Effect of finishing diet on consumer acceptability of Uruguayan beef in the European market

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Abstract

Eighty Hereford steers were used to evaluate the effect of finishing diet [A: pasture, B: pasture plus concentrate (0.6% live weight), C: pasture plus concentrate (1.2% live weight), D: concentrate] on consumer acceptability of Uruguayan beef in France (FR), United Kingdom (UK), Spain (ES) and Germany (DE). Consumers (200 per country) evaluated overall, tenderness and flavour acceptability of beef (8 point scale: 1'dislike extremely', 8'like extremely'). FR and UK rated lower acceptability scores for beef from D compared with A, B, and C. ES showed similar results for tenderness, but flavour scores did not differ between A and D. German consumers preferred beef from B and C. Overall, low levels of supplementation on pasture produced beef with the highest consumer acceptability followed by beef from pasture-fed animals. Feeding cattle with concentrate only may not be necessary to satisfy the EU market resulting in more profitable production systems for Uruguayan producers.

Key Words: Beef; Pasture; Concentrate; Consumer

1. Introduction

Beef production in Uruguay has been targeted to export markets, which account for approximately 78% of total production. In 2005, Uruguay became the world's 7th largest beef exporter with 398,541 tones of beef, the main destinations being the US

(74%), EU (10%), Mercosur, the Southern Common Market comprising Argentina, Brazil, Paraguay and Uruguay (3%), Israel (2%) and Russia (1%). While the EU market represents a minor percentage in volume relative to the US market, its value represents a significant figure compared with the US market supplying the EU with high value cuts (approximately 214.12 for EU vs. 303.60 for US in million USD for beef meat and byproducts, INAC 2008). Uruguay is currently focused on becoming more competitive in the world beef market through increasing beef production and quality according to market needs with concentrated efforts in high value markets. One of the benefits of increasing international trade is that consumers are offered a wider variety of products to choose from in the marketplace. However, cattle genetics and feeding and management practices differ across countries; as a result, beef from different countries has unique flavour attributes (Umberger, Feuz, Calkins & Killinger-Mann, 2002). Oliver et al. (2006) conducted consumer evaluations of the eating quality of Uruguayan beef compared with beef produced locally in Germany, Spain and United Kingdom. Although local beef was generally preferred, results showed that Uruguayan beef raised traditionally would be an acceptable product especially in Germany.

Uruguayan beef cattle production systems are based on pasture feeding, but more recently livestock producers have been investing on improved pastures and supplementation with concentrate leading to cattle with different carcass and meat quality attributes. Feedlot production represents around 5-6% of total slaughter, and it is expected to continue growing due to favorable market access conditions, higher prices of feedlot cattle, high value of land, and new foreign investments. It is important to

understand consumer preferences for the different beef characteristics to develop marketing or branding strategies. Umberger et al. (2002) and Sitz, Calkins, Feuz, Umberger and Eskridge (2005) showed that consumers could differentiate between the flavour of steaks when comparing US corn-fed vs. international grass-fed beef, suggesting that country-of-origin labelling as well as niche marketing may need to be considered to provide consumers with a consistent beef product that meets their palatability expectations. The aim of this study was to evaluate the effect of the inclusion of different levels of concentrate on a pasture feeding system on consumer acceptability of beef assessed in four European countries. Potential consumer clusters with differentiated tastes and preferences for beef from different finishing diets were also evaluated within a country and across countries.

2. Materials and Methods

2.1. Animals and diets

Eighty Hereford steers of the same genetic origin (391±24 kg live weight, 18 months old), initially reared on pasture, were finished on one of the following diets with increasing amounts of concentrate: A) pasture (4% of animal live weight: LW), B) pasture (3% LW) plus concentrate (0.6% LW), C) pasture (3% LW) plus concentrate (1.2% LW), and D) concentrate plus hay. Animals were fed at "La Estanzuela" research station of the National Institute of Agricultural Research of Uruguay located in Colonia,

Uruguay. The pasture included a mix of alfalfa (*Medicago sativa*), white clover (*Trifolium repens*), and tall fescue (*Festuca arundinacea*). Animals supplemented with 0.6 and 1.2% LW of concentrate (treatments B and C) were fed corn in the morning. The concentrate ration (treatment D) was fed twice daily and consisted of 85% ground corn, 12.8% sunflower expeller, 0.98% urea, 0.61% calcium carbonate, 0.61% salt and Rumensin®, and alfalfa hay was fed *ad libitum*.

2.2. Slaughter and sampling procedure

Animals were slaughtered when the average live weight of each treatment reached 500 kg in a commercial meat plant licensed for exporting following standard procedures. The *Longissimus lumborum* muscle was removed from each carcass at 48 h post mortem and cut into four 6 cm thick pieces between the L1-L5 vertebrae corresponding to samples evaluated in Germany (DE), France (FR), United Kingdom (UK) and Spain (ES). Samples were vacuum packaged, aged at 4ºC during 20 d, frozen and shipped to DE, FR, UK and ES for consumer sensory evaluation. Beef from one animal was evaluated by 10 consumers from each of the 4 European countries, and consumers evaluated beef from 20 animals per dietary treatment in each country.

2.3. Sample preparation

Samples were thawed at 4ºC for 24 h, cut into 2-cm thick steaks, and cooked in a double hot-plate grill pre-heated to 200ºC until final internal temperature reached 72ºC

(65ºC in FR) determined using individual thermocouples inserted into the geometric centre of the muscle. Steaks were trimmed of external fat and connective tissue, cut into 2x2x2 cm samples, wrapped individually in coded aluminum foil and kept warm in a heater until tasting.

2.4. Consumer sensory evaluation

Two hundred consumers were recruited in each country (DE, FR, ES) except in the UK where the final number of consumers was 186. Consumers were selected according to their age and gender trying to represent the distribution of the population in each country. Table 1 summarizes consumer demographic data for each country.

Twenty sensory sessions were conducted in each country with 10 consumers per session. Four beef samples were presented to each consumer in a heater to maintain sample temperature. Consumers evaluated the samples under white lights in the order printed on the recording sheet which was established to avoid the effect of sample order presentation, first-order or carry-over effects (Macfie, Bratchell, Greenhoff & Vallis, 1989). Each consumer rated overall acceptability, tenderness and flavour acceptabilities using 8-point category scales (1'dislike extremely', 2'dislike very much', 3'dislike moderately', 4'dislike slightly', 5'like slightly', 6'like moderately', 7'like very much', 8'like extremely'). The intermediate point corresponding to 'neither like nor dislike' was excluded from the scale to stimulate a specific response, since consumers tend to use this point in the scale very often when it is available (Guerrero, 1999). Consumers were asked

to eat unsalted and toasted bread and rinse their mouths out with water before tasting each meat sample.

2.5. Statistical analysis

Demographic and frequency of beef consumption data were summarized in contingency tables using the FREQ procedure of SAS (SAS Inst. Inc., Cary, NC). Sensory data analyses were carried out for each country individually (ES, DE, FR and UK), and globally for all countries. Overall, tenderness and flavour acceptability data were analyzed using the MIXED procedure of SAS. Mean separation was carried out using the Tukey test. The statistical model for each individual country included dietary treatment as a fixed effect, consumer as random, and session as a block effect. The statistical model for all countries included dietary treatment and country as fixed effects, consumer within country as random, and session within country as a block effect. Since all attributes were highly correlated (tenderness and flavour with overall acceptability were r=0.81 and r=0.85 for all countries), cluster analysis was conducted using the CLUSTER procedure of SAS on the 'overall acceptability' scores only.

3. Results

3.1. Frequency of beef consumption

Consumer frequency of beef consumption is shown in Table 2. More than half of the total consumers evaluated consumed beef at least once a week. The same applies for consumers from FR, ES, and UK for which more than 80, 70 and 60% of the consumers eat beef at least once a week, respectively. On the other hand, 76% of the evaluated consumers from Germany consumed beef once a month or with less frequency.

3.2. Beef acceptability of French consumers

Overall, tenderness and flavour acceptability scores of Uruguayan beef from 4 production systems evaluated by French consumers are presented in Table 3. Clusters of consumers based on scores of overall acceptability are also shown. Overall, tenderness and flavour acceptability scores were higher for beef from pasture-based diets (A, B and C) compared with beef from concentrate-based diet (D). These results indicate a preference of French consumers for beef finished on pasture with or without supplementation compared with beef from feedlot cattle.

Four clusters were identified using overall acceptability scores for French consumers. However, there is no clear pattern of preference by consumer clusters. Although consumers in cluster one (n=42) assigned higher scores to treatments A and B, these treatments did not differ ($P>0.05$) from treatment D. In addition, there were no differences among treatments A, C and D. Consumer overall scores in cluster two (n=72) were higher for beef from animals supplemented with 1.2% concentrate, followed by beef from animals fed 0.6% concentrate, and beef from animals fed pasture or concentrate

178 only, which did not differ (P>0.05). This cluster with the largest number of consumers
179 shows preference for beef from production systems based on pasture with some degree of
180 supplementation over beef from animals finished on pasture or concentrate only.
181 Consumers in the second largest cluster (n=59) did not differentiate overall acceptability
182 scores for beef from treatments A, B and D which were higher (P<0.05) than beef from
183 C. Overall acceptability scores for this group of consumers are lower compared with
184 other groups of French consumers. Finally, cluster four with the lowest number of
185 consumers (n=27) showed preference for treatments A and C compared with B and D,
186 which did not differ (P>0.05).
187
188 *3.3. Beef acceptability of British consumers*
189
190 Consumer clusters and overall, tenderness and flavour acceptability scores of
191 Uruguayan beef from 4 production systems evaluated by British consumers are presented
192 in Table 4. Similarly to French consumers, British consumers rated higher scores for
193 treatments A, B, and C compared with D in overall and tenderness acceptability showing
194 a preference for beef from pasture-based production systems. French consumers also
195 assigned higher flavour scores to treatments A, B and C than D, while British consumers
196 did not distinguished between treatments A and D which were rated lower than B and C
197 indicating that flavour scores for beef from production systems based on pasture or
198 concentrate only were least preferred.
199

200 Results from cluster analysis show 3 groups of British consumers with 89, 53 and
201 44 consumers in clusters 1, 2 and 3, respectively. Consumers from cluster 1 showed
202 higher overall acceptability scores for beef from B and D compared with A and C.
203 However, overall acceptability scores of beef from C did not differ (P>0.05) from A and
204 D. Although scores were numerically higher for A, B, and C compared with D in cluster
205 two, suggesting a preference for beef from animals finished on pasture-based systems,
206 there were no differences (P>0.05) in overall acceptability among treatments A, B and D.
207 Consumers in this cluster assigned lower scores compared with consumers in clusters 1
208 and 3. Consumers from cluster 3 preferred beef from animals supplemented on pasture
209 followed by beef from pasture-fed cattle, and beef from concentrate-fed animals which
210 were the least preferred.
211
212 *3.4. Beef acceptability of Spanish consumers*
213
214 Table 5 shows consumer clusters and overall, tenderness and flavour acceptability
215 scores of Uruguayan beef from 4 production systems evaluated by Spanish consumers.
216 Overall acceptability by ES consumers was higher for B and C compared with D, while A
217 did not differ from B, C or D, showing a preference for beef from animals fed a
218 combination of pasture and concentrate compared with concentrate only. Tenderness
219 acceptability scores were higher for beef from pasture-fed animals with or without
220 supplementation compared with beef from animals fed concentrate only. Spanish
221 consumers did not perceive differences in beef flavour among treatments.
222

223 Three consumer clusters were identified using overall acceptability scores. Scores
224 from consumers belonging to the largest cluster (n=86) were higher for D compared with
225 A and C, while A, B and C or B and D did not differ (P>0.05). This cluster shows
226 preference for beef from animals fed concentrate only or 0.6% corn. Cluster two (n=50)
227 showed higher acceptability scores for A, B and C compared with D, although B and D
228 did not differ (P>0.05) indicating a preference for beef from pasture-based diets with or
229 without concentrate. The third cluster (n=64) also showed preference for beef from
230 pasture based production systems compared with beef from animals fed concentrate only.
231
232 *3.5. Beef acceptability of German consumers*
233
234 Overall, tenderness and flavour acceptability scores of Uruguayan beef from 4
235 production systems evaluated by German consumers are presented in Table 6. Clusters of
236 consumers based on overall acceptability scores are also shown. Overall acceptability of
237 C was higher than A and D as rated by DE consumers. There were no differences
238 between B and C or among A, B and D treatments in overall acceptability. Tenderness
239 acceptability was higher for C compared with A, while A, B and D or B, C and D did not
240 differ (P>0.05). Flavour scores were higher for C compared with A and D, and for B
241 relative to A. Data indicate a preference of German consumers for beef from animals fed
242 on pasture and supplemented with 1.2% concentrate.
243
244 Five clusters of DE consumers were identified using overall acceptability scores
245 indicating a higher degree of segmentation compared to consumers from FR, UK and ES.

Consumers from cluster one (n=27) preferred beef from pasture feeding systems compared with beef from concentrate feeding. In contrast, consumers in cluster two (n=33) showed preference for treatments C and D, followed by B with treatment A being least preferred. Consumers in cluster 3 showed higher scores for beef from animals supplemented with 0.6% corn compared with other treatments which did not differ ($P>0.05$). Clusters 4 and 5 did not show differences in overall acceptability of beef from the different production systems, except that beef from B in cluster 4 showed lower acceptability scores compared with A, C and D, and beef from C in cluster 5 showed lower scores than B and D.

3.6. Beef acceptability of consumers from 4 European countries

Consumer clusters and overall, tenderness and flavour acceptability scores of Uruguayan beef from 4 production systems evaluated by European consumers are shown in Table 7. Overall acceptability scores of consumers from the 4 European countries evaluated (n=786) were higher for beef from animals fed on pasture and supplemented with concentrate followed by beef from pasture-fed animals, and beef from concentrate-fed cattle which were the least preferred. Tenderness scores were higher for beef from pasture-fed steers than beef from feedlot cattle. Beef from animals finished on pasture and supplemented with concentrate showed higher flavour acceptability scores compared with beef from animals finished on pasture or concentrate only, which did not differ ($P>0.05$).

Four clusters of consumers were identified according to overall acceptability scores. Cluster 1 with the highest number of consumers (n=333) did not show a clear preference for a particular type of production system. Beef from A and B was rated higher, but overall acceptability scores did not differ (P>0.05) among A, C and D. Consumers in cluster 2 (n=215) did show a preference for production systems with intermediate levels of supplementation with concentrate. Overall acceptability scores were higher for A and B than C and D which did not differ (P>0.05) for consumers in cluster 3 (131). Finally, consumers in cluster four (107) preferred beef from A and C, followed by B with treatment D being preferred the least.

4. Discussion

4.1. Frequency of beef consumption.

France, UK, DE and ES were at the top 5 EU-25 member states in 2007 for beef consumption with 1,615, 1,375, 960 and 680 (1000MT), respectively (Polet, 2007). Values of frequency of beef consumption for the 200 German consumers do not appear to reflect closely the pattern of beef consumption per year for this country. Broad approximations in meat consumption of beef, lamb, pork and poultry in 2006 were 20, 3, 50 and 27% for EU-27; 29, 5, 39 and 26% for FR; 26, 8, 31 and 36% for UK; 13, 5, 54 and 29% for ES; and 13, 2, 62 and 23% for DE, respectively (Bansback, 2007). Consumers from the location of Mainz and surrounding areas in Germany tend to eat

292 pork and poultry with a higher frequency, and beef and lamb less regularly compared
293 with the national German population (B. Nikolaus, *personal communication*).
294
295 *4.2. Acceptability of Uruguayan beef from different production systems by European*
296 *consumers.*
297
298 Tenderness and flavour have been identified as the most important attributes that
299 determine eating quality of Europeans (Glitsch, 2000). Tenderness is one of the major
300 criteria that contributes most to eating satisfaction and consumers are willing to pay more
301 for tender beef (Wheeler & Koohmaraie, 1994; Chambaz, Scheeder, Kreuzer & Dufey,
302 2003). A 9-member trained sensory panel evaluated beef samples from all treatments
303 resulting in differences in tenderness (Campo, Resconi, Olleta, Pardos, Lara & Sañudo,
304 2007). Trained panel tenderness ratings agree with consumer data from FR, UK and ES
305 showing higher values for beef produced on pasture compared with beef produced
306 feeding concentrate only. Instrumental tenderness was measured at 7 d (A:3.2, B:4.2,
307 C:3.6, D:4.5 kg shear force) and 20 d (A:2.9, B:3.7, C:3.2, D:4.0 kg) postmortem, and
308 Warner-Bratzler shear force (WBSF) values were higher ($P<0.05$) for beef from D
309 compared with A and C at both aging times (Campo, Brito, Hernandez, Soares de Lima,
310 Vaz Martins, San Julián, Montossi & Sañudo, 2007). Realini, Duckett, Brito, Dalla Rizza
311 and De Mattos (2004) evaluated the effect of pasture vs. concentrate feeding on quality of
312 Uruguayan beef and found that initial tenderness did not differ for beef from the different
313 production systems. However, beef from pasture-fed cattle had lower ($P<0.05$) WBSF
314 values at 7 and 14 d postmortem (2.91 vs. 3.84 and 2.83 vs. 3.45, respectively) showing

315 greater potential for postmortem tenderization through ageing than beef from
316 concentrate-fed animals. French et al. (2001) found that supplementing grass with low
317 levels of concentrate produced the most tender and acceptable meat at 2 days
318 postmortem, but that further ageing eliminated all treatment effects on eating quality of
319 beef.
320
321 Although initial tenderness (1-2 d postmortem) was not measured in this study,
322 WBSF values at 7 and 20 d postmortem, trained panel and consumer tenderness scores
323 from FR, UK and ES indicate that aged beef from pasture-fed cattle was more tender than
324 beef from concentrate-fed animals. In many experiments dietary effects are confounded
325 with animal age, growth rate or carcass weight and fatness at slaughter. In this study,
326 feedlot cattle were heavier than pasture-fed animals at slaughter (539.4 vs. 497.9 kg LW),
327 and fat percentage of major export cuts higher (16.7 vs. 13.7%, $P<0.05$) for D carcasses
328 compared with A. Temperature of the *Longissimus thoracis* muscle measured at 24 h
329 postmortem was higher ($P<0.05$) for all treatments compared with 100% pasture (A: 3.6,
330 B: 6.0, C: 6.8, D: 7.1ºC; Campo et al., 2007). Concentrate-fed cattle evaluated by Realini
331 et al. (2004) were also heavier, with higher carcass fat depth and higher carcass
332 temperature during chilling than pasture-finished cattle. Feedlot animals from both
333 studies were younger and heavier at slaughter and produced carcasses with higher fat
334 percentage that were chilled at a slower rate in the cooler than cattle fed on pasture
335 indicating that beef from concentrate-fed animals would be more tender than beef from
336 pasture-fed cattle.
337

338 Rowe, Maddock, Lonergan and Huff-Lonergan (2004a) studied the influence of
339 early postmortem protein oxidation on beef quality indicating that increased oxidation of
340 muscle proteins could have negative effects on fresh meat colour and tenderness. The
341 authors showed that protein carbonyl content (one indicator of protein oxidation) was
342 positively correlated with WBSF values. It has been shown that vitamin E levels in
343 muscle influence meat oxidation with high levels resulting in increased rate of
344 tenderization (Harris, Huff-Lonergan, Lonergan, Jones & Rankins, 2001; Rowe,
345 Maddock, Lonergan & Huff-Lonergan 2004b). Muscle vitamin E levels were similar for
346 beef from pasture-fed animals with or without supplementation which were higher
347 ($P<0.05$) compared with beef from concentrate-fed animals (Alvarez, Fuente, Díaz &
348 Cañeque, 2007). Greater protein oxidation due to the lower vitamin E content of beef
349 from treatment D could be related to the higher WBSF values and lower sensory ratings
350 for tenderness assigned by trained panelists and consumers. Rowe et al. (2004a) indicated
351 that increased protein oxidation during the first 24 h postmortem can substantially
352 decrease beef tenderness even in steaks aged 14 d. Although steaks were vacuum
353 packaged and stored frozen until consumer tasting, oxidation processes could have taken
354 place before and after packaging during storage due to residual oxygen. Results of shear
355 force and sensory analysis from this study do not agree with many published data
356 showing negative effects of forage finishing on meat tenderness (Davis, Cole, Backus &
357 Melton, 1981; Berry, Leddy, Bond, Rumsey & Hammond, 1988; Sitz et al., 2005).
358
359 There was a clear effect of the production system on mechanical and sensory
360 tenderness of beef showing that consumers from FR, UK and ES preferred beef from

361 animals finished on pasture with or without supplementation. On the other hand, German
362 consumers did not find beef from concentrate-fed cattle to be less tender than beef from
363 steers finished on pasture. Differences in beef acceptability between German consumers
364 and consumers from FR, UK and ES could be in part, due to the lower frequency of
365 consumption of the evaluated consumers in DE compared with the rest of the consumers.
366 When all evaluated consumers from the 4 European countries are considered (n=786),
367 tenderness ratings were higher for beef from pasture-based systems relative to beef from
368 the feedlot system.
369
370 Flavour is another key sensory characteristic determining overall beef
371 acceptability and influences consumers' willingness to pay for steaks. Umberger et al.
372 (2002), and Killinger, Calkins, Umberger, Feuz and Eskridge (2004) identified groups of
373 consumers who can distinguish a flavour difference between corn-fed beef and grass-fed
374 beef, and these consumers were willing to pay a premium for their preferred flavour. The
375 9-member trained sensory panel found differences in beef-odour and beef-flavour
376 intensity which decreased with increasing amount of concentrate in the diet (Campo et
377 al., 2007). The higher beef-odour and beef-flavour intensity of beef from pasture-fed
378 production systems compared with beef from the feedlot system as assessed by the
379 sensory panel could explain the higher consumer ratings in flavour for beef from A, B
380 and C relative to D assigned by French consumers. These data do not agree with many
381 published research indicating less palatability for grass-fed beef in comparison with
382 concentrate-fed beef (Mandell, Gullett, Buchanan-Smith & Campbell, 1997; Duckett,

383 Neel, Sonon, Fontenot, Clapman & Scaglia, 2007; Kerth, Braden, Cox, Kerth & Rankins,
384 2007).
385
386 British and German consumers also preferred the flavour of beef from treatments
387 B and C. However, flavour consumers' scores were lower for beef from A relative to B
388 and C, with no differences between A and D. Mandell, Buchanan-Smith and Campbell
389 (1998) showed that forage finishing can satisfy tenderness demands of consumers, but
390 intensity of beef flavour still differs from grain-fed beef. Mandell et al. (1997) in a
391 previous study compared forage vs. grain finishing at similar backfat levels and found
392 that tenderness attributes were not affected by forage finishing, but the intensity of beef
393 flavour was greater in grain-fed beef, which was probably due in part to the different fatty
394 acid composition of forage-fed beef. Duckett et al. (2007) also found that finishing steers
395 on forage did not alter tenderness compared with concentrate finishing. However, beef
396 flavour intensity was lower and off-flavour intensity greater for beef from pasture than
397 concentrate finishing. In this study, consumers from UK and DE found that
398 supplementing pasture with 0.6 and 1.2% concentrate produced beef with higher flavour
399 ratings, but feeding animals concentrate only eliminated flavour improvements in beef.
400
401 Several factors contribute to the flavour of beef including marbling level and fatty
402 acid composition. Intramuscular fat content affects flavour, juiciness and tenderness, and
403 it is positively related to overall palatability. A 'window of acceptability' with fat content
404 between 3 and 7.3% has been proposed in the US. Miller (2004) indicated that as fat
405 content increases palatability increases, but the rate of improvement in palatability with

406 each incremental increase in fat is not constant. As fat increases outside the window of
407 acceptability from less than 1 to 3%, palatability increases at the highest rate. Miller
408 (2004) evaluated overall palatability of beef top loin steaks by a trained sensory panel and
409 found that the greatest improvements in reducing the number of steaks with ratings less
410 than 5 (1=extremely undesirable, 8=extremely desirable palatability) occurred when
411 chemical lipid changed from 2 to 3%. This level of change in intramuscular fat of steaks
412 was observed between animals fed on pasture (2.06% lipid) and animals fed on
413 concentrate (2.99%), with treatments B (2.16%) and C (2.30%) showing intermediate
414 values closer to treatment A (Alvarez et al., 2007).
415
416 Miller (2004) demonstrated that consumers can also detect differences in meat
417 palatability as marbling score changes. In the US, beef consumers rated top loin steaks
418 with the highest amount of marbling the highest for juiciness and overall acceptability,
419 and marbling also affected the consumers' perception of tenderness and flavour. In the
420 present study, carried out with European consumers and beef from Uruguayan origin,
421 other factors than marbling content appeared to be important when assigning overall and
422 tenderness acceptability scores, since A, B and C were rated higher than D by French,
423 British and Spanish consumers despite the higher intramuscular levels of beef from
424 concentrate-fed animals. In addition, tenderness, flavour and overall acceptability scores
425 assigned by German consumers were similar for beef from pasture and concentrate-fed
426 cattle despite the marbling differences in beef from both production systems. Sasaki and
427 Mitsumoto (2004) emphasized that the requirements for food quality are becoming

increasingly diverse and, therefore, even marbling is not likely to be important to all consumers.

Animals finished on forages have higher levels of polyunsaturated fatty acids (PUFAs), *n*-3 fatty acids, and conjugated linoleic acid (CLA) than cattle finished on concentrates (Realini et al., 2004; Nuernberg et al., 2005), providing meat to consumers with a more favorable fatty acid profile from a health perspective (Scollan, Hocquette, Nuernberg, Dannenberger, Richardson & Moloney, 2006). However, altering the PUFA content in beef may have important implications for meat quality characteristics such as flavour due to their greater susceptibility to oxidation and the production of volatile compounds during cooking (Campo, Nute, Hughes, Enser, Wood & Richardson, 2006). Maruri and Larick (1992) suggested that the greatest sensory difference in beef from forage-fed and grain-fed steers is in the flavour of fat. The less desirable flavour of forage-fed beef has been described as intense milky-oily, sour, fishy, or grassy flavour (Schroeder, Cramer, Bowling & Cook, 1980; Melton, Black, Davis & Backus, 1982). High concentrations of unsaturated fatty acids increase the potential for rancidity and formation of off-flavours often associated with forage-finished beef (Bennett et al., 1995). Altered meat flavours have been linked to higher concentrations of α-linolenic acid (Mandell et al., 1998) and other lipids including diterpenoids (product of ruminal catabolism of chlorophyll) (Griebenow, Martz & Morrow, 1997), polar lipids, and lipid-soluble compounds from plants.

Lipid analyses showed that saturated fatty acids were similar among dietary treatments, while monounsaturated fatty acids increased and PUFAs decreased with increasing amounts of concentrate in the diet. Beef from pasture-fed steers showed higher levels of *n*-3 fatty acids, particularly α-linolenic acid, compared with beef from concentrate-fed animals with other treatments being intermediate (Alvarez et al., 2007). It seems that UK and DE consumers were able to detect some of the undesirable beef flavour characteristics associated with pasture feeding. On the other hand, British consumers assigned higher flavour ratings for beef from pasture-fed animals than beef from concentrate-fed cattle, while Spanish consumers did not find differences ($P>0.05$) in beef flavour among dietary treatments.

Vitamin E levels in muscle influence meat oxidation with high levels resulting in reduced rate of lipid oxidation (Liu, Scheller, Arp, Schaefer & Williams, 1996). Beef from pasture-fed animals with or without supplementation showed similar muscle vitamin E levels which were higher than the recommended threshold of 3.0-3.5 mg/kg muscle to achieve a significant impact on the reduction of pigment and lipid oxidation (Arnold, Arp, Scheller, Williams & Schaefer, 1993; Liu et al., 1996). Beef from animals fed concentrate only showed vitamin E values lower than 3.0 mg/kg. Muscle vitamin E concentration levels agree with results found by Realini et al. (2004) for pasture-fed and concentrate-fed Uruguayan cattle (3.91 vs. 2.92 mg/kg, respectively). The lower flavour ratings assigned to beef from feedlot cattle compared with beef from animals fed lower levels of supplementation with concentrate (B and C) by French and British consumers, may be associated with higher lipid oxidation during meat storage leading to undesirable

473 volatile compounds detected by consumers after cooking. However, results from the
474 trained sensory panel did not find differences in intensity of rancid flavour in meat among
475 treatments (Campo et al., 2007).
476
477 Summarizing, overall sensory data showed that consumers from FR and UK rated
478 lower acceptability scores for beef from steers fed concentrate only compared with beef
479 from pasture-fed production systems with or without concentrate feeding. Consumer
480 preferences from Spain showed similar results when evaluating tenderness. However,
481 flavour scores among treatments and overall acceptability scores for A and D did not
482 differ for Spanish consumers. German consumers preferred beef from steers
483 supplemented with concentrate on pasture compared with beef from steers fed pasture or
484 concentrate only. When consumers from all evaluated countries are considered (n=786),
485 beef from animals supplemented with concentrate on pasture is preferred, followed by
486 beef from pasture-fed animals and beef from concentrate-fed cattle which was least
487 preferred.
488
489 *4.3. Cluster Analysis*
490
491 Cluster analysis identified groups of consumers with differentiated tastes and
492 preferences in relation to different beef production systems. These groups may constitute
493 significant market segments that demand beef with different characteristics. Oliver et al.
494 (2006) evaluated the eating quality of Uruguayan beef compared with beef produced in
495 DE, ES and UK, and found that consumers did not prefer the same type of beef within the

same country, suggesting that individual preferences could lead to market segmentation based on taste preferences. Since all attributes were highly correlated (tenderness and flavour with overall acceptability were r=0.79 and r=0.83 for FR, r=0.78 and r=0.82 for UK, r=0.75 and r=0.82 for ES, r=0.67 and r=0.74 for DE, and r=0.81 and r=0.85 for all countries, respectively), cluster analysis was conducted on the 'overall acceptability' scores only. Neely et al. (1998) reported that both flavour and tenderness were highly correlated with consumer overall like-ratings for beef steaks (r=0.86 and 0.85, respectively). Killinger et al. (2004) also indicated that flavour ratings were highly correlated with overall acceptability (r=0.86) and tenderness (0.74). Oliver et al. (2006) found correlations of tenderness and overall acceptability of 0.81, 0.79, 0.79, and flavour and overall acceptability of 0.76, 0.85, 0.84, for DE, ES and UK consumers, respectively.

Four categories of beef preference according to production systems were considered as 'pasture-fed beef', 'concentrate-fed beef', 'pasture & concentrate-fed beef' and 'indifferent'. There were no groupings of consumers that preferred 'pasture-fed beef' or 'concentrate-fed beef'. Umberger et al. (2002) identified groups of consumers who could distinguish a flavour difference between US corn-fed beef and Argentine grass-fed beef, and these same consumers were willing to pay a significantly higher price for their preferred flavour. In this study, many variables other than diet differed (management practices, animal type, environment) and extreme diets were compared (grass vs. grain), whereas beef from the present study came from the same genetics and environment except for the feeding system with the inclusion of different levels of concentrate on a pasture feeding system. In the EU many consumers feel that meat from less intensively-

519 fed animals has a better taste, while in the US grass-fed beef is less acceptable (Mandell
520 et al., 1998; Melton, 1990).
521
522 Cluster 3 from DE and UK and cluster 2 from FR preferred 'pasture &
523 concentrate-fed beef'. Many consumer clusters from all evaluated countries could be
524 classified as 'indifferent' with no clear preference for a particular production system
525 (cluster 1 and 2 from ES, 4 and 5 from DE, 1 and 3 from UK and 1 and 2 from FR). A
526 few clusters showed a combination of 2 categories of beef preferences such as 'pasture-
527 fed beef' and 'pasture & concentrate-fed beef' (cluster 3 from ES, 1 from DE and 4 from
528 FR). Only one cluster showed a combination of 'concentrate-fed beef' and 'pasture &
529 concentrate-fed beef' categories of beef preference (cluster 2 from DE). Data averaged
530 across countries indicated that cluster 1 including the majority of the consumers (42.4%)
531 falls in the 'indifferent' category since no clear preference is shown among beef from the
532 different production systems. The second largest cluster (27.3% of the consumers)
533 preferred 'pasture & concentrate-fed beef', while consumers in clusters 3 and 4 (16.7 and
534 13.6%) showed a combination of 'pasture-fed beef' and 'pasture & concentrate-fed beef'
535 categories of beef preference.
536
537 Results from cluster analysis showed that it is difficult to identify groups of
538 consumers within a country and across countries with clear preferences for Uruguayan
539 beef from the different production systems. In addition, consumer information data (age,
540 gender, level of education, frequency of beef consumption and income) were used to
541 identify the characteristics that defined these groups of consumers. However, the clusters

542 did not show any distinct characteristics based on the demographic variables (data not
543 shown). Oliver et al. (2006) also found that the identified clusters in DE, ES and UK with
544 respect to overall acceptability of beef did not reveal relevant differences on the basis of
545 demographic variables (age, gender and with respect to beef consumption).
546
547
548 **5. Conclusions**
549
550 Results confirmed previous findings showing that Uruguayan beef would be an
551 acceptable product in four of the major beef importing countries in the EU market. While
552 consumer sensory preferences were found in overall, tenderness and flavour acceptability
553 for beef from the different production systems in each country and across countries, the
554 overall magnitude of the differences were within 1 point using an 8 point scale. Results
555 from this study showed that low levels of supplementation on pasture produced beef with
556 the highest consumer acceptability followed by beef from pasture-fed animals. Pasture
557 finishing appears to satisfy tenderness demands of French, British and Spanish
558 consumers, and flavour demands of French and Spanish consumers. Feeding cattle with
559 concentrate only may not be necessary to satisfy the EU market of beef resulting in more
560 profitable production systems for Uruguayan producers. Product differentiation between
561 'pasture' and 'pasture plus concentrate' production systems seems to be important to
562 address consumer preferences in tenderness and flavour in Germany and the United
563 Kingdom when developing marketing strategies. Further research is needed including

other countries and more locations within each country to improve understanding of consumer preferences in Europe and better characterize the EU beef market.

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708 Table1. Consumer demographic data (%).

Country	n	Gender		Age			
		Male	Female	18-25	26-40	41-60	61-75
ES	200	48.0	52.0	17.0	33.5	33.0	16.5
FR	200	49.0	51.0	14.5	31.5	34.5	19.5
DE	200	46.5	53.5	23.0	26.5	30.0	20.5
UK	186	43.8	56.2	16.2	22.2	45.9	15.7

709 ES = Spain., DE = Germany., FR = France., UK = United Kingdom

710

711 Table 2. Frequency of beef consumption by European consumers.

Beef		Frequency of consumption				
	N	More than twice per week	Once a week	Once every 15 days	Once a month	Less than once a month
Total	784	21.4	36.0	14.4	12.6	15.6
ES	199*	23.1	49.3	19.1	6.5	2.0
DE	200	2.0	7.5	14.5	28.0	48.0
FR	200	37.0	47.5	7.5	6.0	2.0
UK	185	23.8	40.0	16.8	9.7	9.7

712 *One consumer left a blank answer for frequency of consumption.

713 ES = Spain., DE = Germany., FR = France., UK = United Kingdom

714

715 Table 3. Least square means and standard error (SE) of French consumer scores for
716 overall, tenderness, and flavour acceptability of beef from different production systems,
717 and consumer clusters based on overall acceptability scores.

FR	N	A	B	C	D	SE
Overall acceptability						
Total	200	5.5[a]	5.6[a]	5.7[a]	5.1[b]	0.10
Cluster						
1	42	6.7[ab]	6.7[a]	6.3[b]	6.4[ab]	0.15
2	72	4.9[c]	5.9[b]	6.3[a]	4.8[c]	0.12
3	59	4.9[a]	5.0[a]	4.0[b]	4.8[a]	0.19
4	27	6.4[a]	4.1[b]	6.2[a]	4.1[b]	0.18
Tenderness acceptability						
Total	200	5.6[a]	5.6[a]	5.8[a]	5.2[b]	0.11
Flavour acceptability						
Total	200	5.3[a]	5.5[a]	5.4[a]	5.0[b]	0.11

718 Means within the same row with different letters (a,b,c) differ (P<0.05).

719 A) pasture (4% LW), B) pasture (3% LW) and concentrate (0.6% LW), C) pasture (3%
720 LW) and concentrate (1.2% LW), and D) concentrate plus hay *ad libitum*.

721 Table 4. Least square means and standard error (SE) of British consumer scores for
722 overall, tenderness, and flavour acceptability of beef from different production systems,
723 and consumer clusters based on overall acceptability scores.

UK	N	A	B	C	D	SE
Overall acceptability						
Total	186	5.5[a]	5.8[a]	5.7[a]	5.1[b]	0.10
Cluster						
1	89	6.0[c]	6.5[a]	6.1[bc]	6.3[ab]	0.10
2	53	4.5[ab]	4.2[ab]	4.5[a]	3.8[b]	0.20
3	44	5.5[b]	6.1[a]	6.2[a]	4.0[c]	0.15
Tenderness acceptability						
Total	186	5.4[a]	5.5[a]	5.5[a]	4.9[b]	0.12
Flavour acceptability						
Total	186	5.3[b]	5.7[a]	5.6[a]	5.1[b]	0.11

724 Means within the same row with different letters (a,b,c) differ ($P<0.05$).

725 A) pasture (4% LW), B) pasture (3% LW) and concentrate (0.6% LW), C) pasture (3%
726 LW) and concentrate (1.2% LW), and D) concentrate plus hay *ad libitum*.

727 Table 5. Least square means and standard error (SE) of Spanish consumer scores for
728 overall, tenderness, and flavour acceptability of beef from different production systems,
729 and consumer clusters based on overall acceptability scores.

ES	N	A	B	C	D	SE
Overall acceptability						
Total	200	5.5^{ab}	5.7^{a}	5.6^{a}	5.3^{b}	0.09
Cluster						
1	86	5.3^{b}	5.7^{ab}	5.3^{b}	5.9^{a}	0.12
2	50	6.7^{a}	6.5^{ab}	6.7^{a}	6.1^{b}	0.12
3	64	5.1^{a}	5.3^{a}	5.3^{a}	4.0^{b}	0.15
Tenderness acceptability						
Total	200	5.6^{a}	5.6^{a}	5.6^{a}	5.1^{b}	0.10
Flavour acceptability						
Total	200	5.3	5.6	5.5	5.3	0.10

730 Means within the same row with different letters (a,b,c) differ ($P<0.05$).

731 A) pasture (4% LW), B) pasture (3% LW) and concentrate (0.6% LW), C) pasture (3%
732 LW) and concentrate (1.2% LW), and D) concentrate plus hay *ad libitum*.

733 Table 6. Least square means and standard error (SE) of German consumer scores for
734 overall, tenderness, and flavour acceptability of beef from different production systems,
735 and consumer clusters based on overall acceptability scores.

DE	N	A	B	C	D	SE
Overall acceptability						
Total	200	5.4^{b}	5.6^{ab}	5.8^{a}	5.5^{b}	0.10
Cluster						
1	27	5.6^{a}	5.0^{b}	5.8^{a}	3.3^{c}	0.19
2	33	3.8^{c}	5.0^{b}	6.0^{a}	5.7^{a}	0.16
3	43	5.5^{b}	6.6^{a}	5.7^{b}	5.9^{b}	0.16
4	63	6.6^{ab}	5.9^{c}	6.8^{a}	6.4^{b}	0.12
5	34	4.3^{ab}	4.6^{a}	3.8^{b}	4.8^{a}	0.21
Tenderness acceptability						
Total	200	5.2^{b}	5.4^{ab}	5.7^{a}	5.4^{ab}	0.11
Flavour acceptability						
Total	200	5.3^{c}	5.6^{ab}	5.8^{a}	5.4^{bc}	0.10

736 Means within the same row with different letters (a,b,c) differ ($P<0.05$).

737 A) pasture (4% LW), B) pasture (3% LW) and concentrate (0.6% LW), C) pasture (3%
738 LW) and concentrate (1.2% LW), and D) concentrate plus hay *ad libitum*.

739 Table 7. Least square means and standard error (SE) of Spanish, German, French, and
740 British consumer scores for overall, tenderness, and flavour acceptability of beef from
741 different production systems, and consumer clusters based on overall acceptability scores.

	N	A	B	C	D	SE
Overall acceptability						
Total	786	5.5^{b}	5.7^{a}	5.7^{a}	5.2^{c}	0.05
Cluster						
1	333	6.3^{ab}	6.4^{a}	6.2^{b}	6.2^{b}	0.05
2	215	4.3^{d}	5.5^{b}	5.9^{a}	5.0^{c}	0.08
3	131	4.7^{a}	5.0^{a}	3.7^{b}	4.1^{b}	0.12
4	107	6.1^{a}	4.5^{b}	5.6^{a}	4.0^{c}	0.10
Tenderness acceptability						
Total	786	5.4^{b}	5.5^{ab}	5.6^{a}	5.1^{c}	0.05
Cluster						
Flavour acceptability						
Total	786	5.3^{b}	5.6^{a}	5.6^{a}	5.2^{b}	0.05

742 Means within the same row with different letters (a,b,c) differ (P<0.05).

743 A) pasture (4% LW), B) pasture (3% LW) and concentrate (0.6% LW), C) pasture (3%
744 LW) and concentrate (1.2% LW), and D) concentrate plus hay *ad libitum*.

745