Effect of ageing time on consumer preference and sensory description of foal meat

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13 **Abstract**

14 A consumer test (n=120) was performed in Vitoria-Gasteiz (northern Spain) in order to study the
15 effect of ageing time (0, 7, 14 and 21 days) on the sensory quality of Hispano-Bretón foal meat.
16 Steaks (*Longissimus thoracis et lumborum*) were wet aged and evaluated in-mouth and visually. In
17 both cases, acceptability was scored using a hedonic scale, and sensory drivers related to ageing
18 were characterised by applying check-all-that-apply method in meat. For both, in-mouth and
19 visual acceptability, meat aged for 7 days obtained higher scores than non-aged meat, whereas
20 longer ageing periods did not improve consumer acceptability. Check-all-that-apply method
21 showed to be able to discriminate among samples, both in-mouth and visually. Results revealed
22 that texture related attributes were the most discriminant ones in the in-mouth evaluation, being
23 non-aged meat related to 'dry', 'high residue', 'tough' and 'chewy' terms, whereas aged meat was
24 associated to 'juicy', 'tender' and 'easily dissolving' terms. Visually, consumers perceived that,
25 after 14 days of ageing, meat colour changed to 'brownish'. Under present study conditions, the
26 establishment of a period of 7 days of ageing would be recommended.

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30 **Keywords:** horse meat, vacuum pack, consumer study, visual acceptability, in-mouth acceptability,
31 sensory drivers

32

33 **1. Introduction**

34 Horse meat is not popular in most countries mainly due to religious and/or cultural concerns
35 (Rossier, 2003; Ursin, 2016). However, it is considerably produced and consumed worldwide,
36 being Asia and America the biggest producers and Asia and Europe the most important
37 consumers, as indicated by Belaunzaran *et al.* (2015). This study also highlighted that horse meat
38 consumption is slowly increasing in several countries because of the availability of this interesting
39 meat source but also due to its recognized nutritional and environmental value, since horse
40 production is mainly related to grazing systems.

41 Sensory preference of meat is related to visual appearance and in-mouth perception of texture
42 and flavour (Font-i-Furnols & Guerrero, 2014). More concretely, it has been reported that
43 tenderness, juiciness and flavour are the most important sensory traits affecting meat
44 acceptability (D'Alessandro *et al.*, 2012), being directly correlated with purchase intention and
45 willingness to pay (Banovic, Grunert, Barreira & Fontes, 2009). Thus, it is important to ensure a
46 homogeneous product quality with acceptable tenderness (Robins *et al.*, 2003) in order to meet
47 consumer expectations. In this sense, the role of meat ageing in the improvement of meat
48 tenderness has been widely studied (Brewer & Novakofski 2008; della Malva *et al.*, 2019;
49 Koohmaraie, 1994; Ouali *et al.*, 2013). The level of tenderization will majorly depend on carcass
50 hanging, duration and temperature in the ageing process, together with muscle type and animal
51 species (Cassens, Arnols, Miller, Gehring & Savell, 2018; Mónson, Sañudo & Sierra, 2005; Vieira,
52 Cerdeño, Serrano, Lavín & Mantecón, 2007).

53 Meat ageing is a common practice that has been applied in the meat industry for decades (Warren
54 & Kastner, 1992). In this line, its implications on consumer acceptability have been extensively
55 studied not only in beef (Brewer & Novakofski 2008; Li *et al.*, 2014; Monsón *et al.*, 2005) but also
56 in pork (Chanon, D'Souza & Dunshea, 2016) and sheep meat (Font-i-Furnols *et al.*, 2006). On the
57 contrary, few sensory studies have been focused on horse meat ageing (Gomez & Lorenzo 2012;

58 Lorenzo & Gomez 2012; Ruiz *et al.*, 2020; Seong *et al.*, 2016) and there is a clear lack of both
59 standardized ageing practices and sensory research on the field. Particularly, no consumer
60 preference studies concerning horse meat ageing have been published in the scientific literature.
61 In sensory studies, consumer tests usually focus on hedonic measurements, while sensory
62 descriptive analyses are normally performed by trained panels. The high specialization of trained
63 panels allows the collection of detailed, robust and consistent results. However, creating and
64 maintaining the panels can be quite expensive and time-consuming (Cruz *et al.*, 2013). Thereupon,
65 consumer-based methods for sensory descriptive analyses are gaining popularity (Varela & Ares,
66 2012, Torrico *et al.*, 2018). Among them, Check-all-that-apply (CATA) is a simple approach to
67 gather information about the sensory perception of a product and it is suggested as a valuable
68 alternative to classical descriptive methods that also captures differences among products
69 (Reinbach, Giacalone, Machado & Bredie, 2014). CATA allows the consumer to choose potential
70 terms from a given list to describe a product, with the advantage of being an easy task that may
71 give rise to more spontaneous descriptions than when intensities are rated (Dooley, Lee &
72 Meullenet, 2010). The potential of CATA method as a powerful tool for food development has also
73 been pointed (Ares *et al.*, 2017). Actually, the combination of liking and CATA results facilitates the
74 elucidation of the sensory drivers related to the acceptability of a certain product (Ares, Barreiro,
75 Deliza, Giménez & Gámbaro, 2010). Despite the interesting approach of this sensory technique,
76 few studies have been carried out on meat or meat products (Dos Santos *et al.*, 2015; Jorge *et al.*,
77 2015; Popoola, Bruce, McMullen & Wismer, 2019) and, to our knowledge, this is the first time that
78 CATA is applied to investigate the effect of ageing time on consumer meat acceptability.
79 To this extent, the aim of the present study was to assess, for the first time, the visual and in-
80 mouth consumer acceptability of foal meat aged over 0, 7, 14 and 21 days (d) and to study the
81 sensory drivers affected by meat ageing with CATA approach. This knowledge will contribute to

82 the recommendation of a certain ageing time for the horse meat industry based on consumer
83 preferences.

84 **2. Material and methods**

85 **2.1. Animal handling**

86 Ten foals (5 females and 5 males) of Hispano-Bretón breed were used for the present study. Under
87 extensive grazing conditions, foals suckled their mothers from birth (May to June 2017) until 6-8
88 months of age and then continued under the same grazing conditions until they entered a
89 commercial feedlot at 11-13 months of age. At the feedlot, foals were finished *ad libitum* on a
90 concentrate composed by barley, wheat bran, wheat, soybean flour, dehydrated alfalfa, corn, beet
91 pulp, soybean hulls, molasses, palm oil and salts (13.3 % protein, 2.70 % fat, 7.60 % fibre) for 100-
92 120 d. Foals were cared for in accordance with Directive 2010/63/EU (2010) and were slaughtered
93 in a commercial abattoir at 15-17 months of age (August to October 2018). They were stunned
94 with a captive bolt and slaughtered and dressed according to the specifications outlined in the
95 European legislation (Council Regulation 1099/2009). The average carcass weight was of $246.2 \pm$
96 14.0 kg (249.9 ± 15.0 kg for females and 242.5 ± 12.5 kg for males). All carcasses were classified as
97 U (conformation) and 2 (fat cover) according to the Community scale for the classification of
98 carcasses of adult bovine animals (Council Regulation 1208/81) as there is no specific classification
99 system for meat horses at EU level.

100 **2.2. Sampling**

101 Two foals (female and male) were slaughtered per week during 5 consecutive weeks. After 48
102 hours (4 °C), both right and left rib joints were removed from each carcass and transported to the
103 laboratory under refrigeration conditions. The loin, *Longissimus thoracis et lumborum* (LTL)
104 muscle, was subsequently excised and sliced into 1.5 cm thick steaks. From each loin, 26 steaks
105 were cut and destined for different analyses. Among them, 8 steaks beginning from the 10th rib
106 were employed for the present study. Those steaks were vacuum packed and randomly assigned

107 to an ageing time: 0, 7, 14 or 21 d (2 steaks per ageing day). Ageing was performed in a
108 refrigerated room (4 ± 1 °C) without illumination.

109 When each ageing day was reached, steaks were unpacked and covered with an oxygen-
110 permeable polyvinylchloride film (oxygen permeability of 580 mL/m²/h at standard pressure and
111 temperature). After 1 hour of exposure to air (4 °C), 3 photographs of each steak (uncooked) were
112 taken under controlled artificial illumination conditions (911 ± 10 lux) using a professional digital
113 camera (Nixon-700, Nikon Corporation, Tokyo, Japan). Same white plate was used as background
114 in order to avoid differences in contrast, intensity or direction of the illumination. From the whole
115 set of photographs, 4 representative photographs were selected for each ageing time by a group
116 of experts, taking into account the variability among animals, sexes and loin sides. Same batch of
117 selected photographs were used for visual acceptability and visual CATA of all sessions. Moreover,
118 the microbial safety of foal steaks aged for 21 d was checked and it was ensured that samples met
119 the established safety requirements (TR CU 021/2011).

120 Then, all samples from each ageing time were vacuum packed and frozen at -80 °C until the
121 consumer study.

122 **2.3. Consumer study**

123 **2.3.1. Consumer recruitment and session organization**

124 For recruitment purposes, consumer databases from the Sensory Laboratory of the University of
125 the Basque Country (LASEHU) were used. At the same time, intensive efforts were made to reach
126 potential consumers by e-mailing, posters, broadcast, social media, personal contacts, etc.

127 Interested people fulfilled out a basic recruitment questionnaire (gender, age and foal meat
128 consumption frequency). From among them, 120 volunteers from Vitoria-Gasteiz and surrounding
129 areas (northern Spain) were recruited, balancing as much as possible for age and sex.

130 Ten sessions of 12 consumers were carried out during three consecutive days in LASEHU facilities,
131 which are equipped with individual booths and computers. Sessions lasted approximately 1 hour

132 and were organized in the following order: in-mouth acceptability (IMA), visual acceptability (VA),
133 in-mouth CATA, visual CATA and a final questionnaire. The alternation between visual and in-
134 mouth tests avoided consumer's fatigue and provided enough time to cook the second set of
135 samples for in-mouth CATA. Data were collected using Fizz Acquisition Software Version 2.40
136 (Biosystemes, Couternon, France).

137 **2.3.2. In-mouth evaluation**

138 For each session, batches of 16 steaks (8 steaks per loin; one loin from a female and another loin
139 from a male foal) were used. The 8 steaks contained samples from all ageing times (0, 7, 14 or 21
140 d); 4 steaks were used for IMA and another 4 steaks were used for in-mouth CATA. All samples
141 evaluated by each consumer came from the same animal. Samples were thawed overnight (4 °C).
142 Two hours before cooking, each set of samples (2 animals x 4 ageing times) was taken out of the
143 vacuum pack, covered with an oxygen-permeable PVC film (to avoid surface dryness) and kept at
144 room temperature. Samples were cooked in two rounds; first, the IMA set and second the in-
145 mouth CATA set. All samples per set were cooked at the same time (2 steaks per grill) in 4 double
146 grills (one grill per ageing time) (Dalkyo MB-30, Sogo, Spain). Grills were set at 200 °C and steaks
147 were cooked until they reached an internal temperature of 71 ± 1 °C. Individual internal
148 temperature was monitored using 4-channel thermocouples (Lutron electronic, Pennsylvania,
149 USA). Cooked steaks were immediately trimmed and cut into 2 x 1.5 x 2 cm cuboids, which were
150 wrapped in aluminium foil and labelled with randomly established three-digit codes. Samples were
151 kept in heaters (heat diffusion by glass microspheres) (Indoterm, Indo, Sant Cugat, Barcelona) at
152 60-65 °C until they were served (less than 5 minutes).

153 For IMA and in-mouth CATA, samples (one per ageing time) were provided randomly and
154 monadically. Water and unsalted crackers were available as palate cleansers between samples.
155 Tasting was performed under red light (16 ± 1 lux) in order to avoid colour bias. Acceptability
156 (IMA) was evaluated by answering the question 'How much do you like this steak?' in a 10 cm

continuous hedonic scale with an extra cm in both sides, ranging from 'I extremely dislike' to 'I extremely like'. In-mouth descriptive terms were discussed and selected by a group of experts, with background in meat, from LASEHU. Previously an in-depth bibliographical search of terms was performed (Maughan, Tanasawat, Conrforth, Ward & Martini, 2012; Rodbotten, Kubberod, Lea & Ueland, 2004). The following 19 terms were selected: 'cowshed', 'fatty', 'intense', 'livery', 'low intensity', 'rancid', 'roasted' and 'unpleasant' for odour/aroma category; 'chewy', 'dry', 'easily dissolving', 'high residue', 'juicy', 'tough' and 'tender' for texture category; and 'bitter', 'metallic', 'salty' and 'sweet' for taste and trigeminal sensations category. Consumers were asked to tick off all the terms that considered appropriate to describe each sample (terms from the three categories were presented together and in different order along the sessions). After assessing the 4 samples for in-mouth CATA, consumers were asked to tick off all the attributes that relate to an 'ideal foal meat' sample, using the same list of terms.

2.3.3. Visual evaluation

Visual acceptability and CATA were assessed by the evaluation of selected photographs for each ageing period. Consumers were asked to consider the average impression of the batch of 4 selected photographs. In the booths, a correct position and a fixed distance to the screen were established in order to avoid as much as possible differences among consumers and no illumination was provided.

Visual CATA terms were defined beforehand and selection was performed as described for in-mouth CATA. Initially, the following 9 terms were selected: 'brownish', 'dark', 'fresh', 'maroon', 'not uniform colour', 'pinkish', 'red', 'spoilt', 'uniform colour'. The questions and scale for VA were the same as described for IMA, and consumers were asked to tick off all the terms that considered appropriate to describe each sample. After assessing the samples of the 4 ageing times for visual CATA, consumers were asked to tick off all the terms that relate to an 'ideal foal meat' sample.

2.3.4. Final questionnaire

182 After sensory evaluations, consumers were asked to complete a questionnaire concerning
183 demographic and socio-economic information, and their familiarity with foal and aged meat. The
184 following questions were included in the questionnaire: gender (female, male), age (18-35, 36-55,
185 >55), occupation (student, unemployed, employed, retired), how often do you consume foal
186 meat? (once a week or once a month, once a year or I have not tried), how do you purchase foal
187 meat? (steak, cut in cubes, minced, no answer), how do you prepare foal meat? (deep fried,
188 grilled, oven roasted, barbequed, stewed, no answer), do you do the shopping yourself? (yes, no),
189 have you ever tried aged meat? (yes - at restaurants, yes - at home and restaurants, no - I don't
190 know what aged meat is), do you like aged meat? (yes, no, I have not tried/ I don't know what
191 aged meat is). Questionnaires were available in both original languages (Spanish/Basque) of the
192 Basque region (northern Spain).

193 **2.4. Statistical analysis**

194 Analyses were conducted using IBM-SPSS Statistics Software Version 25.0 (SPSS Inc., IBM
195 Corporation, Armonk, USA) and XLSTAT Statistics Software Version 2011.2 (Addinsoft, Bordeaux,
196 France).

197 **2.4.1. In-mouth and visual acceptability**

198 The General Linear Model (GLM) of the Analysis of Variance (ANOVA) was used to determine the
199 presence or absence of significant differences ($p \leq 0.05$) in the IMA and VA scores among different
200 ageing times. Normality and homoscedasticity of the variables within each group (ageing times)
201 were checked.

202 The following linear models were used:

203 For IMA scores: $Y_{ijkl} = \mu + AT_i + AS_j + (AT*AS)_{ij} + C_k(A_i(AS_j)) + A_i(AS_j) + \xi_{ijkl}$

204 For VA scores: $Y_{ijk} = \mu + AT_i + C_j(S_k) + \xi_{ijk}$

205 Models included ageing time (AT), animal sex (AS), animal (A) and session (S) as fixed factors and
206 consumer (C) as a random factor.

207 Tukey test ($p \leq 0.05$) was applied for multiple comparisons of means.

208 **2.4.2. Agglomerative Hierarchical Clustering and Internal Preference Mapping**

209 Agglomerative Hierarchical Clustering (AHC) was performed on the IMA and VA scores in order to
210 identify groups of consumers with different patterns (Varela, 2014). Euclidean distance and
211 Ward's agglomeration methods were employed. The number of selected clusters was determined
212 by the observation of the dendrogram (MacFie, 2007). Then, the non-parametric Chi-squared test
213 ($p \leq 0.05$) was applied in order to explore relationships among the information gathered from
214 consumers (questionnaires) and the clusters selected.

215 Finally, Internal Preference Mapping (IPM) was constructed by performing Principal Component
216 Analysis (PCA) with Varimax rotation on the covariance matrix of IMA and VA consumer individual
217 scores. Kaiser criterion (eigenvalue > 1) was applied to extract the principal components. Bi-plot
218 graphs were used to depict the associations among ageing times, consumers, and studied
219 variables.

220 **2.4.3. In-mouth and visual CATA**

221 A contingency table was generated by counting the number of assessors (consumers) that used
222 each term to describe meat from each ageing time. Following the criteria suggested by Meyners,
223 Castura & Carr (2013), only terms with effective sample size equal or over 24 were considered in
224 the analysis. In order to evaluate the correct effective sample size (number of assessors for each
225 term), assessors who tick one term from all four samples and those who did not tick any of them
226 were excluded. Then, the non-parametric Cochran's Q test ($p \leq 0.05$) was applied to determine the
227 presence or absence of significant differences in the IMA and VA CATA scores among different
228 ageing times (Manoukian, 1986) and McNemar's test ($p \leq 0.05$) was applied for multiple
229 comparisons (McNemar, 1947). The scores of the 'ideal foal meat' were not included in the
230 aforementioned analysis. Moreover, based on the contingency table built by terms that showed

231 significant differences among the 4 aged meat groups, a Correspondence Analysis was conducted
232 using Chi-squared distances in order to obtain a perceptual mapping of meat samples and terms.

233 **3. Results and discussion**

234 **3.1. Consumer acceptability**

235 Foal meat acceptability scores for each ageing time are shown in Table 1. Both, IMA and VA, were
236 significantly affected by ageing ($p \leq 0.05$). Besides, as it is common in consumer studies, consumer
237 had also a significant effect ($p \leq 0.05$) over IMA and VA when nested with other factors: C(A(AS))
238 and C(S), respectively (data not shown).

239 Meat aged for 7 d obtained significantly higher IMA score than non-aged meat (0 d), while meat
240 aged for longer periods, 14 and 21 d, showed intermediate acceptability scores. In agreement with
241 IMA results, meat aged for 7 d also obtained the highest VA scores. Foal meat aged for 7 d was
242 visually more acceptable than the non-aged (0 d) and meat aged for 21 d, which was the least
243 acceptable for consumers (3.97; $p \leq 0.05$). Finally, foal meat aged for 14 d showed intermediate
244 scores, being significantly better scored than meat aged for 21 d but not significantly different
245 from meat aged for 7 d and non-aged meat (Table 1). From the scientific literature, several studies
246 about acceptability of aged foal meat have not been considered, as according to the Society of
247 Sensory Professionals (2018), trained and semi-trained panels should not be used for liking or
248 acceptance studies. For this reason, these studies have not been included in the discussion
249 section.

250 In the present study, one week of ageing improved both IMA and VA scores, and longer ageing
251 periods did not improve aforementioned scores. This may indicate that, from a consumer point of
252 view, no extra ageing time is needed to improve the acceptability of foal meat, and that ageing for
253 21 d would negatively affect VA scores, mainly due changes in colour (Beldarrain *et al.*, 2019; Ruiz
254 *et al.*, 2018).

255 **3.2. Consumer segmentation**

256 In order to understand consumer behaviour and identify different preference patterns AHC was
257 performed using IMA and VA scores separately. Three clusters were identified using IMA scores
258 while four clusters were identified using VA scores (Table 2).

259 Regarding IMA-related clusters, cluster 1 was composed by 31 consumers which, in general,
260 scored better the aged compared to non-aged meat (4.55). These consumers rated the meat aged
261 for 7 d as the one with the best IMA (7.55). Cluster 2 was composed by 54 consumers which,
262 opposite to cluster 1, rated all foal meat samples with high scores (6.66 to 7.54). These consumers
263 preferred non-aged meat compared to meat aged for 21 d, while intermediate and not
264 significantly different scores were found for other ageing times. Both, cluster 1 and 2, had the
265 ability to discriminate among foal meat samples. On the other hand, cluster 3, composed by 35
266 consumers, did not appreciate significant differences among foal meat samples and, overall, they
267 scored all of them quite negatively (3.14 to 4.26).

268 These cluster information was matched with the information collected in the final questionnaire
269 (Table 3). Chi-squared test revealed that, among all the aspects considered in the questionnaire,
270 only consumption frequency ('How often do you consume foal meat?' question) was significantly
271 different ($p \leq 0.05$) among clusters (data not shown). Consumers from clusters 2 (79.6 %) and 3
272 (88.6 %) stated that they seldom consumed foal meat (once a year or have never tried), while
273 consumers of cluster 1 (58 %) consumed foal meat once a week or once a month. This lack of
274 familiarity with foal meat consumption may have been the reason for the low discrimination and
275 low rating of foal meat by consumers in cluster 3. However, the reason seemed to be different for
276 consumers included in cluster 2. This cluster was a more multitudinous group with scattered liking
277 scores.

278 These results can be visually interpreted in the multidimensional IPM representation, including
279 consumers (Figure 1A) and non-aged/aged foal meat samples (Figure 1B), which explained 75.2 %
280 of the total variability. Additionally, the average acceptability scores of each cluster obtained by

281 AHC were plotted as vectors. As indicated by Varela (2014), the direction of each vector represents
282 the direction of increasing acceptability scores for each consumer cluster (Figure 1A), and is linked
283 to the position of the foal meat samples in the plane (Figure 1B).

284 Regarding VA-related clusters (Table 2), cluster 1 ($n = 33$) and 3 ($n = 30$) followed a similar pattern
285 and discriminated the foal meat aged for 21 d from the rest of the samples ($p \leq 0.05$). However, in
286 cluster 3 the scores were extreme compared to cluster 1. Consumers included in cluster 2 ($n = 40$)
287 preferred the visual appearance of foal meat aged for 7 and 14 d compared to non-aged foal meat
288 or meat aged for 21 d. Consumers included in cluster 4 ($n = 13$) rated quite or very positively the
289 visual appearance of all foal meat samples (7.52 to 9.80) and did not discriminate among them.

290 When these cluster information was matched with the information collected in the final
291 questionnaire (Table 3), it was observed that none of the information gathered was significantly
292 related to any of the clusters.

293 Figure 2 represents the aforementioned data using an IPM multidimensional approach where
294 consumers (Figure 2A) and non-aged/aged foal meat samples (Figure 2B) have been depicted. It
295 explained 88.3 % of the total variability and average acceptability scores of each cluster were
296 plotted as vectors.

297 In general, there is lower homogeneity in IMA than VA scores, as for VA consumers were located
298 primarily on the first and fourth quadrants, whereas for IMA they were distributed all over the
299 sensory plane (Figures 1 and 2).

300 **3.3. Sample description by CATA**

301 From the initial 19 in-mouth CATA terms 13 showed an effective sample size equal or over 24 (at
302 least 24 consumers discriminated among foal meat samples using this term; Meyners *et al.*, 2013)
303 and were the ones statistically analysed (Table 4). 'Cowshed', 'fatty', 'rancid' and 'unpleasant'
304 odour/aromas, and 'metallic' and 'salty' taste and trigeminal sensations did not reach the
305 necessary effective sample size.

306 For odour/aroma related terms, 'intense' and 'roasted' presented higher citation frequencies (CF)
307 at 21 d aged steaks compared with non-aged or steaks aged for 7 d, while 14 d presented
308 intermediate CF values, being not significantly different from 0 or 21 d aged meat. The opposite
309 trend was observed for 'low intensity', since it was significantly more cited in non-aged and meat
310 aged for 7 d compared with 21 d aged meat, while intermediate citation frequencies were
311 observed for 14 d aged meat. These results are comprehensive, as besides its effect on texture,
312 ageing is also known to have an effect on volatile compounds from the Maillard reaction,
313 increasing the concentration of substances that play an important role in the aroma of cooked
314 meat (Watanabe *et al.*, 2015). Some other consumer studies, however, found no change in flavour
315 over time in aged beef (Brewer *et al.*, 2008; Laster *et al.*, 2008). 'Livery' term had a considerable CF
316 value (34.1), although no statistically significant differences were observed among ageing times.
317 Thus, 'livery' could be considered merely descriptive as a typical aroma presented in foal meat as
318 stated in previous studies (Sarriés & Beriain, 2005).

319 For the terms included in the texture category, 'juicy', 'tender', and 'easily dissolving' ($p \leq 0.01$)
320 exhibited similar trends with the lowest CF values in non-aged samples, while non-significant
321 differences were observed among aged samples. Opposite trend was observed for 'dry', 'tough'
322 and 'chewy' terms ($p \leq 0.05$), with the highest CF values in non-aged foal meat and non-significant
323 differences among aged samples. Citation frequencies of 'high residue' term ($p = 0.027$) were
324 significantly higher for non-aged and 14 d aged meat samples, and lower for 7 d aged meat.
325 Intermediate CF value was observed for meat aged for 21 d.

326 These results demonstrate the improvement in meat tenderness during the ageing process, which
327 is explained by *post mortem* proteolysis processes (Koohmaraie, 1994; Ouali *et al.*, 2013). In this
328 sense, della Malva *et al.* (2019) found that instrumental tenderness (by measuring Warner Bratzler
329 shear force) of meat from the *Longissimus lumborum* of 12-month Italian Draft Horses increased
330 after 6 days of ageing, and no statistically significant differences were observed for longer ageing

331 periods. Moreover, this is coherent with the results obtained for IMA, as the acceptability of meat
332 aged for 7 d was higher compared to non-aged meat, and no differences were found when meat
333 was aged for longer periods of time. This also indicates that texture related attributes had a high
334 relevance when evaluating IMA of cooked foal meat. Among the terms included in taste and
335 trigeminal sensations category, 'bitter' and 'sweet' (both taste sensations) showed no statistically
336 significant differences among ageing times.

337 For the description of ideal foal meat, for the odour/aroma category, 'intense' and 'roasted' were
338 the most cited terms (72.5 % and 57.5 % of the consumers, respectively). However, 'low intensity'
339 and 'livery' were not chosen by the consumers as important attributes in their definition of ideal
340 foal meat. Texture terms obtained higher CF values compared to odour/aroma and taste and
341 trigeminal sensations categories being, therefore, critical for the consumer. Within this category,
342 the terms 'juicy', 'tender', and 'easily dissolving' were the most cited terms (98.3, 94.2 and 87.5 %,
343 respectively), and conversely, 'dry', 'tough', 'chewy' and 'high residue' were almost not included in
344 the description of the ideal foal meat. Finally, in terms of taste and trigeminal sensations category,
345 37.5 % of the consumers defined 'sweet' as an attribute of ideal foal meat; very close to the 44.6
346 % of citations of the non-discriminant 'sweet' term as observed by Ruiz *et al.* (2020).

347 With the 10 IMA CATA terms that showed statistically significant differences ($p \leq 0.05$) among
348 ageing times further multidimensional correspondence analysis was performed. A two-
349 dimensional bi-plot of terms and samples, preserving the 97 % of the original inertia of data is
350 depicted in Figure 3. As it can be observed, selected attributes enabled the spatial separation of
351 samples depending on ageing time. Texture attributes defined the first dimension and clearly
352 separated non-aged samples, characterized as 'chewy', 'tough', 'dry' and 'high residue', from the
353 rest of the aged meat samples, characterized as 'tender', 'easily dissolving' and 'juicy'. Moreover,
354 on the left side of the sensory map, samples aged for 14 and 21 d were located closer from each
355 other than meat samples aged for 7 d. Regarding odour/aroma related terms, non-aged samples

356 located close to 'low intensity' term while meat samples aged for 21 d, and to a lower extent meat
357 samples aged 14 d, located close to 'intense' and 'roasted' terms, being indicative of aroma
358 development over ageing time.

359 Citation frequencies of visual CATA terms are gathered in Table 5. In this case, all 9 terms initially
360 selected resulted in an effective sample size equal or over 24 (Meyners *et al.*, 2013), and
361 statistically significant differences were observed in all of them among studied ageing times ($p \leq$
362 0.001).

363 As it could be expected, meat samples aged for 21 d obtained the highest CF values for
364 undesirable terms such as 'brownish', 'not uniform colour', and 'spoilt', confirming that this meat
365 was not visually attractive for consumers. On the other hand, CF values of terms like 'fresh' and
366 'red' were significantly higher in meat aged for 7 and 14 d compared to non-aged or meat aged for
367 21 d. Similarly, in beef studies, the consumer is able to discriminate the meat that is not red, as
368 they associate it with a lack of freshness (Mancini & Hunt, 2005).

369 The term 'dark' presented significantly higher CF values in non-aged and meat aged for 21 d
370 compared to meat aged for 7 and 14 d, and 'maroon' was also more cited in non-aged foal
371 samples compared to others. It seems that the consumer understood 'dark' as intense maroon in
372 non-aged samples and as intense brown in samples aged over 21 d. For the rest of the terms,
373 significantly higher 'pinkish' CF values were observed in meat aged for 14 d compared to non-aged
374 or meat aged for 21 d, while intermediate values were observed for meat aged for 7 d. Similarly,
375 higher 'uniform colour' CF values were observed for meat aged for 14 d compared to meat aged
376 for 21 d, while intermediate values were observed in non-aged and meat aged for 7 d.

377 As reviewed by Mancini & Hunt (2005), myoglobin is a key component of meat colour. When *post*
378 *mortem* time increases, enzyme activity and NADH pool in charge of brown metamyoglobin
379 reduction are decreased and depleted, respectively, leading to meat to discoloration going from
380 'red' to 'brownish' and passing through 'pinkish' (Faustman & Cassens, 1990; McKenna *et al.*,

2005). The time needed for the process to take place depends on both intrinsic and extrinsic factors, but the results suggest that under the conditions of the present study, the change to 'brownish' was mainly perceived by consumers after 14 d of ageing.

Regarding the consumer description of ideal foal meat (Table 5), 'fresh', 'uniform colour' and 'red' were the most cited terms (96.7 %, 89.2 % and 83.3 %, respectively), while 'not uniform colour', 'brownish' and 'spoilt' were the least desired terms (below 3.5 %). Others such as 'maroon', 'pinkish' and 'dark' obtained intermediate CF values (20.8 %, 20.8 % and 14.2 %, respectively).

Correspondence Analysis was performed on the contingency table of visual CATA data, and the first two dimensions explained the 97.2 % of the original inertia enabling the spatial separation of samples depending on ageing time (Figure 4). As it can be noted, visual CATA terms performed a good discrimination of the four ageing times. The first dimension showed the differentiation of meat aged for 21 d and the rest of the meats. Meat aged for 21 d was clearly associated with 'spoilt' and 'brownish' terms. The rest, and especially meat aged for 7 d and 14 d, were characterized by 'fresh', 'red' and 'uniform colour' terms. The second dimension seemed to be related to the evolution of colour where non-aged meat was related to 'maroon', meat aged for 7 d to 'red', meat aged for 14 d to 'pinkish' and meat aged for 21 d to 'brownish' terms.

4. Conclusions

Sensory methodologies based on consumer perception like CATA have shown to be useful to characterize and discriminate foal meat aged for different time periods. For the first time, a hedonic evaluation combined with a CATA characterization of aged foal meat is provided, which highlights the relevance of texture attributes on the acceptability of foal meat. Moreover, it evidences that changes in colour happening during the ageing process are perceived by the consumer. According to these results, the best ageing time could be established at 7 days, since it would be enough to obtain a good in-mouth and visual acceptability. Indeed, longer ageing periods would require an economic investment that would not be translated into higher

406 acceptability by the consumer. Further research would be necessary in order to thoroughly
407 understand the ageing process under other conditions/factors such as breed, feeding systems,
408 muscle type and others.

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- 556

557 **Table 1.** Effect of ageing time (0, 7, 14 and 21 days) on foal meat in-mouth and visual acceptability
 558 scores.

Acceptability	0 d	7 d	14 d	21 d	SEM	<i>p</i> -value
In-mouth	5.49 ^b	6.20 ^a	5.90 ^{ab}	5.86 ^{ab}	0.11	0.029
Visual	5.74 ^b	6.44 ^a	6.22 ^{ab}	3.97 ^c	0.11	<0.001

559 d: day; SEM: standard error of the mean.

560 Within a row, means with different superscripts indicate statistically significant differences by
 561 Tukey's test ($p \leq 0.05$).
 562

563 **Table 2.** Effect of ageing time (0, 7, 14 and 21 days) on foal meat in-mouth and visual acceptability
564 scores depending on clusters (Agglomerative Hierarchical Clustering).

Acceptability	Cluster	n	0 d	7 d	14 d	21 d	SEM
In-mouth	1	31	4.55 ^c	7.55 ^a	5.53 ^{bc}	6.62 ^{ab}	0.165
	2	54	7.54 ^a	6.94 ^{ab}	7.10 ^{ab}	6.66 ^b	0.166
	3	35	3.14 ^a	3.83 ^a	4.26 ^a	3.91 ^a	0.167
Visual	1	33	3.95 ^a	4.70 ^a	4.16 ^a	2.51 ^b	0.168
	2	44	5.90 ^{cb}	6.70 ^{ab}	6.92 ^a	5.62 ^c	0.169
	3	30	6.35 ^a	7.07 ^a	6.36 ^a	1.50 ^b	0.170
	4	13	7.52 ^a	9.80 ^a	9.68 ^a	8.00 ^a	0.171

572 d: day; SEM: standard error of the mean.

573 Within a row, means with different superscripts indicate statistically significant differences by
574 Tukey's test ($p \leq 0.05$).

575

Table 3. Number of responses and frequencies from the questionnaire distributed according to the clusters obtained from in-mouth and visual acceptability scores (Agglomerative Hierarchical Clustering).

Question	Possible answers	TOTAL	In-mouth acceptability			Visual acceptability			
			Cluster 1	Cluster 2	Cluster 3	Cluster 1	Cluster 2	Cluster 3	Cluster 4
Gender	Female	69(57.5)	18(58.1)	29(53.7)	22(62.9)	19(57.6)	27(61.4)	18(60.0)	5(38.5)
	Male	51(42.5)	13(41.9)	25(46.3)	13(37.1)	14(42.4)	17(38.6)	12(40.0)	8(61.5)
Age	18-35	39(32.5)	9(29.0)	18(33.3)	12(34.3)	6(18.2)	17(38.6)	14(46.7)	2(15.4)
	36-55	53(44.2)	17(54.8)	22(40.8)	14(40.0)	15(45.5)	18(40.9)	13(43.4)	7(53.8)
	Over 55	28(23.3)	5(16.1)	14(25.9)	9(25.7)	12(36.4)	9(20.5)	3(10.0)	4(30.8)
Occupation	Student	23(19.2)	5(16.1)	11(20.4)	7(20.0)	3(9.1)	11(25.0)	7(23.3)	2(15.4)
	Unemployed	74(61.7)	21(67.7)	31(57.4)	22(62.9)	22(66.7)	25(56.8)	19(63.3)	9(69.2)
	Employed	3(2.5)	1(3.2)	2(3.7)	0(0.0)	0(0.0)	1(2.3)	1(3.3)	0(0.0)
	Retired	20(16.7)	4(12.9)	10(20.4)	6(17.1)	8(24.2)	7(15.9)	3(10.0)	2(15.4)
How often do you consume foal meat?	Once a week or once a month	28(23.3)	13(41.9)	11(20.4)	4(11.4)	5(15.2)	9(20.5)	9(30)	3(23.1)
	Once a year or I have not tried it	92(76.7)	18(58.1)	43(79.6)	31(88.6)	28(84.8)	35(79.5)	21(70)	10(76.9)
How do you purchase foal meat?	Steak	26(21.7)	12(38.7)	9(16.7)	5(14.3)	9(27.3)	9(20.5)	4(13.3)	2(15.4)
	Cut in cubes	15(12.5)	9(29.0)	3(5.6)	3(8.6)	2(6.1)	0(0.0)	1(3.3)	1(7.7)
	Minced	6(5.0)	5(16.1)	0(0.0)	1(2.9)	0(0.0)	2(4.5)	4(13.3)	2(15.4)
	No answer	73(60.8)	5(16.1)	42(77.8)	26(74.3)	22(66.7)	33(75.0)	21(70.0)	8(61.5)
How do you prepare foal meat?	Deep fried	5(4.2)	2(6.5)	2(3.7)	1(2.9)	2(6.1)	3(6.8)	0(0.0)	0(0.0)
	Grilled	26(21.7)	13(41.9)	9(16.7)	4(11.4)	7(21.2)	7(15.9)	8(26.7.0)	4(30.8)
	Oven roasted	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
	Barbequed	1(0.8)	0(0.0)	0(0.0)	1(2.95)	1(3.0)	0(0.0)	0(0.0)	0(0.0)
	Stewed	5(4.2)	1(3.2)	2(3.7)	2(5.7)	1(3.0)	2(4.5)	1(3.3)	1(7.7)
	No answer	83(69.2)	15(48.4)	41(75.9)	27(77.1)	22(66.6)	32(72.7)	21(70.0)	8(61.5)
Do you do the shopping yourself?	Yes	81(67.5)	25(80.7)	32(59.3)	24(68.6)	23(69.7)	31(70.5)	18(60.0)	9(69.2)
	No	39(32.5)	6(19.3)	22(40.7)	11(31.4)	10(30.3)	13(29.5)	12(40.0)	4(30.8)
	Yes, at restaurants	13(10.8)	2(6.5)	8(14.8)	3(8.6)	4(12.1)	5(12.8)	3(10.0)	2(15.4)

Have you ever tried aged meat?	Yes, at home and restaurants	16(13.3)	5(16.1)	8(14.8)	3(8.6)	4(12.1)	9(23.1)	2(6.6)	1(7.7)
	No	16(13.3)	3(9.7)	5(9.3)	8(22.9)	6(18.2)	6(15.4)	4(13.3)	1(7.7)
	I don't know what aged meat is	75(62.5)	21(67.7)	33(61.1)	21(60.0)	19(57.6)	24(48.7)	21(70.0)	9(69.2)
Do you like aged meat?	Yes	20(16.7)	5(16.1)	11(20.4)	4(11.4)	6(18.2)	9(20.5)	4(13.8)	2(15.4)
	No	11(9.2)	3(9.7)	5(9.7)	3(8.6)	3(9.1)	5(11.4)	2(6.9)	1(7.7)
	I have not tried/ I don't know what aged meat is	89(74.2)	23(74.2)	38(70.4)	28(80.0)	24(72.7)	30(68.2)	23(79.3)	10(76.9)

Table 4. Effect of ageing time (0, 7, 14 and 21 days) on foal meat in-mouth CATA term citation frequencies and the overall citation frequencies of the ‘ideal foal meat’.

Category	CATA TERMS	ESS	CF 0 d	CF 7 d	CF 14 d	CF 21 d	ACF	CF (%)	p-value	‘ideal foal meat’	
										CF	CF (%)
Odour/Aroma	Intense	67	24 ^b	28 ^b	35 ^{ab}	44 ^a	131	48.9	0.004	87	72.5
	Livery	58	14	24	18	23	79	34.1	0.250	6	5.0
	Low intensity	73	43 ^a	36 ^a	26 ^{ab}	22 ^b	127	43.5	0.004	11	9.2
	Roasted	71	23 ^{bc}	18 ^c	33 ^{ab}	39 ^a	113	39.8	0.003	69	57.5
Texture	Easily dissolving	86	20 ^b	44 ^a	48 ^a	45 ^a	157	45.6	≤0.001	105	87.5
	Dry	99	63 ^a	46 ^b	44 ^b	45 ^b	198	50.0	0.027	0	0.0
	High residue	80	42 ^a	26 ^b	41 ^a	30 ^{ab}	139	43.4	0.031	2	1.7
	Juicy	87	25 ^b	49 ^a	45 ^a	41 ^a	160	46.0	0.003	118	98.3
	Chewy	95	71 ^a	38 ^b	35 ^b	29 ^b	173	45.5	≤0.001	1	0.8
	Tender	91	14 ^b	45 ^a	53 ^a	52 ^a	164	45.1	≤0.001	113	94.2
	Tough	75	59 ^a	21 ^b	12 ^b	19 ^b	111	37.0	≤0.001	0	0.0
Taste sensations	Bitter	24	6	6	7	12	31	32.3	0.289	0	0.0
	Sweet	46	23	23	21	15	82	44.6	0.335	45	37.5

ESS: effective sample size; CF: citation frequency; d: day; ACF: absolute citation frequency (sum of citation frequencies in foal meat aged of 0, 7, 14 and 21 d).

CF (%) = (ACF / ESS *4 ageing times) * 100

Within a row, means with different superscripts indicate statistically significant differences by Cochran’s Q test ($p \leq 0.05$).

Ideal sample was analysed separately and effective sample size was 120.

Table 5. Effect of ageing time (0, 7, 14 and 21 days) on foal meat visual CATA term citation frequencies and the overall citation frequencies of the ‘ideal foal meat’.

CATA TERMS	EES	CF 0 d	CF 7 d	CF 14 d	CF 21 d	ACF	CF (%)	p-value	‘ideal foal meat’	
									CF	CF (%)
Brownish	77	16 ^b	15 ^b	12 ^b	64 ^a	107	34.7	≤0.001	3	2.5
Dark	87	61 ^a	22 ^b	4 ^c	69 ^a	156	44.8	≤0.001	17	14.2
Fresh	107	68 ^b	88 ^a	81 ^a	10 ^c	247	57.7	≤0.001	116	96.7
Maroon	81	63 ^a	33 ^b	19 ^c	25 ^{bc}	140	43.2	≤0.001	24	20.8
Not uniform colour	94	46 ^b	44 ^b	25 ^c	62 ^a	177	47.1	≤0.001	4	3.3
Pinkish	50	10 ^c	20 ^b	37 ^a	6 ^c	73	36.5	≤0.001	25	20.8
Red	100	43 ^b	69 ^a	64 ^a	17 ^c	193	48.3	≤0.001	100	83.3
Spoilt	105	31 ^b	11 ^c	20 ^{bc}	97 ^a	159	37.9	≤0.001	0	0.0
Uniform colour	95	47 ^b	43 ^b	68 ^a	20 ^c	178	46.8	≤0.001	107	89.2

EES: effective sample size; CF: citation frequency; d: day; ACF: absolute citation frequency (sum of citation frequencies in foal meat aged of 0, 7, 14 and 21 d).

CF (%) = (ACF / ESS * 4 ageing times) * 100

Within a row, means with different superscripts indicate statistically significant differences by Cochran’s Q test ($p \leq 0.05$).

Ideal sample was analysed separately and effective sample size was 120.

Figure 1. Internal preference map of consumer IMA scores of foal meat samples aged over 0, 7, 14 and 21 days including the representation of **A)** individual consumers depending on the cluster they belong to and clusters projected as supplementary variables, and **B)** non-aged and aged foal meat samples.

Figure 2. Internal preference map of consumers VA scores of foal meat samples aged over 0, 7, 14 and 21 days including the representation of **A)** individual consumers depending on the cluster they belong to and clusters projected as supplementary variables, and **B)** non-aged and aged foal meat samples.

Figure 3. Representation of the in-mouth CATA terms and samples in the first and second dimensions of the Correspondence Analysis based on Chi-squared distance.

Figure 4. Representation of the visual CATA terms and samples in the first and second dimensions of the Correspondence Analysis based on Chi-squared distance.