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► To cite this version:

Mathilde M. Causse, Chloé Friguet, Clément Coiret, Mélanie Lépicier, Brigitte Navez, et al.. Consumer Preferences for Fresh Tomato at the European Scale: A Common Segmentation on Taste and Firmness. *Journal of Food Science*, 2010, 75 (9), pp.S531-S541. 10.1111/j.1750-3841.2010.01841.x . hal-00910339

HAL Id: hal-00910339

<https://hal.science/hal-00910339v1>

Submitted on 27 Nov 2013

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1 **Consumer Preferences for Fresh Tomato at the European Scale : a Common**
2 **Segmentation on Taste and Firmness**

3

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25 *Short title* : **European consumer preference for Tomato**

26 *Journal section* : *Sensory and Food Quality*

27 **Abstract**

28 Although tomato flavour has not been a major goal for breeders, nowadays it becomes
29 important as it is a subject of consumer complaint. A better knowledge of tomato consumer
30 preferences, at the European level, should provide the basis for improvement of fruit quality
31 and for market segmentation. In the framework of a large European project, 806 consumers
32 from three countries, The Netherlands, France and Italy, were presented with a set of 16
33 varieties representing the diversity of fresh tomato offer in order to evaluate their
34 preferences. In parallel, sensory profiles were constructed by expert panels in each country.
35 Preference maps were then constructed in each country revealing the structure of consumer
36 preferences and allowing identification of the most important characteristics. Then a global
37 analysis revealed that preferences were quite homogeneous across countries.

38 This study identified the overall flavour and firmness as the most important traits for
39 improving tomato fruit quality. It showed that consumer preferences from different European
40 countries, with different cultures and food practices, are segmented following similar patterns
41 when projected onto a common referential plan. Moreover the results clearly showed that
42 diversification of taste and texture is required to satisfy all consumers' expectations as some
43 consumers preferred firm tomatoes, while other preferred melting ones and were more or
44 less demanding in terms of sweetness and flavour intensity. Detailed comparisons also
45 showed the importance of the fruit appearance in consumer preference.

46

47 **Key words** : consumer acceptance, descriptive analysis, external preference, sensory
48 analysis, internal preference Mapping; tomato

49 **Practical application**

50 The consumer preferences for fresh market tomato were studied in three European
51 countries. The main descriptors for further breeding for consumer satisfaction were identified.
52 Four clusters of consumers were identified in the overall analysis, the three countries
53 contributing the same way to each cluster. The impact of appearance in the preferences was
54 also underlined.

55 **Introduction**

56 Tomato is the primary vegetable produced and consumed in the world after potato. In
57 Europe, consumption varies greatly between countries with a clear gradient from the south to
58 the north, with for instance 42 and 15 kg/capita/year consumed in Italy and the Netherlands,
59 respectively (<http://faostat.fao.org/>). Since the 1990's and concomitantly with, on the one
60 hand the availability of tomato all year long and on the other hand a move towards much
61 firmer fruit, consumers tend to complain about tomato taste (Hobson 1988; Bruhn and others
62 1991), often blaming modern cultivars for lack of flavour. Until recently, quality was not the
63 main objective for tomato breeders who first improved yield, adaptation to specific growth
64 conditions, disease resistances and fruit shelf life. As sensory quality has become an
65 important objective, breeders need clear targets and tools to improve fruit quality. Tomato
66 fruit quality for fresh consumption is determined by a set of attributes, describing external
67 (size, colour, firmness) and internal (flavour, aroma, texture) properties. Sensory analysis is
68 an efficient way of describing these internal properties and to analyse consumer preferences.
69 Relationships between tomato taste and fruit characteristics have been widely studied.
70 Flavour is mostly due to the content in sugars and acids (Stevens and others 1977), to their
71 ratio (Stevens and others 1979; Bucheli and others 1999), and to volatile aromas. More than
72 400 volatiles have been identified (reviewed by Petro-Turza 1987), about 30 of them
73 contributing to the particular aroma of tomato fruit. Sweetness and sourness are related to
74 sugar and acid content (Stevens and others 1977; Janse and Schols 1995; Malundo and
75 others 1995). Both sugars and acids contribute to the sweetness and to the overall aroma
76 intensity (Baldwin and others 1998). Texture traits are more difficult to relate to instrumental
77 measurements, although firmness perceived when eating is partly related to compression
78 tests (Causse and others 2002), and mealiness can be related to the texture parameters of
79 the pericarp (Verkeke and others 1998; Devaux and others 2005; Chaib and others 2007).
80 Genetic variability for quality traits has been reviewed by Davies and Hobson (1981) and
81 Stevens (1986), whilst Dorais and others (2001) reviewed the impact of environmental
82 conditions in greenhouse production. Genetic variation has been identified for every quality

83 components (Davies and Hobson 1981; Langlois and others 1996; Causse and others 2003;
84 Tikunov and others 2005). Most of the studies on genetic variation in fresh tomato quality
85 describe a few cultivars or compare groups of cultivars (cherry, cocktail, beef types), and
86 preferences of consumers faced with genetic variability have rarely been studied. Cherry
87 tomatoes, with fruits rich in acids and sugars, are usually preferred (Hobson and Bedford
88 1989). In contrast, long shelf life cultivars have been described as less tasty than traditional
89 ones (Jones 1986), with lower volatile content (Baldwin and others 1991). Analysis of trait
90 inheritance shows a polygenic control of most of the traits (Stevens 1986; Causse and
91 others 2003).

92 Several studies have been set up to identify the most important characteristics for consumer
93 preferences. Acceptable tomato fruit must be high in tomato-like aroma intensity and in
94 sweetness, but intermediate in acidity (Jones 1986; Baldwin and others 1998, Alonso and
95 others, 2010). Malundo and others (1995) show that given levels of sweetness correspond to
96 optimal acid concentrations, beyond which acceptability decreases. Baldwin and others
97 (1998) relate the overall acceptability to the ratio of sugars to titratable acidity, and to the
98 concentration of several aroma compounds. Verkeke and others (1998) underline the role of
99 texture traits in the preference of consumers. Causse and others (2003) show that consumer
100 preference for fruit firmness reaches an optimum that can be obtained in hybrids between
101 firm modern and traditional soft varieties. By comparing consumer preferences, sensory
102 profiles and physico-chemical attributes, several groups of consumers differing in their liking
103 of tomato varieties have been identified, mainly differentiated by sweetness and tomato
104 flavour on the one hand and firmness on the other hand (Lê and Ledauphin 2006; Lengard
105 and Kermit 2006).

106 The present experiment aimed at comparing the consumer preferences across three
107 European countries. More than 800 consumers from the Netherlands, France and Italy were
108 presented with a set of 16 varieties representing the diversity of tomato available in the
109 market in order to evaluate their preferences. In parallel, sensory profiles were established
110 by trained sensory panels in each country. Preference maps were constructed and cluster

111 analysis revealed the structure of consumer preferences in each country and allowed
112 identification of the major traits to improve in order to satisfy the diversity of consumer tastes.
113 The results obtained in one country, Italy, are presented in detail in Sinesio and others
114 (2010). We thus herein present briefly the results obtained in France and the Netherlands
115 and then the global analysis of the data obtained in the three countries. Comparison of
116 sensory profiling strategies is also performed.

117

118

119 **Materials and Methods**

120

121 ***Plant Materials***

122 Nineteen cultivars were grown but only 16 were tested in each country (Table 1), 13 were
123 tested in the three countries, 3 were tested in two countries, and 3 were tested in only one
124 country. Eight cultivars were grown in the Netherlands and 11 in France (5 in grower's
125 greenhouse from the West and 6 from growers in the South East). Fruits were harvested in
126 each location over 3 consecutive weeks in June 2007 and were sent successively to the
127 Netherlands, to Italy and to France. The tomatoes were selected primarily from the harvest
128 site before being transported to the test locations. The harvests took place on Wednesday
129 and Thursday of the previous week at a level of maturity of 7-8 on a 11-point color scale and
130 travelled for a maximum of 5 to 7 days. The level when tasting was 10-11. The fruit selection
131 ensured the minimum variation within a cultivar in colour, size and firmness.

132 The latter is regarded as the most important criterion. An ideal firmness was determined by a
133 gentle finger pressure which should give only a slight indentation on the locular cavity wall,
134 but be firm between the cavity walls. Although the primary selection was done, the sample
135 quality was also checked at each test locations. Tomatoes which greatly differed from the
136 other fruits of a cultivar in size or colour, or physically damaged/ bruised during the
137 transportation were removed.

138 A sufficiently large number of fruits was sent to select batches of fruits homogenous for size
139 and color within each cultivar. After harvest, fruits were stored at 12°C, and were taken out to
140 acclimatise to room temperature a day prior to the evaluation.

141

142 ***Sensory evaluations***

143 To evaluate the sensory characteristics of the tomatoes, the sensory panels were trained by
144 an adapted Quantitative Descriptive Analysis (QDA®) methodology during 4 (in Italy) to 6 (in
145 France and Netherlands) training sessions. Performances of the panel have been controlled
146 during the last training session, where the consensus, accuracy and repeatability of the
147 results were validated as described in Sinesio and others (2007) and Lê and Ledauphin
148 (2006). Trained sensory panels were composed of 15 assessors in France, 8 in Italy and 10
149 in the Netherlands. These panels were already specifically trained for the evaluation of
150 tomatoes. Tasting sessions took place in sensory analysis laboratories (AFNOR XP V09-
151 105), in white light, at a temperature of 22°C ± 2°C. The samples were removed of the stalk
152 and crown, washed with cold running water dried with a paper towel. A whole tomato was
153 presented per sample in a plastic plate. The samples were presented as a blind man
154 (identified by codes with 3 random numbers), in a monadic mode, and in a complete
155 balanced experimental plan. The presentation orders were optimised in order to limit the
156 order effect.

157 As panellists in each country had previously generated a list of descriptive terms for tomato
158 texture and flavour and had consensus definitions for each attribute (Lê and Ledauphin 2006;
159 Sinesio and others 2007), a set of 8 descriptors common to the three countries was used but
160 specific descriptors familiar to the assessors were added in each country (**Table 2**).

161 Each panel was free to adopt its own glossary and evaluation scale to avoid changing their
162 habits. They all attended several pre-testing sessions during which they familiarised with the
163 test samples and experienced the range of variation of each sensory descriptor. Descriptors
164 were selected for being perceived as appropriate to the product and quantitatively different in
165 the sample set. In France the panel tasted 16 cultivars in 2 days (8 products tasted per day

166 in 2 sessions separated by a 15' break) and gave a score from 0 to 10. Each product was
167 thus tasted once by each panellist. In Italy and the Netherlands, the 16 cultivars were tasted
168 twice by each panellist and scores were noted on a scale from 0 ("nul") to 9 ("strong").

169

170 ***Consumer tests***

171 Consumer tests were performed in 2 or 3 locations per country, in Avignon, Paris and
172 Rennes in France (304 consumers), in Milan and Naples in Italy (179 consumers) and in
173 Delft, Heerlen and Utrecht in the Netherlands (323 consumers), for a total of 806 consumers.

174 The consumers met the following criteria: They had to be regular consumers of (fresh) salad
175 tomatoes (with a minimum frequency of one consumption event per month), over 18 years
176 old and have not taken part in a market research survey on tomato during the three months
177 before the test. The panels were equilibrated in gender and age although the frequencies of
178 age segments per location could differ. Central location test were conducted for each panel.
179 No information was provided to the consumers about the tomato cultivars.

180 The French panel was composed of 100 people per site, recruited by the service provider,
181 (Sensory Evaluation Laboratory of PEIFL, Avignon). The panels were managed according to
182 standard XP V 09-500 "Sensory Analysis - Methodology - general Directives for the
183 realization of hedonic tests in sensory evaluation laboratory in controlled conditions implying
184 of the consumers". In France the tests were performed during 2 successive sessions, each
185 consumer assessing 8 fruits per session, following a sequential monadic mode, in sensory
186 analysis boxes, under white light. The tomatoes were presented entire, placed on their
187 peduncular face in plastic plate. The consumers had a kitchen knife and an explanatory card
188 about the tasting protocol. They had water in bottle (Evian) to rinse their mouth between two
189 samples. The products were presented according to a complete balanced experimental plan.
190 No dummy sample was presented. Each sample was presented "as a blind man", i.e.
191 identified by a random code with 3 digits. The hedonic tests were carried out in parallel in the
192 3 locations (Avignon, Paris, and Rennes). Consumers gave a score from 1 (do not like) to 9
193 (like very much) for the overall appreciation. To describe the segments of consumers

194 according to their attitudinal and usage characteristics, at the end of the last test session,
195 after answering the hedonic questionnaire, the consumers were asked to fill a questionnaire
196 in which information on consumption habits and demographic information were requested.
197 In Italy 3 sessions were performed over 3 days as described in Sinesio and others (2009).
198 Consumers tasted 5 or 6 tomatoes in each session. The scale was the same as in France.
199 Appearance was also scored independently. In the Netherlands 8 fruits were scored in 2
200 sessions, over 2 consecutive days. Consumers started with the tasting of a dummy sample
201 that was not included in the data-analyses, followed by eight tomato samples according to a
202 balanced block design. The session duration was about 1 hour. Crackers and water were
203 supplied to clean the palate between tastings. The tests started with the evaluation of
204 appearance, familiarity and taste, in that order. Consumers were asked to indicate on a 9-
205 point scale anchored by “dislike extremely” (1) to “like extremely” (9). The samples were
206 served in separate transparent plastic containers: one container with an integral, unwashed,
207 fruit for appearance and familiarity, and a second container with a defined part of tomato for
208 the taste evaluation. Consumers were allowed to swallow the tomato segment.
209 Samples were served within 15 minutes after cutting. To describe the segments of
210 consumers according to their attitudinal and usage characteristics, at the end of the last test
211 session, after answering the hedonic questionnaire, the consumers were asked to fill a
212 questionnaire in which information on consumption habits and demographic information were
213 requested.

214

215 ***Statistical analyses***

216 All the analyses were performed using the Rgui software (R Development Core Team 2008)
217 and the SensoMineR package devoted to sensory analysis (Lê and Husson 2008).

218 *Country per country analysis*

219 For each country, an ANOVA was first performed on the sensory data with the model:

220 *Descriptor = Mean + Product + Judge + Product x Judge + error,*

221 except in France where the interaction could not be tested. Function *decat* of SensoMineR
222 was then used to estimate the average of each product for each descriptor. Then a Principal
223 Component Analysis (PCA) was performed to summarise visually the data. On consumer
224 data, an ANOVA was also performed on the following model: *Hedonic score = Mean +*
225 *Product + Consumer + error.*

226 Then external preference mapping was performed on the average value adjusted per product
227 and descriptor and the scores given by each consumer to each product; a PCA was
228 performed with the descriptors as active variables (function *carto* of SensoMineR). The
229 consumer preferences were then segmented by cluster analysis on the liking scores centred
230 on the average of each consumer. A Ward's hierarchical cluster analysis was used with
231 Euclidian distances and the number of clusters validated by k-means. Each cluster was then
232 described according to the consumer's answers to the questionnaires and to the cultivars
233 that were significantly characteristic for each segment.

234 A multiple factor analysis (MFA) was then performed on the table that described the
235 tomatoes, one line per cultivar, with as many columns as sensory attributes and consumers.
236 The three groups of descriptors from each country constituted the active groups, balanced in
237 order to give the same weight to each group. Three groups composed of the preference
238 scores of each country were then projected on the common plan, which allowed the
239 comparison of preference maps. Products that were specific to one or two countries were
240 added as supplementary individuals (BS1504, Cotabel, Marmandino, Picolino, Savantas and
241 Thesis). A hierarchical MFA was finally performed integrating all data (function HMFA in
242 SensoMineR). The fact that the groups of descriptors are different from one country to
243 another is taken into account in the Multiple Factor Analysis (MFA) and in the Hierarchical
244 Multiple Factor Analysis (HMFA). These methods were developed to take into account such
245 structure of variables organised in several groups (variables are descriptors and groups, the
246 three countries). In the HMFA, in each country, two groups of variables were considered,
247 hedonic scores and sensory descriptors. The MFA (Pages and Tenenhaus, 2001) works as a
248 weighted PCA. According to this method each variable belonging to group j is weighted by

249 $1/\lambda_1^j$, where λ_1^j denotes the first eigenvalue of the matrix of variance–covariance associated
250 with each data table X_j . (for more details see Pages & Tenenhaus, 2001). This kind of
251 standardization on a data matrix is analogous to the one used on variables when doing a
252 PCA on the correlation matrix. The MFA weights the contribution of each group (country) and
253 permits a common referential to be obtained, including all the sensory descriptors. We thus
254 construct a preference map of all the products for each country on the same reference of
255 sensory descriptors.

256

257

258 **Results and Discussion**

259

260 ***Descriptive profiles and consumer preferences in France***

261 In France, 16 cultivars were described by 15 panellists with 15 descriptors for appearance,
262 flavour, texture, odour and taste (**Table 2**). The cultivar and judge effects were significant for
263 all the descriptors except salty taste and odour intensity (data not shown). **Table 3** shows the
264 range of the mean score per cultivar and descriptor. The projection of the descriptors on the
265 first plan of the PCA based on sensory profiles explained 66% of the variation (**Fig. 1**). The
266 first axis was characterised by appearance descriptors (colour, size, ribbed) but also by
267 sweet and acid tastes, odour and flavour intensity opposed to mealy texture. The second
268 axis opposed melting and juicy to firm, crunchy tomatoes. The 304 French consumers scored
269 each fruit from 1 (“I do not like”) to 9 (“I like very much”). The average scores per cultivar
270 ranged from 4.63 to 7.19. The product effect was significant in the ANOVA and eight cultivars
271 appeared significantly different from the average, Picolino, Red Delight and Savantas being
272 scored higher than average and Fergie, Maribel, Climberley, Nun3120 and Cotabel lower
273 (**Table 4**).

274 **Fig. 2** shows the projection of the hedonic scores on the first plan of the PCA constructed
275 with the sensory traits. This external preference map confirmed that Picolino and Red Delight

276 were preferred as 80% of the consumers scored them higher than the average. On the
277 contrary, Alison, Nun3120 and Bonaparte were the least appreciated. The classification of
278 the consumer scores by cluster analysis clearly suggested four clusters (data not shown).
279 The cultivars that were different from the average in each segment are presented in **Table 4**.
280 Picolino was significantly preferred in each segment. According to the questionnaires, the
281 segment 1 was characterised by a large number of old people (39% were more than 65
282 years old). They liked several types of cultivars, but the differences between the average
283 scores per cultivar were not strong. It was difficult to characterise their preferences according
284 to the sensory traits. Consumers of this segment frequently buy their tomatoes in open
285 market. Segment 2 was the largest group with 98 consumers. The consumers of this
286 segment did not like ancient type cultivars (like Marbonne and Cotabel with large ribbed and
287 melting fruits), but preferred Exquise a cultivar with large round fruits. Segment 3 consumers
288 (49 consumers) particularly liked Picolino and Red Delight, with small and juicy fruits with
289 intense flavour. They favoured taste and flavour, and did not like the mealiest cultivars Fergie
290 and Cotabel. On the contrary to segment 2, the 85 consumers belonging to segment 4
291 appreciated ancient cultivars with soft melting fruits like Marbonne and Cotabel. They argued
292 that they prefer sweet fruits and that thick skin is not a problem for them. Gender was not a
293 discriminating characteristic.

294

295 ***Descriptive profiling and consumer preferences in the Netherlands***

296 In the Netherlands 16 cultivars were compared (**Table 1**). The panel characterised the
297 products with 27 descriptors including several after-taste descriptors (**Table 2**). Salty taste,
298 several after taste (at_rough, at_chemical,...) and odour descriptors did not discriminate the
299 products and were thus not considered in the subsequent analysis. **Fig. 3** shows the
300 projection of the cultivars tasted in the Netherlands on the first plan of the PCA constructed
301 on sensory profiles. The first plan explained 62% of the variation. The first axis opposed
302 sweet, juicy tomatoes with a strong taste intensity to green-taste, sour, astringent tomatoes.
303 The second axis was characterised by taste and odour intensity and spicy odour in the

304 positive part and by firmness in the negative part. Several cultivars were similarly
305 appreciated, but Cheers and Red Delight were separated from the others by their sweet and
306 green taste and by juicy texture, while Climberley and Plaisance were particularly firm,
307 Thesis rather acid, with green taste and low sweetness.

308 The Dutch consumer panel was composed of 323 consumers spread in three cities.
309 **Table 4** shows the average score per cultivar and those that were significantly scored higher
310 or lower than the average score. The external preference map confirmed the preference for
311 Red Delight and Cheers as more than 60% of consumers scored these lines higher than
312 average (**Fig. 3**). Cultivars Alison, Hipop, Bonaparte, Maribel and Nun3120 were less
313 appreciated. The cluster analysis of preferences revealed four segments (**Table 4**).
314 Consumers in segment 1 preferred sweet, juicy cultivars, with tomato-like and spicy taste. In
315 this segment, 45% of the consumers had a higher school level. Flavour was more important
316 to them than fruit size. Consumers in segment 2 attributed more importance to price than to
317 fruit size. They buy their tomatoes in market place and frequently buy beef type tomatoes.
318 They preferred Red Delight, Cheers, Plaisance, Maribel, Globo and poorly appreciated
319 Marbonne and Nun3120. This segment seemed to appreciate many cultivars and their
320 preference was not driven by a specific descriptor. Consumers in segment 3 look for fruit size
321 and firmness. In this segment, 41% of the consumers had a medium school level and only
322 9% a higher level. They particularly liked Red Delight, Cheers, BS1504 and Climberley, but
323 disliked Marbonne and Marmandino. Consumers in segment 4 said they look at the price and
324 origin of tomatoes. On the contrary to the other segments, they did not particularly appreciate
325 fruits of Red Delight and Cheers, but preferred tomatoes with a sour, astringent taste.
326 Preferences of Italian consumers are described in Sinesio and others (2009).

327

328 **Overall analysis**

329 *Are the trained panels homogenous?*

330 In order to have a description of all the tomatoes tested by consumers, we performed
331 sensory descriptive profiling in each country. As sensory panels were already trained with

332 their own descriptive list of tomato attributes, we decided not to use a unique list but to have
333 a minimum list of common descriptors (the 8 most important ones) and leave each panel with
334 its specificity. The analyses per country provided much information and allowed the study of
335 consumer clustering, but not a global analysis across countries. Several alternative
336 methodologies were possible to compare the preferences in the three countries, using for
337 instance only one set of descriptive profiles. Nevertheless in order to take into account all the
338 information, we chose to perform Multiple Factor Analysis (MFA). The MFA weighted the
339 contribution of each country and permitted a common referential to be obtained, including all
340 the sensory descriptors. **Fig. 4** shows the first plan of the MFA comparing the results of the
341 three panels for the eight common descriptors used in the three countries. Many descriptors,
342 like firmness, tough skin and juiciness, were similarly perceived by the three panels, as their
343 coordinates were very close from each other on the plan. Differences among countries were
344 detected for sourness, saltiness and sweetness.

345

346 *Consumer preferences across three countries*

347 In order to compare the preferences across countries on a common plan, we performed a
348 MFA taking into account all the descriptors. The three groups of descriptors from each
349 country constituted the active groups, which were balanced in order to give the same weight
350 to each group. Three groups composed of the preference scores from each country were
351 then projected on the common plan, allowing the comparison of the preference maps.

352 The first axis (**Fig. 5**) opposed fruits with an intense flavour, sweet taste, juicy and melting
353 texture (like Red Delight and Marbonne) to the crunchy, firm fruits with a green flavour or
354 bitter taste (like Nun3120, Bonaparte and Alison). The second axis corresponded in the
355 positive part to fruits with an acid taste and thick skin (like Picolino, Exquise, Globo).

356 The coordinates of a group of descriptors on the axis could be considered as a quantification
357 of the link between this group and the corresponding factor. The three groups of descriptors
358 were strongly represented on the first two axes (correlations ranging from 0.89 to 0.98), thus
359 the first plans of the PCA performed on the data of each country were very close to the first

360 plan of the global MFA. The MFA allowed the projection of consumer preferences onto a
361 common referential. **Fig. 6** shows the three external preference maps on this common plan.
362 The preferences were very close in the three countries. Red Delight was preferred in the
363 three countries, while Nun3120 had the lowest score. There were small differences for
364 intermediate ranking cultivars, as for example Marbonne was appreciated in France, but less
365 in the Netherlands, and Climberley was preferred by Dutch more than by French or Italian
366 consumers.

367 Finally, in order to obtain complementary information on the characterisation of products and
368 consumer preferences a Hierarchical MFA (HMFA) was performed. Two levels of
369 comparison were taken into account. The first level consisted in comparing hedonic
370 judgement to sensory description. The second level allowed comparison across countries.
371 Firstly, two MFA were performed, one on the three groups of sensory descriptors, the other
372 on the three groups of consumer scores. The coordinates of the products on the factor axes
373 of each MFA were then used as data for the second MFA in which the two groups (sensory
374 descriptors and preference scores) were simultaneously considered. We thus obtained the
375 coordinates on the axes of the HMFA with two levels. The projection on the first plan of all
376 traits is shown in **Fig. 7**. Most of the traits were correlated with the first axis, which opposed
377 tomatoes with intense taste and flavour (sweet, acid, salty taste, tomato flavour) and a juicy
378 texture to fruits with a bitter green taste and uncommon aftertastes or odours. The second
379 axis was characterised by appearance descriptors (size, ribbed, pulp thickness, skin
380 thickness). The first diagonal was related to texture opposing melting to firm fruits.

381 On the HMFA, tomatoes were separated on the same plans by trained panellists and
382 consumers. The axes were common and the projections of the two clouds of sensory profiles
383 and consumer scores were almost homothetic to the overall cloud. This means that cultivars
384 were separated in the same manner by expert panels (with many descriptors) and
385 consumers' unique scores. Nevertheless, the order of importance of the axes was different,
386 as the first dimension of variability for trained panels was taste and flavour followed by
387 appearance, while for consumers texture was the most discriminating. The second

388 dimension for consumers was correlated to the preference, revealing the existence of
389 cultivars appreciated by all the consumers (Red Delight) and others disliked by most
390 consumers (Cotabel). For some cultivars, like Marbonne, Red Delight or Cotabel, differences
391 were more striking (**Fig. 8**). These cultivars had visual characteristics (Red Delight a small
392 size, Cotabel and Marbonne ribbed fruits). They were also considered as specific by
393 consumers. This indicates that consumers took into account in their appreciation not only
394 fruit taste but also appearance. Appearance was only described by the French descriptors
395 (colour, size, ribbed) and for the cultivars discriminated by their appearance, French
396 descriptors were closer to consumer appreciations.

397

398 ***Discussion***

399 The objective of the experiment was to compare the consumer preferences for tomato
400 cultivars in three European countries. Today, the tomato market proposes to customers a
401 large range of segments including truss, cocktail, long, cherry tomatoes or “ancient” cultivars,
402 in addition to the common round fruits. The 19 cultivars assessed in this study covered a
403 large range of variation representative of the fresh market. Some of the cultivars showed
404 differences in appearance (fruit size, shape or firmness) and were clearly discriminated.
405 Other cultivars with less visible differences were also discriminated either positively or
406 negatively only by their taste and/or texture. As the fruits were produced in three locations
407 and each cultivar was only grown in one place, it is not actually possible to separate the
408 influence of the growing location from the cultivar effect.

409 Three to four clusters of consumers were identified in each country, the clusters being
410 segmented first by taste then by texture attributes. The same trend was already found in a
411 previous preference mapping experiment in France (Lê and Ledauphin 2006; Lengard and
412 Kermit 2006).

413 The MFA allowed the comparison of panel assessment in spite of different glossary and
414 scales used in each country. The analysis revealed that consumers from different countries,
415 even with different cultures and food practices, had similar segmentation of preferences

416 when projected onto a common reference plan constructed with all the sensory descriptors.
417 The HMFA allowed analysing relatedness between sensory profiles and consumer scores. In
418 France, appearance descriptors were scored and the consumers and trained panels average
419 scores were quite close. This indicates that it is important to introduce appearance
420 descriptors in sensory profiles in order to get closer to consumer appreciation. This is in
421 agreement with previous observations on the importance of fruit size (Bruckner and others
422 2007), colour (Francis 1995), as well as other information about the origin and growth
423 conditions (if available) in consumer preferences (Johansson and others 1999).

424

425 **Conclusion**

426 In agreement with previous analyses, this study identified sweet and acid tastes, tomato
427 flavour intensity and firmness as the most important traits for improving tomato fruit quality. It
428 showed that consumers from different European countries, even with different cultures and
429 food practices, have similar preferences when projected onto a common plan of sensory
430 descriptors. Moreover the results clearly showed that diversification of taste and texture is
431 required to satisfy all consumers' expectations as some consumers prefer firm tomatoes,
432 while other prefer melting ones and that they are more or less demanding in terms of
433 sweetness and flavour intensity.

434

435 **Acknowledgements**

436 We acknowledge Ben Silvertrand (Nunhems), Dimitri Atanassiou (Rougeline) and Pierrick
437 Rault (Saveol) for providing fruits into the three places of experiment, the three sensory
438 panels and all the consumers. This work was funded by the EUSOL project PL 016214-2.

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522 **Figure captions**

523

524 **Fig. 1**

525 First plan of the Principal Component Analysis based on sensory profiles obtained in France.

526 Circle of correlations of descriptors

527

528 **Fig. 2**

529 Contour plot of the external preference map of the French consumers. The consumer scores

530 were projected on the PCA constructed on the sensory descriptors (figure 1). The isolines

531 correspond to the percentage of consumers who gave a score higher than average. Small

532 dots correspond to consumers.

533

534 **Fig. 3**

535 Contour plot of the external preference map of the Dutch consumers. The consumer scores

536 were projected on the PCA constructed on the sensory descriptors. The isolines correspond

537 to the percentage of consumers who gave a score higher than average.

538

539 **Fig. 4**

540 Projection of the sensory descriptors common to the three countries on the first plan of a

541 Multiple Factorial Analysis using three groups of sensory descriptors as active groups.

542

543 **Fig. 5**

544 Projection of all the sensory descriptors used in each country on the first plan of the Multiple

545 Factorial Analysis based on 3 active groups (the three groups of descriptors)

546

547 **Fig. 6**

548 Contour plot of the external preference map of consumers on the Multiple Factorial Analysis
549 first plan based on the sensory profiles from the three countries (descriptors plotted on figure
550 5). A French consumers; B Italian consumers; C Dutch consumers

551

552 **Fig. 7**

553 First plan of the Hierarchical Multiple Factorial Analysis using as active variables the
554 coordinates extracted from two Multiple Factorial Analyses, one on the three groups of
555 sensory descriptors, the other on the three groups of consumer scores used in each country.

556

557 **Fig. 8**

558 Projection of the group average on the Hierarchical Multiple Factorial Analysis described
559 figure 7 for each cultivar

560 **Tables**

561

562 **Table 1**

563 Cultivars tested in each country, fruit type, average fruit weight (in grams), firmness
 564 (assessed in France) and growth place (NL: fruits provided by Nunhems, grown in the
 565 Netherlands, F-S: fruits provided by Rougeline, grown in Southern France; F-W: fruits
 566 provided by Saveol, grown in Western France)
 567

Cultivar	Type	Fruit weight	Firmness [°]	Growth Place	Tested in France	Tested in Italy	Tested in Netherlands
Alison	Round	111	70	F-S	x	x	x
Bonaparte	Round	103	74	F-W	x	x	x
BS1504	Round	80	na	NL		x	x
Cheers	Truss	134	59	F-S	x	x	x
Climberley	Truss	144	66	F-S	x	x	x
Cotabel	Ancient	173	55	F-W	x	x	
Exquise	Round	167	66	NL	x	x	x
Fergie	Round	179	72	NL	x	x	x
Globo	Round	81	65	NL	x	x	x
Hipop	Ribbed	216	65	F-S	x	x	x
Marbonne	Ancient	186	47	F-S	x	x	x
Maribel	Round	106	68	NL	x	x	x
Marmandino	Green shoulder	120	na	NL			x
Nun3120	Round	80	69	NL	x	x	x
Picolino	Cocktail	26	52	F-S	x		
Plaisance	Truss	109	66	F-W	x	x	x
Red Delight	Cocktail	47	54	F-W	x	x	x
Savantas	Long	92	63	F-W	x	x	
Thesis	Round	130	na	NL			x

568 [°] Durofel index

569

570

571

572 **Table 2**
 573 Descriptors used by sensory panels in each country
 574

Descriptor	Dutch descriptors	French descriptors	Italian descriptors
<i>Flavour and basic tastes</i>			
Overall flavour intensity*	t_intensity	t_Aromint	Overall _flavour
Sweet taste*	t_sweet	t_Sweet	Sweet
Acid taste*	t_sour	t_Acid	Acid
Salty taste*	t_salty	t_Salty	Salty
Tomato flavour	t_tomato		Tomatofl
Green flavour	t_green		Green
Earthy flavour	t_earthy		
Spicy flavour	t_spicy		
Sharp flavour	t_sharp		
Astringent mouthfeel	t_astringent		
Watermelon flavour			Watermelon
Fruity flavour			Fruity
Herbaceous flavour			Herbaceousfl
<i>Texture</i>			
Juicy texture*	x_moist	x_Juicy	Juiciness
Mealy texture*	x_mealy	x_Mealy	Mealiness
Firm texture*	x_firm	x_Firm	Firmness
Skin thickness*	x_toughskin	x_Skin	Skinthick
Crunchy texture		x_Crunchy	
Melting texture		x_Melting	
<i>Odour</i>			
Odour intensity	od_intens	od_Intens	
Tomato odour	od_tomato		
Spicy odour	od_spicy		
Sweet odour	od_sweet		
Smokey odour	od_smokey		
Other odour	od_other		
<i>Appearance</i>			
Ribbed appearance		a_Rib	
Firm appearance		a_Firm	
Tomato colour intensity		a_Colext	
Tomato size		a_Size	
Seed number			Seeds
Pulp thickness			Pulpthick
Watery aspect			Watery
<i>Aftertaste</i>			
Bitter aftertaste	at_bitter		at_Bitter
Sweet aftertaste	at_sweet		
Acid aftertaste	at_sour		
Salty aftertaste	at_salty		
Fresh aftertaste	at_fresh		
Chemical aftertaste	at_chemical		
Rough aftertaste	at_rough		

575 * Descriptors common to the three countries are indicated with a star

576 **Table 3**
 577 Characteristics of products described by French panel
 578 Average score for each cultivar and descriptor. The scores followed by + or - indicate the
 579 values significantly higher or lower than the average ($P < 0.05$). The *decat* function ranks the
 580 descriptors and cultivars according to their overall proximity
 581

	a_ Size	a_ Rib	x_ Mealy	x_ Melting	a_ Firm	x_ Juicy	x_ Firm	x_ Crunchy	t_ Salty	od_ Intens	t_ Acid	x_ Skin	a_ Colext	t_ Aromint	t_ Sweet
Cotabel	6.58 +	7.92 +	7.08 +	7.33 +	4.58 -	4.00 -	1.83 -	2.33 -	3.33	6.17	3.5	4.33 -	6.17 -	5.25	2.75
Marbonne	6.50 +	5.75 +	1.83 -	6.58 +	5.08 -	7.50 +	3.17 -	3.75 -	3.08	6.75	2.92 -	5.17	5.67 -	5.25	2.83
Hipop	7.33 +	2.17	3.92	5.08	6.75	6.17	4.83	5.00	2.83	6.17	3.75	4.42 -	6.33 -	5.08	2.50
Climberley	6.17 +	1.25 -	3.67	4.58	6.92	6.42	5.42	5.08	2.58	5.92	3.08	5.67	6.33 -	4.58 -	2.50
Plaisance	4.92	1.50	3.92	4.42	7.42 +	5.08	4.67	5.00	2.50	5.42 -	3.5	5.42	7.75 +	4.83	2.67
Cheers	5.42	1.25 -	2.58 -	5.92 +	5.83	7.17 +	3.83	3.33 -	3.42	6.67	3.00 -	4.58 -	6.92	4.92	2.92
Alison	4.75	0.92 -	3.75	3.33 -	7.42 +	5.33	5.92 +	6.08 +	2.67	6.17	3.00 -	5.83	5.25 -	4.92	3.67
Fergie	7.08 +	2.25	4.83 +	5.50	6.92	5.08	4.33	4.83	3.25	6.42	4.58	6.08	7.67 +	5.42	2.33 -
Nun3120	3.75 -	0.67 -	4.58 +	3.83 -	7.75 +	5.08	5.75 +	5.25	2.67	5.75	3.92	6.08	7.42	4.92	3.00
Savantas	3.92 -	0.58 -	4.25	6.58 +	4.75 -	5.83	3.00 -	3.08 -	3.08	6.42	3.33	5.17	6.92	5.92	4.42 +
Bonaparte	4.50 -	1.67	2.67 -	2.75 -	7.83 +	4.83 -	6.67 +	6.42 +	2.17	6.33	4.00	5.08	6.83	4.92	3.75
Maribel	4.67	1.25 -	4.83 +	3.42 -	7.25 +	4.92 -	5.17	5.58	3.17	6.83	4.92 +	7.00 +	6.75	5.58	2.58
Exquise	6.33 +	1.58	3.08	4.33	6.25	6.33	4.67	4.83	2.75	7.08	5.08 +	6.08	7.50 +	6.50 +	3.08
Globo	3.92 -	1.42 -	3.92	3.42 -	7.33 +	4.83 -	6.08 +	6.83 +	3.50	6.83	3.75	7.08 +	7.50 +	5.83	4.58 +
Red Delight	2.75 -	0.58 -	2.58 -	6.75 +	4.58 -	6.75 +	3.17 -	3.75 -	4.00 +	6.75	4.33	5.92	7.50 +	7.17 +	5.42 +
Picolino	1.92 -	0.75 -	1.08 -	4.25	4.67 -	6.58 +	5.08	5.67	4.17 +	7.08	5.08 +	6.17	8.58 +	7.08 +	5.92 +

582
583

584 **Table 4**
 585 Mean preference scores per cultivar in France and the Netherlands
 586 The scores followed by + or - indicate the values significantly higher or lower than the
 587 average. For the cultivars significantly discriminating each segment identified by the
 588 hierarchical cluster analysis, the difference from the average score in each segment is
 589 indicated, with the number of consumers per segment (N).
 590

	Mean (sd)	France (mean =5.59)				Mean (sd)	Netherlands (mean = 5.87)			
		segment 1 N = 72	segment 2 N = 98	segment 3 N = 49	segment 4 N = 85		segment 1 N=60	segment 2 N=136	segment 3 N=80	segment 4 N=47
Picolino	7.19 (1.79) +	0.62	1.27	2.37	2.31	na				
Red Delight	6.59 (1.80) +	0.16		2.08		7.05 (1.76) +	2.26	0.42	1.57	
Savantas	6.23 (1.94) +	0.23				na				
Cheers	5.71 (1.89)	-0.30		0.80		6.65 (1.91) +	1.34	0.34	1.43	0.20
Exquise	5.69 (1.92)		0.82	-0.79	-0.44	6.24 (2.03) +	-0.24			1.26
Plaisance	5.64 (1.79)					5.72 (2.00)	-1.29	0.21	0.53	-0.87
Marbonne	5.49 (2.29)	0.55	-1.79		1.37	5.01 (2.45) -	0.39	-0.11	-3.23	
Alison	5.49 (1.92)					5.59 (2.11) -			0.12	
Globo	5.44 (2.02)		0.24			6.27 (2.08) +	1.42	0.06		-0.44
Bonaparte	5.41 (1.93)					5.84 (2.10)				-0.72
Hipop	5.41 (1.97)	0.45			-0.53	5.57 (2.19) -				
Fergie	5.35 (2.09) -		0.33	-1.10		5.98 (2.14)			-0.41	1.54
Maribel	5.16 (2.00) -	-0.08		0.08	-1.21	5.52 (2.11) -	-1.23	0.14		-0.85
Climberley	5.16 (2.00) -		-0.1		-0.87	6.01 (2.11)			0.78	-1.76
Nun3120	4.91 (2.06) -		-0.41		-1.13	5.13 (2.29) -	-1.99	-0.44		0.52
Cotabel	4.63 (2.35) -	-0.28	-1.67	-2.69	0.27	na				
BS1504	na					6.11 (1.98) +	-0.61		0.97	
Thesis	na					5.85 (2.15)	0.49			
Marmandino	na					5.41 (2.30) -			-1.37	0.64

591 na : non available