc test was conducted on the data set of 90 subjects.

526

527 **Figure captions**

528

529 Fig. 1. Consensus maps obtained from General Procrustes Analysis (GPA) applied on the Free-  
530 Choice Profile data conducted with 21 experts. Individual configurations and sample's  
531 positioning are depicted. Descriptors with a vector loading  $\leq 0.7$  or  $\geq 0.7$  on the first two  
532 dimensions (Dim) are shown.

533 Individual attributes are indicated by the name of the attribute itself and the number of judge who  
534 used the descriptor.

535 Letters o- and f- : odor and flavor.

536 Samples: B = *Barbera* grape variety, C= *Chardonnay* grape variety, 0.8 = 0.8 w grape skin  
537 powders/w curd, 1.6 = 1.6 w grape skin powders/w curd, 2.4 w grape skin powders/w curd.

538

539 Fig. 2. Map obtained from Partial Least Square Regression (PLS) performed considering as X data  
540 set the sensory data from Free-Choice Profile and as Y data set the overall liking of 90 consumers.  
541 The first and the second percentage on each axis express the variability explained by the X and Y  
542 data set, respectively.

543 Descriptors with a vector loading  $\leq 0.7$  or  $\geq 0.7$  on the first two dimensions (Dim) of GPA have  
544 been included.

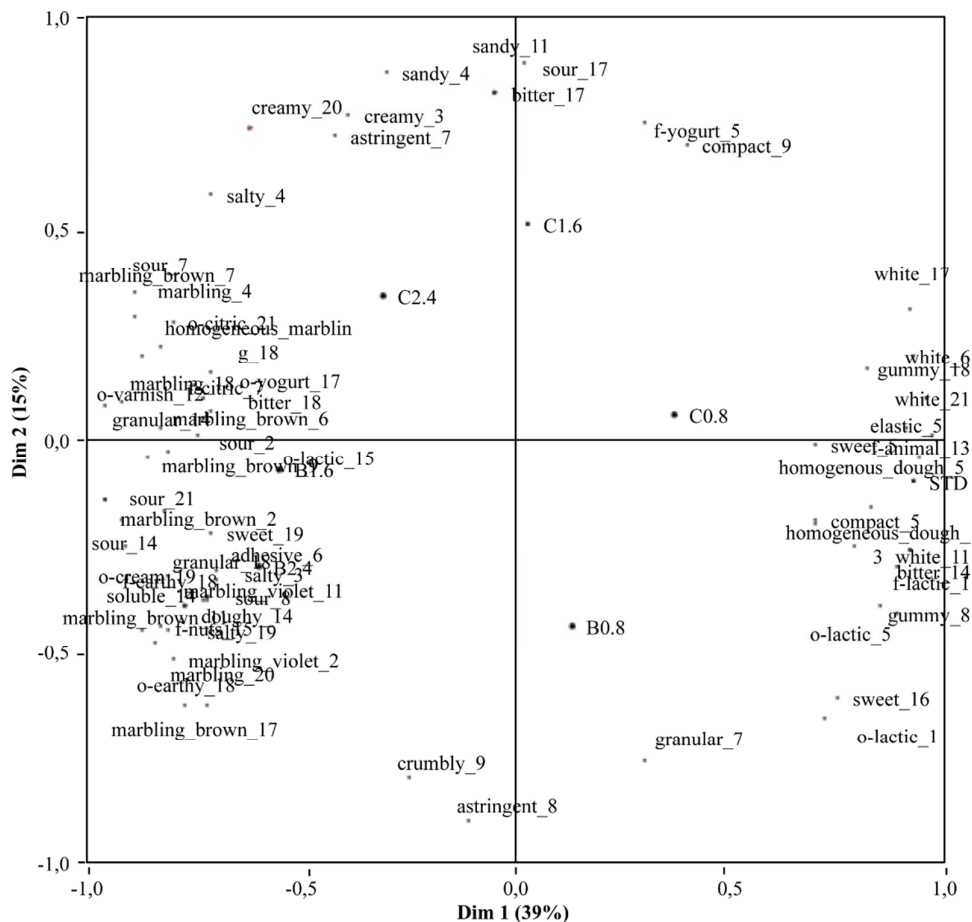
545 Individual attributes are indicated by the name of the attribute itself and the number of judge who  
546 used the descriptor.

547 Letters o- and f- : odor and flavor.

548 ● = Consumers

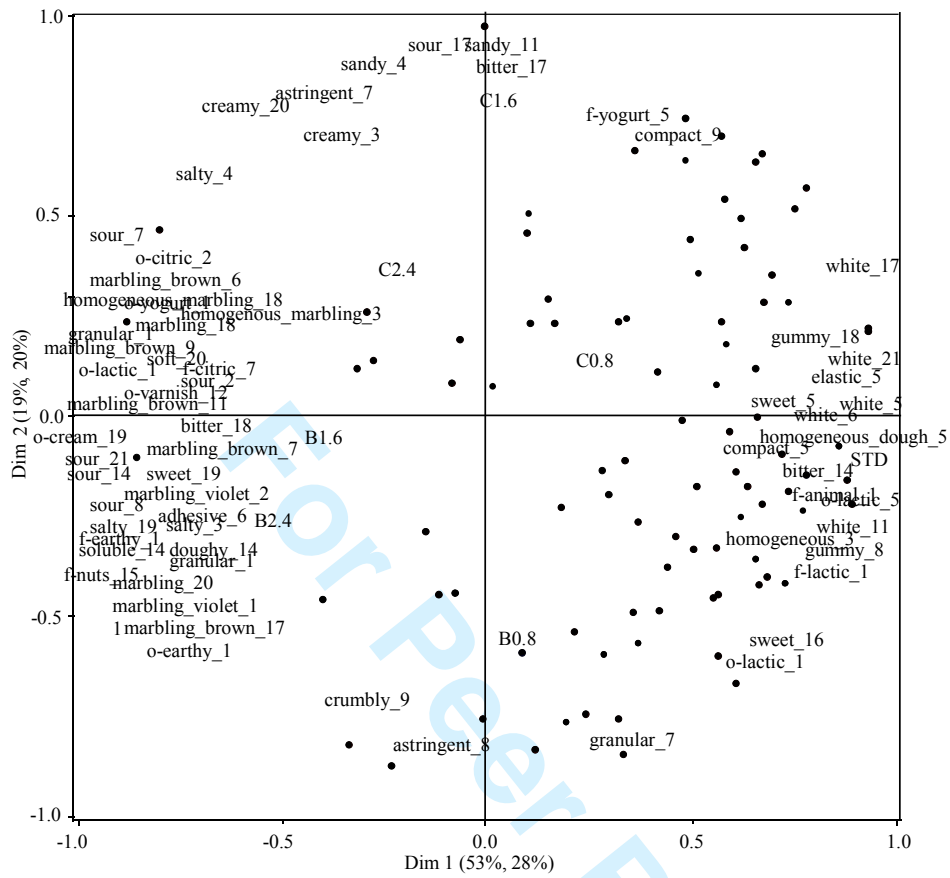
549 Samples: B = *Barbera* grape variety, C= *Chardonnay* grape variety, 0.8 = 0.8 w grape skin  
550 powders/w curd, 1.6 = 1.6 w grape skin powders/w curd, 2.4 w grape skin powders/w curd.

551 Torri Figure 1

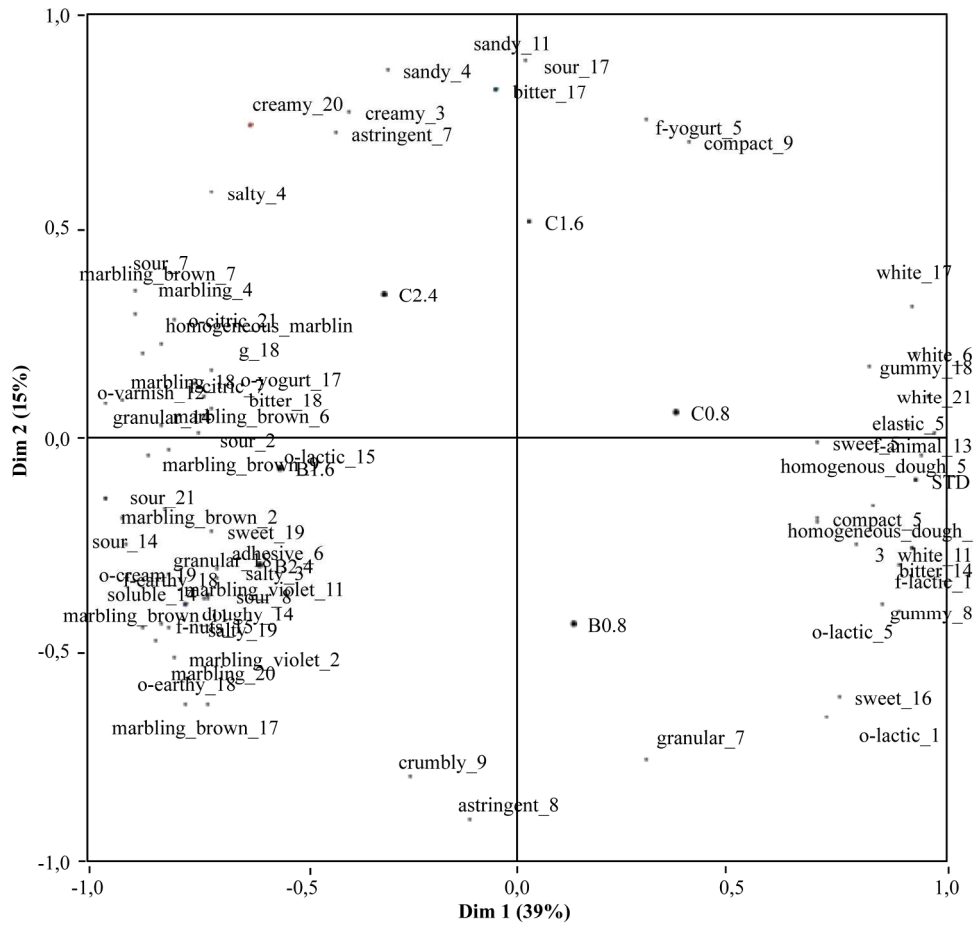


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569 Torri Figure 2

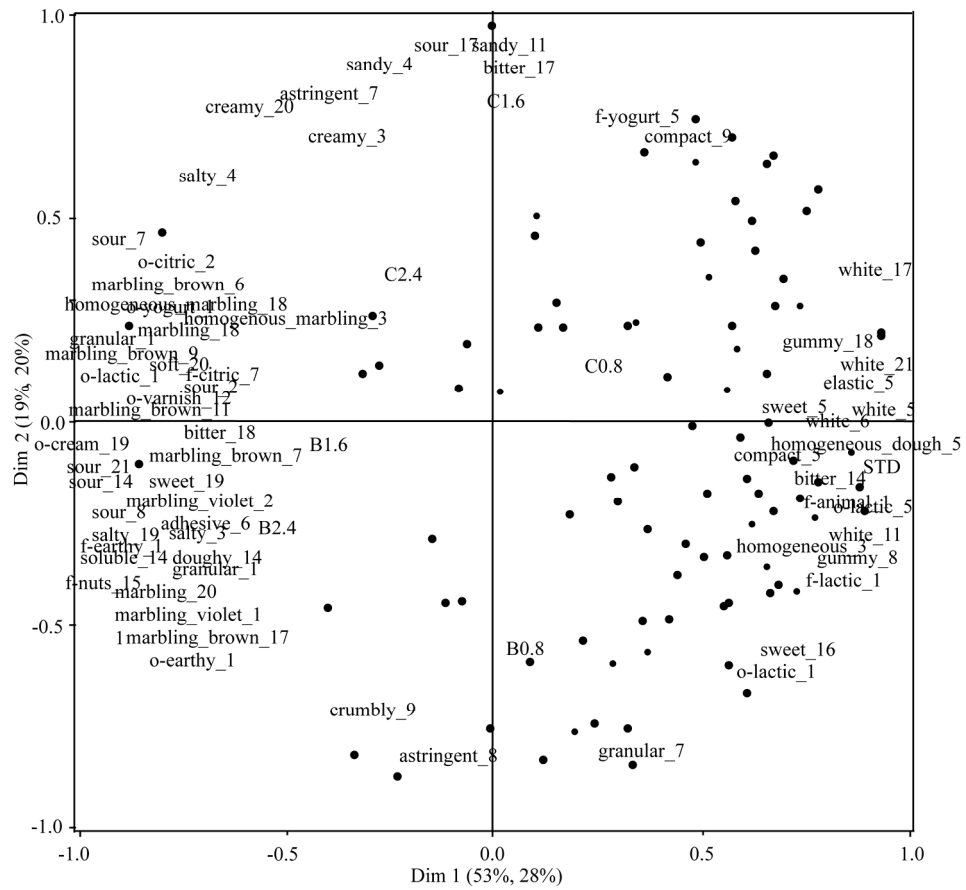


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190x179mm (300 x 300 DPI)





194x186mm (300 x 300 DPI)



1 | A sensory- and consumer based approach to optimize cheese enrichment ~~conditions~~with grape skin  
2 | powders

3 | **Torri**

4 | **Summary.** A sensory- and consumer based approach to optimize cheese enrichment conditions was  
5 | proposed. Innovative cheeses developed by adding grape skin powders (GSP) from winemaking process to  
6 | cow's milk curd were described by cheese taster experts and evaluated by consumers for their  
7 | acceptability. Even though cheese is not an optimal vehicle for GSP enrichment, the adopted approach  
8 | clearly ~~clearly underlined~~identified the effect of the addition of the GSP on the sensory properties of  
9 | cheese, ~~it~~ pointed out which sensory features were detrimental for the product acceptability and ~~it~~ allowed  
10 | to obtain suitable information ~~on how~~ to optimize the ingredient use and the process conditions.

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14 **SENSORY APPROACH FOR CHEESE OPTIMIZATION**15  
16 **A sensory- and consumer based approach to optimize cheese enrichment with grape skin powders**17  
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25 0172-45850026  
27 **ABSTRACT**28 The present study aimed to present a sensory- and consumer based approach to optimize cheese  
29 enrichment conditions with grape skin powders (GSP). The combined sensory evaluation approach,  
30 involving a descriptive and an affective test respectively, was applied to evaluate the effect of the addition  
31 of grape skin powders (~~GSP~~) from two grape varieties (*Barbera* and *Chardonnay*) at different levels (0.8,  
32 1.6 and 2.4% w powder/w curd) on the sensory properties and consumer acceptability of innovative soft  
33 cow's milk cheeses. The experimental plan envisaged seven products, six fortified prototypes (B0.8, B1.6,  
34 B2.4, C0.8, C1.6, and C2.4) and a control sample, having 1 week ripening. By means of a Free Choice  
35 Profile, 21 cheese experts described the sensory properties of prototypes. A Central Location Test with 90  
36 consumers was subsequently conducted to assess the acceptability of samples. The GSP enrichment  
37 strongly affected the sensory properties of innovative products, mainly considering the appearance and the  
38 texture. Fortified samples were typically described with a marbling aspect (violet or brown as function of  
39 the grape variety) and with an increased granularity, sourness, saltiness and astringency. The fortification



40 also contributed certain vegetable sensations perceived at low intensity (grassy, cereal, nuts), and some  
41 potential negative sensations (earthy, animal, winy, varnish). The white color, the homogenous dough, the  
42 compact and elastic texture and the presence of lactic flavors resulted the positive drivers of preference. On  
43 the contrary, the marbling aspect, granularity, sandiness, sourness, saltiness and astringency negatively  
44 affected the cheese acceptability for amounts of powder exceeding 0.8% and 1.6% for the *Barbera* and  
45 *Chardonnay* prototypes, respectively. Therefore, the amount of powder resulted a critical parameter for  
46 liking of fortified cheeses and a discriminant between the two varieties. Reducing the GSP particle size and  
47 improving the GSP dispersion in the curd would reduce the impact of powder addition on sensory  
48 properties, thereby encouraging the use of these polyphenol-based fortifiers in cheeses. The proposed  
49 approach allowed the identification of sensory properties critical for product acceptability by consumers  
50 thus helping the optimization of both fortifier characteristics and new cheese production and composition.

51

52 **Key Words:** consumer acceptability, free-choice profile, soft cheese, grape skin powder

53

54

## INTRODUCTION

55 Consumers are increasingly aware that food directly contributes to their health (Mollet and Rowland,  
56 2002), and the dairy market plays an active role in health and wellness (Brockman and Beeren, 2011). The  
57 use of functional ingredients represents one of the most important trends in dairy product technological  
58 innovation. Dairy product enrichment can include (1) fortification with micro-ingredients (isolated and  
59 purified high-value compounds) to enhance the nutritional value of the food or (2) addition of macro-  
60 ingredients (complex ingredients, composed by a mixture of components). Within the first category,  
61 several examples are available (Bermúdez-Aguirre and Barbosa-Cánovas, 2011; Rinaldoni et al., 2014;  
62 Stratulat et al., 2014). Recently, winery by-products, such as the grape pomace, were added as macro-  
63 ingredients to several foods to obtain novel functional food products enriched in terms of polyphenols and  
64 dietary fiber (Mildner-Szkudlarz et al., 2013; Yu and Ahmenda, 2013).

65 Several biological activities are reported for dietary fiber and polyphenols from grape pomace, and  
66 advantages from their use in dairy production processes, as well as in product quality, have been envisaged

67 (Zhu et al., 2014). Environmental sustainability (Augustin et al., 2013) and contributions to managing waste  
68 (Fontana et al., 2013) are similarly important factors encouraging the use of non-dairy products as  
69 ingredients in the dairy industry. To authors' knowledge, among dairy products grape pomace has been  
70 uniquely used to fortify yogurt (Karaaslan et al., 2011; Codaet et al., 2012) and salad dressing (Tseng and  
71 Zhao, 2013).

72 Beside the wide literature focusing on the advantages associated to the use of grape pomace as a food  
73 ingredient (Zhu et al., 2014; Yu and Ahmedna, 2013), there is a lack of information considering the  
74 sensory impact of this ingredient on food prototypes. Generally, the use of ingredients obtained by vegetal  
75 by-products to fortify or enrich foods contributes unpleasant sensations, which result detrimental for the  
76 overall quality (Braghieri et al., 2014; Ajila et al., 2010) and the acceptability (Rinaldoni et al., 2014; Marti  
77 et al., 2014) of food products. A limited number of studies took into account the effect of fortification with  
78 grape pomace on product sensory properties (Torri et al., 2015) and on its acceptability by consumers  
79 (Sant'Anna et al., 2014; Lavelli et al., 2014).

80 Health benefit belief from functional foods emerges as the strongest positive determinant of consumer  
81 willingness to compromise on taste (Verbeke, 2006). Moreover, considering the appeal of nutrition and  
82 health claims, significant interaction effects were found between claim type and the product concept,  
83 indicating that consumers differently react to the carrier product, functional ingredient and claims as  
84 function of the product concept (Verbeke et al., 2009).

85 Thus, implementing healthy properties without taking into account taste modifications and consumer  
86 response to the new fortified food appears a highly speculative and risky strategic option (Verbeke, 2006).  
87 This aspect deserves even more attention in the case of fortification/enrichment of familiar food. In fact,  
88 the more a consumer is familiar with the product the more a deviation from the expected sensory properties  
89 will negatively affect the consumer's response (Mildner-Szkudlarz et al., 2013). Based on these  
90 considerations, and given the importance of developing successful product for the food industry, it seems  
91 extremely important to include a consumer-based approach in product innovation and optimization process,  
92 in order to investigate the effect of the fortification/enrichment on acceptability and to increase the success  
93 probability of new products.

94 In the present study, a sensory- and consumer based approach to optimize cheese enrichment/fortification  
95 conditions was proposed and applied to an innovative cow's milk soft cheese developed by incorporating  
96 the grape skin powders (GSP) obtained from two grape varieties (*Barbera*, a red grape variety, and  
97 *Chardonnay*, a white grape variety) into the curd. The sensory- and consumer-based approach presented (1)  
98 evaluates the effect of enrichment conditions (type and concentration of added ingredient) on cheese  
99 sensory properties and (2) identifies the sensory drivers of the acceptability of the enriched soft cheeses  
100 developed in this study.

## 102 MATERIALS AND METHODS

### 103 *Products*

104 **Grape Skin Powders.** Grape pomace from non-fermented white *Vitis vinifera* cv *Chardonnay* was  
105 provided by the Fontanafredda winemaking factory (Serralunga d'Alba, Cuneo, Italy) while that from  
106 fermented red *Vitis vinifera* cv *Barbera* was provided by the Clarea winemaking factory (Chiomonte,  
107 Torino, Italy). The skins were mechanically separated, vacuum packaged and stored at -20 °C prior to  
108 being dried in an oven (Memmert, UFE 550, Schwabach, Germany) at 54 °C for 48 h and then ground with  
109 a Retsch ZM200 grinder (Retsch GmbH, Haan, Germany) to obtain grape skin powder (GSP) with a  
110 particle size of less than 250 µm.

111 **Cheese Samples.** Raw cow's milk (protein 3.5%, fat 3.6%, lactose 5.1%) was provided from a local  
112 farm, pasteurized at 72°C for 15 sec then added of calcium chloride (0.1% v/v) and mesophilic starter  
113 bacteria Lyofast MOSO60D (Clerici-Sacco, Cadorago, CO, I). Coagulation was performed at 38-40 °C  
114 with cow rennet (chimosine:pepsine 20:80; Clerici, Milan, Italy). After 30-40 min of resting, the curd was  
115 cut two times and left to stand for 10 min at 37°C. Ripening was performed at  $6 \pm 1^\circ\text{C}$  for 6 days. During  
116 ripening, each cheese was manually dry-salted. The obtained soft cheeses were fresh products similar to  
117 Robiola and considered as control sample (STD). Six samples of enriched cow's milk soft cheese were  
118 developed by incorporating GSP from *Barbera* (B) and *Chardonnay* (C) into the curd during the  
119 cheesemaking process. Three different percentages of powders (0.8, 1.6 and 2.4% w powder/w curd) were  
120 added directly to the curd before shaping and manually mixed. A preliminary production test showed that it

121 is not possible to obtain a cheese with a powder percentage higher than 2.5%, since cheeses were not able  
122 to maintain their shape. The enriched samples were codified as B0.8, B1.6, B2.4, C0.8, C1.6, and C2.4. In  
123 total, the study envisaged seven cheese samples. At the end of ripening, the obtained cheeses ( $250 \pm 10$  g)  
124 were cut in slices ( $5 \times 3 \times 1.5$  cm) at room temperature ( $20 \pm 1$  °C) approximately 20 minutes prior to each  
125 sensory evaluation. Slices were placed in transparent plastic cups (38 ml) and hermetically sealed with a  
126 clear plastic lid. Samples were identified with three digit codes, served in randomized and balanced order  
127 among subjects and evaluated at room temperature ( $20 \pm 1$  °C).

128

### 129 *Methods*

130 **Free Choice Profile.** A group of 21 expert cheese tasters voluntarily participated in one session of the  
131 Free Choice Profile. Assessors (M=13, F=8; aged from 24 to 70, mean age=55) were selected from among  
132 the tasters of the Italian National Cheese Taster Association (ONAF, Organizzazione Nazionale  
133 Assaggiatori Formaggio) and declared a cheese consumption greater than 3 times a week. The session  
134 lasted 120 minutes. Sensory analysts briefed the experts on the methodology and the tasting procedure. The  
135 Free Choice Profile session was divided in two parts separated by a 15-minute break. In the first part, a  
136 vocabulary describing the sensory characteristics of prototypes was developed. The procedure required the  
137 assessors to observe, smell and taste samples and describe the sensory characteristics of prototypes  
138 considering appearance, odor, taste, flavor, and texture freely using their own terms. Panelists were  
139 encouraged to use associative and cognitive terms, rather than quantitative or affective ones (such as good,  
140 bad, or intense). Next, the panelists were asked to select from their own list of self-elicited attributes those,  
141 which they considered the most discriminative among samples. Each assessor freely selected the number of  
142 attributes to use. In the second part, a new set of the same samples was served (with different codes and in  
143 a different order) and assessors were asked to taste the samples and rate the intensity of sensations  
144 described by the attributes they selected using a 9-point scale (1=extremely weak, 9=extremely intense).  
145 Thus, in agreement with literature (Guardia et al., 2010; Vit et al., 2011), assessors tasted each sample  
146 twice evaluating the intensity of the descriptors once. The sample codes and presentation order were  
147 randomized across assessors in the two parts of the session. Instructions required the assessors to rinse their

148 mouths with still water before the beginning of the test. After each sample, subjects rinsed their mouths  
149 with water, had plain crackers for 30 s and finally rinsed their mouths with water for a further 30 s.  
150 Subjects took a 1 min break between sample evaluations.

151 **Consumer Test.** A Central Location Test (CLT) with 90 consumers (M=43, F=47; aged from 18 to 70,  
152 mean age=43) was performed during the “Cheese 2013” International Cheese Exhibition (Bra, Cuneo,  
153 Italy). Consumers voluntarily participated in the sensory test. Demographic information (age: 18-35, 36-55,  
154 56-70; gender: M, F; nationality: Italian, non-Italian), socio-economic information (educational level:  
155 primary, high school, college, bachelor, other advanced degrees; occupational status: student, worker,  
156 retired, unemployed) and frequency of cheese consumption (once or less a week, 2-3 times a week, 4-5  
157 times a week, once a day, more than once a day) were collected. Participants received individual trays with  
158 the seven cheese samples and rinsed their mouths with still water before beginning the evaluation.  
159 Participants tasted the samples according to the tray presentation order and in blind conditions, without any  
160 information about the innovativeness of the cheeses in order to avoid a potential effect of the information  
161 on liking scores. Participants rated their liking for appearance, odor, taste, flavor, texture and overall liking  
162 using a 9-point hedonic scale (1=extremely dislike, 9=extremely like) (Peryam and Pilgrim, 1957). Cheese  
163 prototypes were served in a randomized and balanced order. The subjects followed the same rinsing  
164 procedure adopted in FCP.

165

#### 166 **Data Analysis**

167 **Free Choice Profile.** Data collected using the Free Choice Profile were submitted to Generalized  
168 Procrustes Analysis (GPA) to obtain a consensus map (Gower, 1975) by using the software Senstools v.  
169 1.2x (OP&P Product Research BV, Utrecht, Netherlands). To estimate the significance of the GPA results,  
170 a Permutation Test was carried out (500 permutations were conducted on the raw matrix) and the total  
171 accounted variance of first dimensions was considered.

172 **Consumer Test.** The effect of the amount of GSP on liking in terms of appearance, odor, taste, flavor,  
173 texture and overall liking was assessed using a 2-way ANOVA mixed model with interactions (fixed  
174 factor: GSP amount, 3 levels 0.8, 1.6, 2.4%; random factors: subjects). The effect of grape variety on

7

175 liking in terms of appearance, odor, taste, flavor, texture and overall liking was assessed using a 2-way  
176 ANOVA mixed model with interactions (fixed factor: grape variety, 2 levels *Barbera*, *Chardonnay*;  
177 random factors: subjects). A 2-way ANOVA mixed model with interactions was used to estimate the effect  
178 of the product on the overall liking and on liking in all sensory modalities (fixed factor: product, 7 levels;  
179 random factors: subjects). A Partial Least Square Regression (PLS) was performed for exploratory  
180 purposes, considering the sensory data from FCP as the X data set and the overall liking of 90 consumers  
181 as the Y data set. To select the most discriminating attributes, those with a loading equal to or greater than  
182 0.7 (absolute value) on the GPA consensus map for the first two principal Dimensions (Dim1 and/or Dim2)  
183 were selected to create the matrix. The PLS was performed using The Unscrambler X software, vers. 10.3  
184 (Camo Software AS, Norway). ANOVA analyses were conducted using SYSTAT software, version 13.1  
185 (Systat Software Inc, San José, USA).

186

187

## RESULTS

### *Cheese Sensory Properties*

189 Experts elicited 64 terms in total. The number of elicited attributes per subject ranged from a minimum of  
190 four to a maximum of 17 attributes. The average number of attributes elicited by experts was eight, in  
191 agreement with findings in the literature (Guàrdia et al., 2010). The initial list of attributes was reduced to  
192 achieve a unique list that comprehensively and accurately described the product space; redundant and/or  
193 less-cited terms were grouped on a semantic basis and/or eliminated. The final list consisted of 54  
194 descriptors classified according to sensory modality: appearance (7), aroma (11), taste and mouthfeel  
195 sensations (6), flavor (17) and texture (13) (Table 1). Analysis of occurrences showed that the most  
196 frequently elicited descriptors (cited by at least one third of experts at least 7 times) were: marbling brown,  
197 white, odor and flavor of lactic, odor and flavor of yogurt, bitter, sour and gummy.

198 Appearance resulted a key sensory modality for sample discrimination with a relatively low number of  
199 descriptors (7) and a relatively high number of occurrences (31). New prototypes were generally described  
200 by using terms related to the marbling aspect (marbling, brown marbling, violet marbling, homogeneous

201 marbling), homogenous dough, white color and by the presence of holes. The control sample was described  
202 as having a white color, in contrast to the fortified samples.

203 Taste and mouthfeel were described using four attributes for fundamental tastes (sour, bitter, sweet, salty)  
204 and the tactile sensation of astringency with 35 occurrences in total. Sourness was the most used taste,  
205 elicited by 11 out of 21 judges. Secondly, bitter and salty tastes were elicited seven and six times,  
206 respectively, both showing higher intensity scores in the enriched samples compared to the reference  
207 standard. Judges elicited astringency only three times. For two assessors this attribute had high loading  
208 values on the Dim2, but it was perceived in a contrasting way by judges.

209 Considering the olfactory sensations, judges used a high number of attributes to describe odor and flavor  
210 (11 and 17 terms, respectively). Among these descriptors, several terms described vegetable sensations  
211 (cereal, grassy, fruity, citric, nuts, vanilla), while other terms were not related to food and tended to have a  
212 negative connotation (earthy, varnish, ammonia, acetone, animal, metallic, winy). However, a low number  
213 of judges elicited odor and flavor sensations, and most of the sensations in this sensory modality occurred  
214 fewer than three times. The odor and flavor of lactic and the odor and flavor of yogurt were the only  
215 attributes with a number of occurrences equal to or higher than seven. These two sensations typically  
216 characterized the perception of cheese.

217 Texture was extremely important in discriminating among samples, showing the highest number of  
218 occurrences (41). Judges mainly used the attributes: gummy, adhesive, elastic and granular, with the last  
219 one clearly characterizing the enriched samples. The attributes sandy, creamy and compact had low  
220 occurrences but showed high loading values on the consensus map.

221 The experts' individual configurations were submitted to GPA. The Permutation Test indicated a  
222 probability of less than 0.05% that the consensus generated in the study could have arisen by chance. The  
223 consensus space obtained from GPA and applied to individual configuration is depicted in Fig. 1. The total  
224 variance explained by the first two dimensions accounted for 39 and 15% on Dim1 and Dim2, respectively.  
225 Samples were clearly discriminated according to the percentage of GSP along the Dim1. The reference  
226 sample was positively correlated to Dim1 and is highly correlated to white color, homogenous dough,  
227 gumminess, sweet, bitter and lactic sensations. Judges also detected an animal flavor in this sample.

228 Fortified samples tend to move on the left side of Dim1 as a function of their GSP content. In general,  
229 sourness, saltiness and bitterness tended to increase as a function of the amount of GSP added,  
230 independently from the grape variety.

231 The grape variety showed a significant effect on sensory properties along the Dim2. In particular, all  
232 samples containing *Barbera* GSP were on the lower part of the map, while samples with *Chardonnay* GSP  
233 spread in the upper quadrant of the map. The grape variety affects the prototype color and marbling  
234 descriptors (marbling, marbling violet, marbling brown) along Dim1. In particular, B2.4 and B1.6 were  
235 closely associated with intense violet marbling and samples C2.4 and C1.6 had a brown marbling  
236 appearance.

237 Grape variety also influenced the relative differences among samples fortified with increasing amounts of  
238 the same GSP. The perceived differences between C1.6 and C2.4 were greater than those detected between  
239 B1.6 and B2.4, as shown by the relative distance between samples on the map; specifically, the perceived  
240 difference was higher between C1.6 and C2.4 than between B1.6 and B2.4. It is possible to assume that the  
241 higher color intensity perceived in cheese prepared with 1.6 and 2.4% of *Barbera* GSP with respect to B0.8  
242 tend to suppress the perception of other sensory differences between this pair of samples. C0.8 and B0.8  
243 were shown to be quite similar in terms of appearance and texture, with B0.8 being associated with  
244 granularity and crumbliness sensations, while C0.8 was described as more gummy and having a clearer  
245 color. Samples C1.6 and C2.4 were positively correlated to the Dim2 and were primarily described as  
246 sandy, creamy, sour, bitter and astringent.

247

### 248 ***Cheese Liking***

249 Results from the 2-way mixed ANOVA model did not reveal a significant effect ( $F=0.921$ ;  $p=0.34$ ) of the  
250 grape variety on the overall liking expressed by all 90 consumers ( $B=5.0499\pm 0.10$ ;  $C=5.12\pm 0.10$ ). A  
251 significant effect of the GSP percentage on the overall liking was found ( $F=9.10$ ;  $p<0.01$ ). In particular, the  
252 overall liking significantly decreased with the increase of GSP: prototypes with the lowest percentage of  
253 GSP (0.8%) obtained the highest overall liking scores ( $5.34\pm 0.12$ ), while the prototypes with 2.4% of GSP  
254 were the least preferred ( $4.768\pm 0.13$ ). A significant effect of product ( $p<0.001$ ) was found on liking as



255 expressed by 90 consumers considering the appearance, odor, taste, flavor, texture and overall liking (Table  
256 2). The reference sample was the most liked according to scores relevant to all the sensory modalities. The  
257 addition of GSP to the cheese induced a significant decrease in liking ratings ( $p < 0.05$ ).

258 Accordingly to the overall liking ratings, all fortified samples ranged from ~~slightly disliked~~4.7 to ~~slightly~~  
259 ~~liked~~5.5 (Tab. 2). In particular, C0.8, B0.8 and C1.6 ~~were obtained~~ the ~~most highest lik~~averageed samples  
260 ~~scores, and~~ C2.4 ~~was received~~ the ~~least liked sample~~lowest mean value with no significant differences from  
261 samples B0.8 and B1.6. C0.8, C1.6 and B0.8 showed the highest ~~liking-mean~~ scores for the appearance.  
262 *Barbera* samples fortified with 1.6 and 2.4% of GSP tended to be the least ~~preferred~~liked samples in terms  
263 of the appearance. Results showed only slight differences among samples in liking for the aroma. Samples  
264 containing the lowest and intermediate GSP amount (B0.8, B1.6, C0.8, and C1.6) tended to be ~~more~~  
265 ~~liked~~preferred than B2.4 and C2.4 in terms of taste and flavor. Considering the texture, C0.8 had the ~~most~~  
266 ~~liked texture~~highest score, with the mean rate not significantly different from B0.8 and C1.6. Samples with  
267 the highest amount of GSP (B2.4, and C2.4) had the ~~least-lowest liked~~texture ratings, with a mean rate not  
268 significantly different from B0.8 and B1.6.

### 270 *Relationship between Sensory Properties and Hedonic Responses*

271 The map obtained by the PLS regression performed for exploratory purposes shows the relationship  
272 between the hedonic responses of 90 consumers and the sensory properties of the samples (Fig. 2). The  
273 map indicates consumers' clear preference for the reference sample, as shown by the high concentration of  
274 consumers positioned on the right part of the map. The sensory properties characterizing the standard  
275 tended to be the positive drivers of the overall liking, particularly the white color, the homogenous dough,  
276 the compact and elastic texture and the presence of lactic flavors. On the contrary, all sensations perceived  
277 at high intensity in samples with a high amount of GSP appeared to be negative drivers of overall liking,  
278 particularly for attributes describing the marbling appearance (violet and brown), the intense sourness and  
279 the perception of granularity and sandiness, together with some odors and flavors (varnish, earthy, citric).  
280 In general, the analysis of the preferences suggests the importance of reducing the sandiness and granular

281 sensations associated with the less liked cheeses to match consumers' preferences, as well as to reduce the  
282 perceived intensity of sourness.

283 Results showed an inverse relationship between the amount of GSP added and the acceptability of  
284 prototypes. In general, GSP addition clearly induced lower consumer liking for prototypes. This effect was  
285 more evident in B than C samples. In fact, liking strongly decreased as the amount of B GSP increased  
286 from 0.8 to 1.6%, whereas only a slight change in liking occurred for the same range of GSP variation in  
287 the C samples. Grape variety clearly affects consumer preference for fortified prototypes. In particular, a  
288 visual inspection of PLS regression plot shows that consumers tended to be almost equally distributed  
289 along the Dim2 between the upper and lower quadrants of the map. This finding suggested the presence of  
290 two distinct groups of subjects. One group, composed of the consumers located in the upper right quadrant,  
291 preferred the samples prepared with the white grape variety (*Chardonnay*). The other group, located in the  
292 lower right quadrant, tended to prefer samples prepared with the red grape variety (*Barbera*). Results  
293 confirmed this finding, by computing the mean overall liking ratings of the two separate groups (the first  
294 positioned in the right upper quadrant, the second in the lower right quadrant). Both groups preferred the  
295 standard sample but among the fortified samples, the former segment ~~rated as preferred~~ samples C1.6  
296 ( $6.326 \pm 0.22$ ) and C0.8 ( $5.495 \pm 0.273$ ) ~~as slightly pleasant~~, while the latter group preferred the cheese B0.8  
297 ( $5.667 \pm 0.24$ ).

## 299 DISCUSSION

### 300 *Effect of the Addition of Grape Skin Powder on Cheese Sensory Properties*

301 Considering the frequency of the occurrence of sensory attributes used in FCP, the most frequent attributes  
302 mentioned by experts were related to taste (sourness elicited by 11 out of 21 experts) and appearance,  
303 particularly the marbling aspect (16 elicitations in total considering marbling, violet marbling, brown  
304 marbling and homogenous marbling). These results confirm the importance of the visual inspection in the  
305 description and appreciation of food products (Dinnella et al., 2014). Authors partially explained this result  
306 by recalling that generally, visual attributes are easier to describe than the olfactory and gustative

307 sensations because vision and hearing are an inborn mechanism, whereas the other senses rely largely on  
308 learning (Köster, 2003).

309 The visual inspection of the consensus map obtained from the GPA clearly showed the strong effect of  
310 GSP fortification on the sensory properties of the new developed prototypes. Considering the appearance,  
311 the high amount of colored phenol compounds contained in red grape skins from *Barbera* and released  
312 from the GSP into the cheese induced a violet and brown marbling, a color that was not present in the  
313 reference sample. Other studies showed an analogous effect on food color induced by the use of phenol  
314 based winery by-products in biscuits (Mildner-Szkudlarz et al., 2013; Pasqualone et al., 2014). Moreover,  
315 the addition of GSP strongly affected the cheese texture. In particular, the granularity sensation perceived  
316 in the soft cheese was probably due the particle size of GSP used, which was under 250  $\mu\text{m}$ . This particle  
317 size is above the perception threshold, estimated approximately 25  $\mu\text{m}$  (Hintonet et al., 1970), and hard and  
318 irregular particles can produce gritty sensations, even at the lower size of 10  $\mu\text{m}$  (Utz, 1986). In agreement  
319 with our findings, the addition of solid particles in a food matrix increased the sensation of roughness and  
320 significantly decreased the ratings of a number of texture attributes, such as smooth, creamy, fatty and  
321 slippery (Engelen et al., 2005). Considering soft model systems containing solid particles, larger particle  
322 sizes and higher concentrations reduced creaminess (Kilcast and Clegg, 2002). Moreover, both the  
323 concentration and the particles size influenced grittiness (Imai et al., 1997), as well as the shape and surface  
324 of particles (Tyle, 1993; Engelen et al., 2005). Thus, a finer and rounded-shaped particle size for GSP  
325 could help to reduce the perceived sensation of granularity, which was one of sensory properties  
326 responsible for decreasing overall liking in the cheese prototypes. In agreement with data from the  
327 literature, GSP from both grape varieties contributes a sour taste and peculiar vegetable orto- and retro-  
328 olfactory sensations such as grassy, winy, fruity, citric, cereal, nut, toasted, and spicy (Pasqualone et al.,  
329 2014).

330

### 331 *Effect of the Grape Skin Powder Addition on Consumers' Preference*

332 In studies about food acceptability, a critical question is, "To what extent the variation in perceived sensory  
333 characteristics influences consumer response?" (Bayarri et al., 2011). In certain cases, sensory differences

334 among products do not affect the acceptability (Costell et al., 2010), while in other cases, the sensory  
335 properties strongly influence liking (Murray and Delahunty, 2000).

336 In the present study, the addition of GSP significantly affected the acceptability of the newly developed  
337 samples, inducing a decrease in the liking ratings for all considered sensory modalities ( $p < 0.05$ ). This  
338 result is in complete agreement with Sant'Anna and collaborators (Sant'Anna et al., 2014), who recently  
339 reported a decrease in the liking for aroma, aftertaste, flavor and appearance in fettuccine pasta fortified  
340 with grape marc powder. Consumers' familiarity with conventional unfortified food (such as commercially  
341 available fettuccini pasta or soft cheese) and clear expectations about their sensory properties probably  
342 accounts for the low acceptability found for fortified versions of food (Wardle and Cooke, 2008;  
343 Sant'Anna et al., 2014). It is noteworthy that the level of familiarity with a food strongly influences its  
344 acceptability by consumers,

345 In agreement with our findings, Rinaldoni and colleagues (2014) also reported that the spreadable cheese-  
346 like product supplemented with the lowest degree of soybean proteins had the best hedonic performance in  
347 terms of overall liking. These results clearly show that the functionalization of products obtained by the  
348 addition of a powdery ingredient (i.e., powder) could negatively affect consumer liking; consequently, the  
349 amount of the added material is a crucial parameter when developing new prototypes. Moreover, the  
350 amount of powder which can be added without lowering liking below the level of acceptability depended  
351 on the considered matrix to which the powder is added. Our study indicated that in soft cow's cheeses,  
352 while the small amount of 0.8% was already the critical acceptability threshold in the case of cheeses  
353 prepared with *Barbera* GSP, consumers tolerated an amount of 1.6% of *Chardonnay* GSP in cheese  
354 without further negative effects on sample acceptability. It could be hypothesized that the violet marbling  
355 of *Barbera* samples appeared more unusual to consumers, who then became less inclined to compromise  
356 on flavor compared to those consumers who preferred the *Chardonnay* samples enriched at 0.8 and 1.6%.

357 Because the difference between the two grape varieties was evident mainly considering the color of the  
358 marbling aspect, the color resulted the main sensory properties discriminating between the two blocks of  
359 samples. Similarly, a recent study (Braghieri et al., 2014) on the acceptability of Scamorza cheeses  
360 enriched with peptidolytic adjunct showed higher values of overall liking for standard samples compared to

361 enriched samples. In some cases, the fortification of cheese with health related compounds did not play a  
362 significant role for the liking of color expressed by consumers (Bermúdez-Aguirre and Barbosa-Cánovas,  
363 2011). However, color influenced consumers' acceptability of low-fat cheeses with added annatto colorant  
364 (Wadhvani, and McMahon, 2012). Similarly, in the present study, the deviation from the white color  
365 characterizing the reference sample compared to the marbling aspect of the enriched samples negatively  
366 impacted the latter's acceptability. Presumably, consumers perceived the intense violet and brown marbling  
367 characterizing samples with the highest amount of GSP (B2.4 and C2.4) as overly strange or not  
368 appropriate for a fresh cheese.

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### CONCLUSIONS

371 Collecting sensory information allows to develop new fortified/enriched products with an increased  
372 probability to meet the consumers' acceptance, factor which could not be neglected especially when  
373 dealing with food products very familiar to consumers, such as in the case of cheese. This study showed the  
374 feasibility of developing soft cow's milk cheese enriched with grape skin powders (GSP). However, the  
375 amount of GSP added to cheeses resulted a critical parameter for the acceptability of innovative prototypes.  
376 To obtain satisfactory results in terms of consumers' hedonic responses, no more than 0.8% should be  
377 added to samples prepared with the red grape variety *Barbera*, while the threshold for samples prepared  
378 with the white grape variety *Chardonnay* should not exceed 1.6%. The fortification with GSP strongly  
379 influenced the sensory properties of new prototypes, particularly considering the texture and the  
380 appearance. High amounts of GSP were generally associated with an increase in the perceived marbling  
381 aspect, granularity, sandiness, sourness, saltiness and astringency. All samples were described as having a  
382 lactic flavor, but fortification generally added certain vegetable sensations (grassy, cereal, nuts) in  
383 combination with other sensations sometimes perceived as possible defects (earthy, animal, winy, varnish).  
384 For the fortification, the amount of GSP added played the main role in modifying the sensory properties of  
385 soft cheeses; however, also the grape variety was important for the color modifications, with the *Barbera*  
386 and *Chardonnay* samples being described with a violet and brown marbling aspect, respectively. This  
387 differentiation of the prototypes based on the grape variety tended to discriminate consumers into two

388 groups with opposite preferences for violet and brown colored cheeses. Therefore, in our study, the grape  
389 variety (intended as a modifier of the product appearance, particularly in terms of color) represented an  
390 opportunity to differentiate cheeses. In future, a marketing strategy aiming to inform consumers about the  
391 addition powder from *Barbera* and *Chardonnay* GSP to cheeses could be developed and represent a good  
392 opportunity to differentiate prototypes suitable to satisfy the needs of different consumer segments with  
393 opposing preferences. However, the optimization of the prototype is suitable, however, particularly  
394 considering (1) the reduction of the GSP particle size, possibly beyond the perception threshold, and (2) the  
395 improvement of the dispersion of GSP in the milk curd.

396 In conclusion, even probably cheese is not a good vehicle for fortification with GSP, the sensory- and  
397 consumer based adopted approach allowed us (1) to identify the effect of the addition of the GSP on the  
398 sensory properties of soft cheese, (2) to point out which sensory properties were detrimental for the product  
399 acceptability by consumers and (3) to obtain information to optimize the ingredient characteristics and the  
400 process conditions.

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#### ACKNOWLEDGMENTS

403 This research was supported by AGER (contract number 2010-2222).The authors thank the Fontanafredda  
404 and Clare winemaking factories for providing the grape pomace used in this study and the 21 assessors of  
405 the Italian National Cheese Taster Association (ONAF, Organizzazione Nazionale Assaggiatori  
406 Formaggio) for their participation in the Free Choice Profile evaluation.

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For Peer Review

509 **Table 1.** Descriptors used by experts divided on sensory modalities, number of occurrences of each  
 510 descriptor in the data set and number of occurrences of each construct.

Sensory Modality	Descriptor	Occurrences	O/SM <sup>1</sup>	Dim1 (39%)		Dim2 (15%)	
				+	-	+	-
Appearance	holes	5		0	0	0	0
	homogeneous_dough	2		1	0	0	0
	homogeneous_marbling	2		0	2	0	0
	marbling	3	31	0	3	0	0
	marbling_brown	7		0	6	0	0
	marbling_violet	4		0	2	0	0
	white	8		5	0	0	0
Odor	o-cereal	2		0	0	0	0
	o-citric	1		0	1	0	0
	o-cream	1		0	1	0	0
	o-earthy	1		0	1	0	0
	o-fruity	2		0	0	0	0
	o-grassy	1	30	0	0	0	0
	o-lactic	7		1	1	0	0
	o-nuts	2		0	0	0	0
	o-varnish	1		0	1	0	0
	o-winy	4		0	0	0	0
	o-yogurt	8		0	1	0	0
	Taste and mouthfeel	bitter	7		1	1	1
salty		6		0	3	0	0
sour		11	36	0	5	1	0
spicy		3		0	0	0	0
sweet		5		2	1	0	0
astringent		3		0	0	1	1
Flavor	f-acetic	1		0	0	0	0
	f-acetone	1		0	0	0	0
	f-ammonia	1		0	0	0	0
	f-animal	1		1	0	0	0
	f-citric	2		0	1	0	0
	f-cream	3		0	0	0	0
	f-earthy	1		0	1	0	0
	f-grassy	1		0	0	0	0
	f-lactic	8	35	1	0	0	0
	f-floury	2		0	0	0	0
	f-metallic	1		0	0	0	0
	f-nuts	2		0	1	0	0
	f-toasted	2		0	0	0	0
	f-vanilla	1		0	0	0	0
	f-winy	1		0	0	0	0
	f-yogurt	7		0	0	1	0
	f-overall intensity	1		0	0	0	0
Texture	adhesive	5		1	0	0	0
	compact	3		1	0	1	0
	creamy	2		0	0	2	0
	crumbly	1		0	0	0	1
	doughy	4		0	1	0	0
	elastic	5		1	0	0	0
	granular	5	41	0	2	0	1
	gummy	8		2	0	0	0
	sandy	3		0	0	2	0
	soft	1		0	1	0	0
	soluble	2		0	1	0	0
	sticky	1		0	0	0	0
	watery	1		0	0	0	0
	Total	54	173	173	17	37	9

511  
 512 <sup>1</sup>O/SM = number of occurrences per sensory modality.

513 Descriptors with a vector loading  $\leq 0.7$  or  $\geq 0.7$  on the first two dimensions (Dim) of GPA have been  
 514 included.

515 A descriptor can have a loading on more than one axis.

516 **Table 2.** Overall liking and liking for appearance, odor, taste, flavor and texture of the cheese  
 517 samples expressed by 90 consumers.

518

Liking	Samples <sup>1</sup>						STD	SEM	F	P
	B0.8	B1.6	B2.4	C0.8	C1.6	C2.4				
appearance	4.93 <sup>bcd</sup>	4.586 <sup>de</sup>	4.283 <sup>e</sup>	5.282 <sup>b</sup>	5.061 <sup>bc</sup>	4.82 <sup>cd</sup>	7.10 <sup>a</sup>	0.18	36.34	<0.001
odor	5.462 <sup>b</sup>	5.364 <sup>bc</sup>	5.14 <sup>bc</sup>	5.43 <sup>b</sup>	5.384 <sup>bc</sup>	5.00 <sup>c</sup>	6.33 <sup>a</sup>	0.16	10.32	<0.001
taste	5.372 <sup>bc</sup>	5.061 <sup>bcd</sup>	4.768 <sup>d</sup>	5.44 <sup>b</sup>	5.13 <sup>bcd</sup>	4.985.0 <sup>cd</sup>	6.293 <sup>a</sup>	0.17	10.98	<0.001
flavor	5.263 <sup>bc</sup>	5.091 <sup>bc</sup>	5.00 <sup>c</sup>	5.42 <sup>b</sup>	5.061 <sup>bc</sup>	4.94 <sup>c</sup>	6.44 <sup>a</sup>	0.17	13.32	<0.001
texture	5.34 <sup>bcd</sup>	5.21 <sup>cd</sup>	5.04.96 <sup>d</sup>	5.62 <sup>b</sup>	5.56 <sup>bc</sup>	5.172 <sup>cd</sup>	6.52 <sup>a</sup>	0.17	12.85	<0.001
overall	5.20 <sup>bc</sup>	4.995.0 <sup>cde</sup>	4.787 <sup>de</sup>	5.472 <sup>b</sup>	5.152 <sup>bcd</sup>	4.74 <sup>c</sup>	6.394 <sup>a</sup>	0.17	3.97	<0.001

519 <sup>1</sup>Samples: B = *Barbera* grape variety, C = *Chardonnay* grape variety; 0.8 = 0.8 w grape skin  
 520 powders/w curd, 1.6 = 1.6 w grape skin powders/w curd, 2.4 w grape skin powders/w curd; STD =  
 521 control, not fortified.

522  
 523 SEM: standard error of the mean

524  
 525 Table shows results from 2-way mixed ANOVA models (fixed factor: product; random factor:  
 526 subject, interaction product/subject).

527  
 528 Different letters within a row indicate significant differences ( $p < 0.05$ ) between mean values.  
 529 Fisher's Least Significance Difference post hoc test was conducted on the data set of 90 subjects.

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 531

532 **Figure captions**

533

534 Fig. 1. Consensus maps obtained from General Procrustes Analysis (GPA) applied on the Free-  
535 Choice Profile data conducted with 21 experts. Individual configurations and sample's  
536 positioning are depicted. Descriptors with a vector loading  $\leq 0.7$  or  $\geq 0.7$  on the first two  
537 dimensions (Dim) are shown.

538 Individual attributes are indicated by the name of the attribute itself and the number of judge who  
539 used the descriptor.

540 Letters o- and f- : odor and flavor.

541 Samples: B = *Barbera* grape variety, C= *Chardonnay* grape variety, 0.8 = 0.8 w grape skin  
542 powders/w curd, 1.6 = 1.6 w grape skin powders/w curd, 2.4 w grape skin powders/w curd.

543

544 Fig. 2. Map obtained from Partial Least Square Regression (PLS) performed considering as X data  
545 set the sensory data from Free-Choice Profile and as Y data set the overall liking of 90 consumers.  
546 The first and the second percentage on each axis express the variability explained by the X and Y  
547 data set, respectively.

548 Descriptors with a vector loading  $\leq 0.7$  or  $\geq 0.7$  on the first two dimensions (Dim) of GPA have  
549 been included.

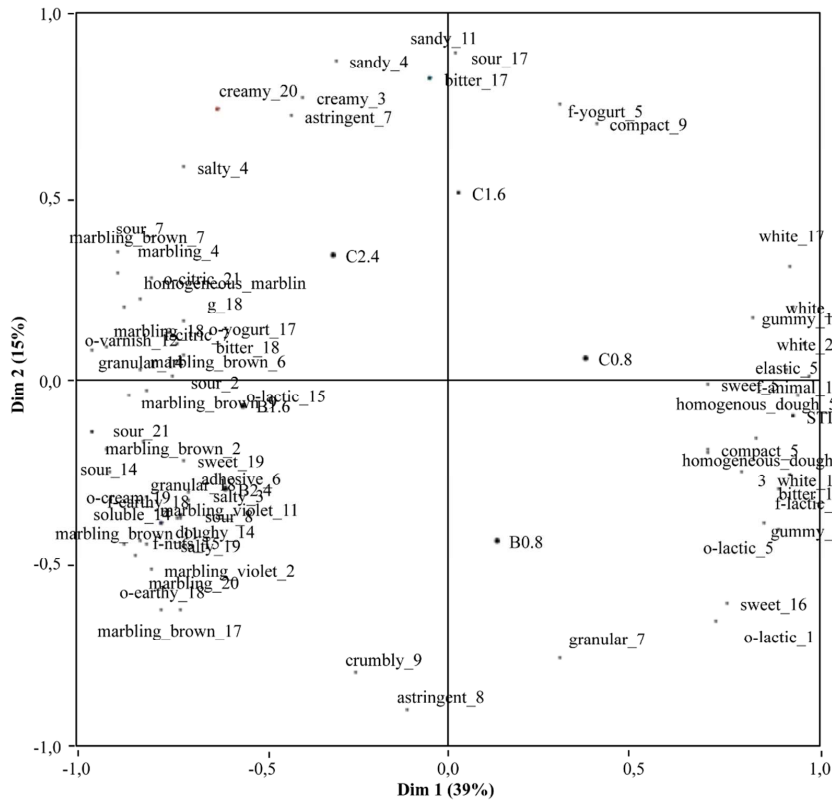
550 Individual attributes are indicated by the name of the attribute itself and the number of judge who  
551 used the descriptor.

552 Letters o- and f- : odor and flavor.

553 ● = Consumers

554 Samples: B = *Barbera* grape variety, C= *Chardonnay* grape variety, 0.8 = 0.8 w grape skin  
555 powders/w curd, 1.6 = 1.6 w grape skin powders/w curd, 2.4 w grape skin powders/w curd.

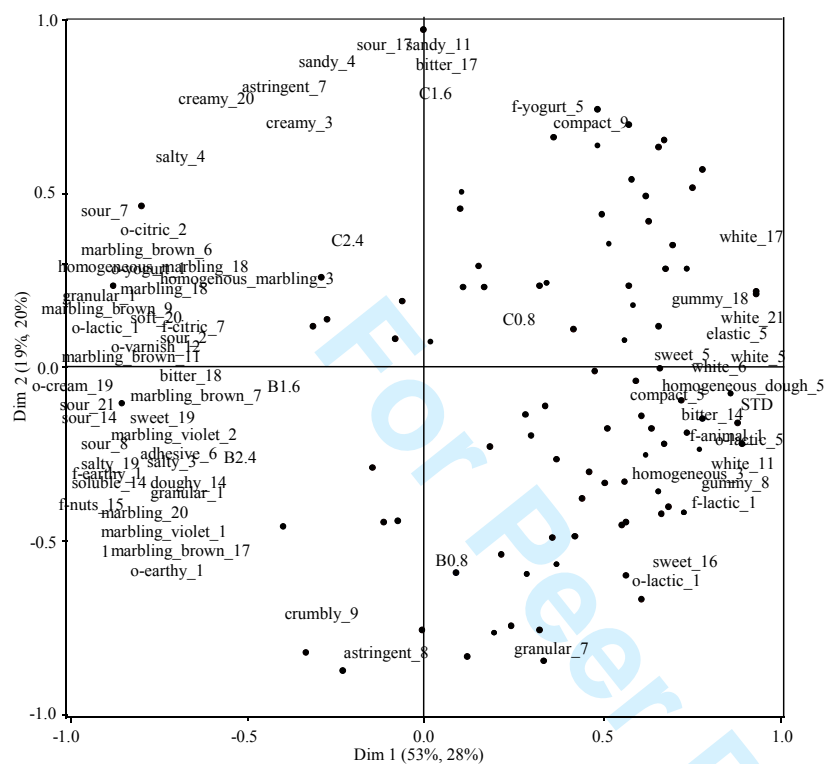
556 Torri Figure 1



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Review

574 Torri Figure 2



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