# The impact of the sensory experience on scale and preference heterogeneity: The GMNL model approach applied to pig castration and meat quality

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# The impact of the sensory experience on scale and preference heterogeneity: The GMNL model approach applied to pig castration and meat quality

**Abstract**

The EU is considering a future ban on surgical pig castration by 2018 which may affect markets and consumers preferences. This study analysed consumers' expected preference toward a masking strategy obtained from a mixture of spices and smoking of high level boar taint frankfurter sausages. In addition, we analysed the impact of the sensory experience on the non-observed heterogeneity both at the scale and mean preferences. We carried out two Non-Hypothetical Discrete Choice Experiments (DCE) by creating a real shopping scenario before and after the hedonic sensory test for a sample of 150 consumers from the Metropolitan area of Madrid, Spain. Data used in this analysis were obtained from questionnaires completed in a controlled environment and estimated the recently developed Generalised Multinomial Logit Model (GMNL).

Results showed the appropriateness of the proposed masking strategy of boar meat as a raw material for the processed meat industry in Spain. Consumers also declared their willingness to pay a premium for this flavours. The sensory experience have had impact on both the scale and preference heterogeneity. The degree of randomness and uncertainty of consumers decreased significantly in their final election and the source of unobserved heterogeneity obtained from the scale become more independent.

## Introduction and objectives

While the piglet castration is regulated by the CE Directive 93/2001 stating that it may only be performed using methods that do not involve tearing of the tissue, the EU is considering a future ban on surgical pig castration by 1 January 2018 (EC, 2010). This potential prohibition relies not only on its negative impact on pig welfare[1] (Rault *et al*., 2011) but also because consumers demand lean meat with no off-odours and the production costs associated with entire males (Prunier *et al*., 2006) are lower. In a first pronouncement, from January 2012, in certified organic pig production, the surgical castration of piglets, if carried out, should be performed with prolonged analgesia and/or anaesthesia (Commission Regulation (EC) Nº 889/2008). In a transition period, surgical castration should only be performed with pain relief and efforts should be undertaken to facilitate the end of surgical castration (Heid & Hamm, 2013). The European changes in the animal welfare regulations and policies, in particular the pig sector, have been the results of an increasing societal pressure to seek for more humane production systems (EC, 2005 and EC, 2007). The pig welfare is one of the most studied sector as pork is the most produced and consumed meat in the EU (FAOSTAT, 2012). In this context, the pig production has received a special attention from the European authorities and several regulations have been approved. Recently, the EC directive 120/2008 banned the use of sow stalls since January 2012.

Annually, approximately 100 million pigs or about 80% of the total population of male piglets are surgically castrated in the EU of which 48.7% are surgically castrated without anaesthesia (Fredriksen *et al*., 2009; Borrisser-Pairó et al., 2014). The practice of castration of male piglets is important to avoid boar taint, which is a distinctive and unpleasant odour and flavour perceived through a combination of Skatole and Androstenone compounds. In this context, within the EU, the Meat Hygiene Regulation 842/2004/EC states that meat manifesting a "pronounced sexual odour" is to be declared unfit for human consumption (Whittington *et al*., 2011). However, the castration practice increases the production costs and leads to fatter carcasses (Tuyttens *et al*., 2012). Raising entire male pigs is more profitable for farmers due to leaner carcasses and higher protein content (Lundström *et al*., 2009). In this context, the importance to implement alternatives for castration is gaining relevance (Heid & Hamm, 2012; Font-i-Furnols, 2012).

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[1] Behavioural changes observed after castration included reduced nursing and walking, and increased pain related behaviours suggesting that pigs experience acute pain in response to castration (Sutherland, 2015).

Many alternatives to castration have been explored: *a)* genetic selection and gender selection for 'low-taint' pigs (De Campos *et al.*, 2015), *b)* different management and rearing strategies (Bonneau & Lebret 2010; Wesoly *et al.*, 2015), *c)* slaughter at a younger age and lower weight (Von Borell *et al.*, 2009), *d)* detection of boar taint at slaughter line (Vestergaard *et al.*, 2006), *e)* mixing of tainted with untainted meat (Walstra, 1974) and *f)* masking unpleasant odours and flavours with the appropriate masking strategy such as spices, marinades or heat treatment (Valeeva *et al.*, 2009; Mörlein *et al.*, 2015) and if the castration is applied, the immunocastration is one of the recently most studied alternatives (Gamero-Negrón *et al.*, 2015).

An overwhelming majority of people are sensitive to the odour of skatole (Weiler *et al.*, 2000), however less people is sensitive to androstenone (Blanch *et al.*, 2012). In this context, the production of meat from entire males may appears to have a promising future (Bonneau & Chevillon, 2012) if is adequately commercialized within the processed pig meat sector (Bonneau, 1998; Gunn *et al.*, 2004), since the boar tainted meat is better accepted in processed products than in retail cuts (Bañón *et al.*, 2003; Valeeva *et al.*, 2009). In this context, an effective and specific strategy of masking boar taint in the pork processed products became a worthy aspect to investigate. In the Spanish case, there is a need for updated knowledge about processing opportunities for boar meat, particularly if the castration is banned in a near future. As commented by Lunde *et al.* (2008), if castration is prohibited, it would be relevant to identify processing methods that could still provide quality products by allowing the processing industry to adjust their recipes to minimize such off-flavour.

Several studies suggested different strategies to mask boar taint in processed meat. In ready-to-eat marinades meat the use of liquid smoke and oregano extracts appeared to be a strategy for masking (Lunde *et al.*, 2008). Likewise in fermented sausage the use of spices, liquid smoked or starter cultures have been proposed as potential solution to remove the perception of boar taint (Malmfors & Lundström, 1983; Stolzenbach *et al.*, 2009).

However, focusing only on the acceptance of the most effective masking strategy gives only a partial view of the consumers' preferences. Liking or disliking a food product does not only depend on physicochemical properties but also on the consumers' expectations and attitudes toward extrinsic cues (Lange *et al.*, 1998; Franchi, 2012; Meier-Dinkel *et al.*, 2013; Asioli *et al.*, 2014). The consumer final choice of a food product, and thus its willingness to pay for it (WTP), is a mixture between the sensory experience (measured by the intrinsic cues) and the other descriptors

of the products (commonly measured by the extrinsic cues) such as the price, the brand and the origin. The relevance of the sensory experience in food choices is not new and the hedonic experiences have a strong influence on the willingness-to pay (Heid & Hamm, 2013). Consumers' experience modifies product quality perceptions and scoring behaviour, as well as it is likely to affect repurchase decisions (Poole *et al*., 2006). Even more, in some cases it is more important than label information (Combris *et al*., 2009).

In this context, the objective of this paper is threefold: First, to analyse the consumers' expected preference toward a masking strategy of high level boar taint of frankfurter sausages by a flavour developed from different herbs and natural smoking. Second to study the impact of the sensory experience of this masking strategy on such preferences through a hedonic test of four different frankfurter sausage; flavoured and original taste obtained from castrated pigs and boars[2]. Third, to assess how the non-observed heterogeneity both at the scale and mean preferences of the sausage' attributes are affected by the experience in a real shopping scenario.

To reach these objectives, we applied two Non-Hypothetical Discrete Choice Experiments (DCE) by creating a real shopping scenario before and after the hedonic sensory test for a sample of 150 consumers that carried out in Madrid, Spain. The Discrete Choice Experiments aims to identify the individual's indirect utility function associated with attributes of products by examining the trade-offs they make when making choice decisions. Thus, several alternatives (products) that are described by several attributes with varying levels are presented to respondents in an array of choice sets. The respondent is then asked to select its preferred alternative within each choice set, thereby revealing his/her preference for certain attributes and levels. Subsequently, the relative importance or willingness to pay of the attributes can be indirectly recovered from respondents' choices. To motivate the consumers in the recruitment process, they were rewarded by €15. In addition, before the DCE tasks, all participants were unexpectedly rewarded by an additional €5 while explaining that a real shopping scenario is to be created at the end of the experiment. Individuals who agree to participate were asked to purchase their selected product from a randomly chosen choice set obtained from the DCE and to pay its posted price.

From one hand, at the empirical level, this study is the first paper that analyse consumers acceptance toward the proposed masking strategy in the frankfurter sausage obtained from boars

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[2] The sensory experiment details; how pigs were reared and slaughtered, the meat sampling, the sausage preparation, the masking flavour development, acceptance heterogeneity are the objective of another paper that is in progress as above commented.

meat in the Spanish market. On the other hand, at the methodological level, this paper contributes to the literature of the Discrete Choice Modelling (DCM) using the recently developed Generalised Multinomial Logit Model (GMNL) of Fiebig *et al*. (2010). In this context to our knowledge, this research is the first application, in the literature of boar tainted meat preferences studies that analyse the impact of sensory experience on consumers' preferences and on both the scale and the preference heterogeneity.

## Materials and methods

### Consumer panel

The impact of sensory experience on the expected preferences was analysed on a sample of 150 consumers selected from the Metropolitan area of Madrid province. Participants represent the Spanish consumers over 18 years of age who regularly purchase food and beverages and having purchased and consumed frankfurter sausage at least one time in the last month. Data used in this analysis were obtained from questionnaires completed in a controlled environment. A quota sampling procedure was used to guarantee a representative sample in terms of gender, postal districts (67 different districts) and age. Consumers were recruited from a specialized consumers study company (Silliker Ibérica, S.A.) and were economically compensated by €15 to participate in an experiment of about 1.5 hours. Table 1 summarize the main socio-demographic variables of the sample components.

Table 1: Summary of the socio-demographic variable of the sample.

| Socio-demographic variables (N) | Age (150) (years) | Gender (150) % female | Study level (150) | | | Family Income (€/month) (146) | | |
|---|---|---|---|---|---|---|---|---|
| | | | Primary | Secondary | University | <1,500 | 1,500-3,000 | >3,000 |
| | 41.5 | 48.7 | 12.0 | 40.0 | 48.0 | 42.5 | 46.6 | 11.0 |

| Employment situation (150) | Housewife | Retired | Student | unemployed | Employee Part-time | Employee full time | Self-employed part-time | Self-employed |
|---|---|---|---|---|---|---|---|---|
| | 5.3% | 6.0% | 15.3% | 28.7% | 10.7% | 24.0% | 2.0% | 8.0% |
| N | | | | 150 | | | | |

**Experiment performance**

The applied methodological approach can be summarized into five main subsequent steps:

i. First, participants were asked to answer in a short questionnaire their attitudes and consumption behaviour towards pork meat and pork frankfurter sausage in particular. Socioeconomic and life-style variables were also collected.

ii. Second, participants were unexpectedly rewarded by an extra €5 and asked to select their preferred frankfurter sausage from different choice sets built within the DCE design. Consumers were warned that their selection will have a consequence as a real market will be created at the end of the experiment to exchange real money and real products. Thus, consumers who agree to participate in this market should purchase their selected product. No additional information about the products was given, except what appears in each choice set label. In this step we aimed to analyse the expected preferences of consumers on the basis of their past experiences and available information related to the characteristics of the product or to a similar one (Deliza & MacFie, 1996).

iii. Third, a hedonic evaluation test was carried out to assess the impact of the chosen masking strategy for boar taint and to create a current sensory experience of the analysed product. Participants tasted four different frankfurter sausages with two different treatments: if the meat is obtained from castrated pig or boars and if the flavour is original or flavoured with spices and naturally smoked.

iv. Fourth, consumers were informed about which type of sausages they tasted in order to associate their sensory experience with the specific products and characteristics. Then, the

same DCE was repeated and consumers turned to reselect their preferred products from the same choice sets and asked to take into consideration their sensory experience. This phase allow to analyse if the sensory experience have resulted in agreement or disagreement with what they expected. These changes play an important role in the final acceptance or rejection of the product (Font-i-Furnols & Guerrero, 2014) and may affect the final choice decision of the consumers.

v. Fifth, a real market was created to exchange real product and money. Consumers who accepted to participate were obliged to purchase their chosen product from a randomly selected choice set.

**Attitude and consumption behaviour towards pork meat**

The survey collected information on the socio-economic backgrounds of the consumers along with their attitudes, preferences and opinions regarding pork consumption, especially frankfurter sausage. The short survey contains questions regarding the consumption frequency of fresh pork meat and frankfurter sausage, the brand they usually purchase and how much they usually pay when purchase frankfurter sausage. They were also asked to state if at the moment of the survey they have frankfurter sausage at home and if they are planning to purchase in future days. These questions were completed by life style questions about if they do sport or any physical activities not related to work, the last time they have made a blood test, if they are smoker, if they are alcohol drinker and in which frequency.

**The hedonic test**

The inclusion of a natural spices mixture (white pepper, paprika, mustard seed, nutmeg mace, coriander, sweet marjoram and small cardamom) combined with smoking process was the strategy selected to mask the perceived boar taint in frankfurter sausage.

For consumer sensory analysis, four different batches of frankfurter sausages were prepared: *1)* sausages with meat and fat from male castrated pig (original flavour), *2)* smoked sausages with meat and fat from male castrated pig, manufactured including a natural spices mixture (flavoured), *3)* sausages with meat and fat from entire pigs with androstenone concentrations 1.10-2.75 µg/g of fat (original flavour) and *4)* smoked sausages with meat and fat from entire pigs manufactured including a natural spices mixture (flavoured).

The products were prepared in a pilot plant according to industrial procedures. The basic recipe contained lean meat (50%), pork fat (25%), ice/water (25%), potato starch (2.5%), soybean protein (2%), sodium chloride (2%), kappa carrageenan (0.5%), sodium polyphosphate (0.3%), dextrose (0.25%), pork flavour JBT-200 (0.2%), sodium ascorbate (0.05%) and sodium nitrite (150 ppm). To manufacture flavoured sausages a natural spices mixture (0.7%) was added to basic recipe. All additives and spices were provided by Proanda S.L. (Sevilla, Spain). For each batch of sausage, meat, fat, ice, water, and other ingredients were emulsified by using a bowl cutter (CM -41, Mainca. Barcelona, Spain). The batters obtained were vacuum stuffed (Tecmaq Microwat, Barcelona, Spain) into 20 mm collagen casing (NB300, Edicas, Ripoll, Spain), smoked by sawdust (in case of flavoured sausages) and cooked to 72° C core temperature (Verinox Junior 1100, Vigolo Vattaro, Italy). After cooking, sausages were cooled, vacuum-packaged and kept at 4ºC until the day of the analysis.

All tests were performed in a room equipped with individual tasting booths according to ISO 8589 (2007). Sensory evaluation was carried out on two consecutive days, starting 7 days after the production of the sausages. Seven sensory sessions were conducted with approximately 22 consumers per session. For each session, samples were prepared shortly before analysis as described below. Sausages were heated for 3 min in a pot of boiling water on a ceramic glass cooktop (TEKA - IR 642). After cooking, the sausages were cut into pieces about 4.5 cm length and placed in aluminum souffle cups with lids, coded with a 3-digit random code. The cups were kept warm in an oven (Bosh-HB 22R251E) at 60 ºC for 10 min before being served. Serving temperature of the samples was $50 \pm 2$ °C. Ambient conditions (temperature and relative humidity) in the sensory room were 23-25ºC and 40-60% respectively, which were within the range of acceptable conditions.

Consumers evaluated in a blind condition, the acceptability of the four different frankfurter sausage (meat obtained from castrated and boars pig and with original flavour or flavours with spices and naturally smoked) under white light 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 et al., 1989). Consumers ate unsalted toasted bread and drank mineral water to rinse their palate between samples.

Although castration might affect texture sensory parameters, such as tenderness and juiciness, Bañón et al. (2003) reported that these attributes were not related with boar taint when the meat is cooked, whereas the aroma and taste were strongly affect. Thus, in this study, each consumer rated odour, flavour and overall acceptability as the most important sensory attribute (Resurreccion, 2004)

using a 9-point category scale (1'dislike extremely', 2'dislike very much', 3'dislike moderately', 4'dislike slightly', 5 'neither like nor dislike' 6'like slightly', 7'like moderately', 8'like very much', 9'like extremely'). Finally, the acceptability data of meat were analysed using the IBM, SPSS, 21 and mean separation was carried out using the Tukey's test.

**The Discrete Choice Experiment**

Empirical application

For the empirical application of the DCE, it is highly important to well identity the attributes and levels that constitute the main characteristics of the studied product, including those descriptors that are of interest of the research. In our case, we identified the main set of attributes that consumers take into consideration when purchasing meat and processed meat, in particular the frankfurter sausage, including the castration and the flavour as the attributes of interest.

▪ Attributes and levels

In a first step, we analysed different studies that have focused on attitudes and the determinants factors affecting the purchasing decision of meat and processed meat products. As a results, several attributes are identified as the main extrinsic and intrinsic descriptors of the product (Font-i-Furnols & Guerrero, 2014) from which we highlight: The physiological quality cues such as the water-binding capacity (Bredahl *et al*., 1998), the colour, meat appearance and the shelf-life (Topel *et al*., 1976; Glitsch, 2000; Fortomaris *et al*., 2006; Ngapo *et al*., 2007), the fat content (Verbeke *et al*., 2005; De Oliveira Faria *et al*., 2015), the price (Murphy *et al*. 2015), the food safety claims (Finn & Louviere, 1992; Grunert, 2005; Grunert *et al*., 2015), the meat quality (Verbeke *et al*., 2010; Grunert *et al*., 2015), the origin (Huang & Fu, 1995; Ehmke *et al*., 2008), the product convenience (Grunert *et al*., 2004) the traceability (Loureiro *et al*., 2007), the brand and the label information (Roosen *et al*., 2003; Fenger *et al*., 2015), the production methods such as organic, conventional, free range and hormone free meats (Lusk *et al*., 2003; Dransfield *et al*., 2005), the health claims (Scollan *et al*., 2006; Realini *et al*., 2014), the ethical claims mainly animal welfare aspects (Verbeke & Viaene, 2000) and the environmental claims such as the carbon food print (Koistinen *et al*., 2013).

Due to the impossibility to cope with all the meat preference attributes we selected an array of the most important ones, focusing on the attributes that we were interested in. The procedure was to consider *ceteris paribus* some attributes for all the offered alternative products (i.e the different

sausage products had the same package, the same appearance, the same sausage size, the same format, the same shelf life -maximum date allowed-, the same origin and the same production method). Thus, in our case study, we focused on if the meat is obtained from castrated animal or boars, and if the sausage had an original flavour or enriched with the masking strategy.

In a second step, we carried out a discussion group comprised by university lecturers and researchers in the fields of agro-food marketing and meat science experts to determine the final set of attributes that were: Flavour (original and the masking strategy with spices and naturally smoked), castration (meat obtained from castrated pigs or boars), brand type (manufacturer and private brands) and price (€1.79, €1.39, €0.99, €0.59). The price vector was not determined by the actual prices of the product, but rather by the unobserved demand curves and thus, was based on prior knowledge concerning the maximum willingness to pay for such product (Mørkbak et al., 2010). Finally, a pilot questionnaire was applied to a small sample of respondents to test for the complete understanding of the attributes.

All attributes, were coded with effect coding as discrete variables in order to avoid the base levels being confounded with the intercept (no purchase option), we use effects coding (Bech & Gyrd-Hansen, 2005). The base level of each attribute was castrated pig, manufacturer brand and original flavour, the price was coded as continuous variable to allow for the willingness to pay calculation. Finally, all models were estimated by using 500 Halton draws.

▪ Choice set construction

We followed the Dual Response design in the construction of choice sets (Brazell et al., 2006; Kallas et al., 2012). According to this design, respondents are allowed to face a "purchase/ no-purchase" decision response mode, which better mimic the circumstances under which actual choices are made while replicating market situations (Ryan & Skatum, 2004). To construct the choice sets, we first determined the number of alternatives to be included (m). We considered 4 alternatives by choice set as it showed the highest D-efficiency (100%) and to be consistent with the four samples of the frankfurter sausage presented in the hedonic test. In a further phase, we followed a full factorial design using the total number of attributes and levels which led to a total of 32 ($2^3 x 4^1$) hypothetical products. Thus, for each choice set there is a potential of $(2^3 x 4^1)^4$ possible combinations. As it is impossible to use of the combination created, we followed an orthogonal fractional factorial design to estimate all main effects of the attributes enabling us to reduce the

number of choice sets from all the initial possible combinations in the full design to only 8 choice sets. Figure 1 shows one of these choice sets.



Figure 1: Example of a choice set.

The 8 standard choice set generated from the efficient fractional factorial and orthogonal design represent the main choice task where consumers should select their preferred product among 4 alternative sausages and decide if they purchase it or not. Participants were also asked to perform an additional task (hold-out task) to conduct validity tests *(*Ding *et al*., 2005). This task 5 consisted of a single-choice set with eight different sausages to those provided in the main task and obtained from the original full fractional design (Figure 2). At last, several follow up question were offered regarding attributes non-attendance and choice uncertainty among other aspects that will not be included in this paper as this is beyond the scope of this work.
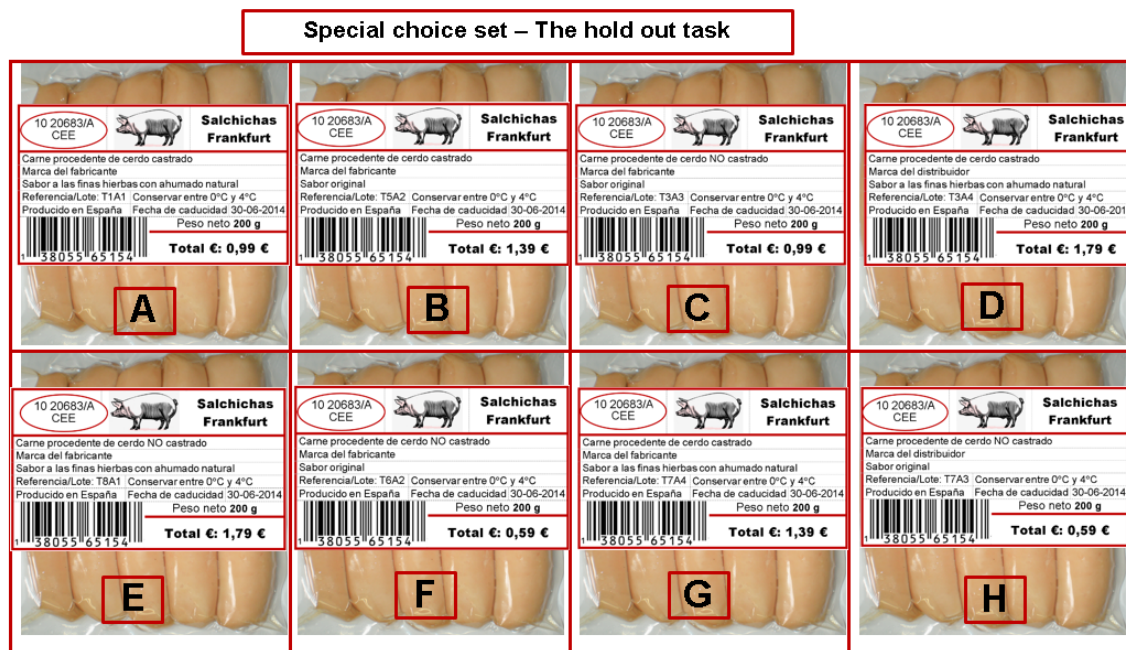
Figure 2: The choice set of the hold task.

Finally, as commented before, the real market of frankfurter sausages was created (Figure 3) by randomly selecting one choice set from the eight choice sets (main task) and the single-choice set (hold out task). We first randomly select between two numbers to decide which task is used as a real market (one in the case of the main task and two for the hold out task). If one is selected, we further randomly select a number between 1 and 8 (the total number of choice sets) to determine with which choice set we construct the real market. Individuals should then purchase the product that they had chosen and pay the corresponding posted price, unless they picked do not purchase option. If the hold-out task was selected, then they should purchase the product they had chosen in this task.

Figure 3: the real market created after the experiment with a real exchange of product and money.

Theoretical foundation of the Discrete Choice Experiment

DCE rely on Lancaster's Theory of Value (Lancaster, 1966) which proposes that utility of a product is decomposed into separable utilities for their characteristics or attributes. It is also based on the Random Utility Theory (RUT) laid out by Thurstone (1927). This theory propose that subjects choose among alternatives according to a utility function with two main components: a systematic (observable) component and a random error term (non-observable):

$$U_{jn} = V_{jn}(X_j, S_n) + \varepsilon_{jn} \tag{1}$$

where $U_{jn}$ is the utility of alternative $j$ to subject $n$, $V_{jn}$ is the systematic component of the utility, $X_j$ is the vector of attributes of alternative $j$, $S_n$ is the vector of socio-economic characteristics of the subject $n$ and $\varepsilon_{jn}$ is the random term.

To predict the subjects' preferences for attributes (k), we need to define the "probability of choice" that an individual *n* chooses the alternative *i* rather than the alternative *j* (for any *i* and *j* within choice sets, $T$). McFadden (1974) developed an econometric model that formalized respondents' decision making process. This model is often referred to as the multinomial logit (MNL) model, which is considered the base model for DCE.

- The Multinomial Logit Model (MNL)

According to MNL model the utility to person $n$ from choosing alternative $j$ on choice scenario $t$ is given by:

$$U_{njt} = \beta x_{njt} + \varepsilon_{njt} / \sigma_n \qquad n = 1, \ldots, N \quad j = 1, \ldots, J \quad t = 1, \ldots, T \tag{2}$$

Where, $x_{njt}$ is a $K$-vector of observed attributes of alternative $j$, $\beta$ is a vector of mean attribute utilities (utility weights) and $\varepsilon_{njt}$ is the "idiosyncratic" error term called "residual" heterogeneity and motivated as consumer heterogeneity in tastes (preferences) for unobserved (latent, intangible) product attributes (Fiebig $et$ $al.$, 2010) that follows independent and identically distributed (i.i.d.) Type 1 extreme value distribution with scale parameter $\sigma_n$.

The probability $(P_j | X_{nt})$ that an individual $n$ will choose alternative $j$ among other alternative of an array of choice set $T$ is formulated as follows:

$$(P_j | X_{nt}) = \frac{\exp(\beta x_{njt})}{\sum_{j=1}^{J} \exp(\beta x_{njt})} \qquad \forall j \in T \tag{3}$$

Where $X_{nt}$ is the vector of attributes of all alternatives $j = 1, \ldots, J$. In the case of estimating a MNL, the scale parameter $\sigma_n$ is normalized to one for identification.

In this context, the MNL has an asymmetric heterogeneity structure: it can estimate heterogeneous preferences for the unobserved attributes (Scale_MNL). However, it imposes homogeneity in preferences for observed attribute. Thus, only average attributes' utilities are estimated which is often unrealistic as consumers' preferences are, by nature, heterogeneous. While the heterogeneity analysis is an important issue, especially for the New Product Development (NPD) such as the case of the enriched beef meat, estimating only the average preferences may lead one to miss that a product with particular attributes would have great appeal for a subset of the population (Fiebig $et$ $al.$, 2010). Thus, the failure in understanding the preference heterogeneity may lead to a failure to optimally target potential adopters of the new product. Therefore, the mixed or $heterogeneous$ logit models (MIXL) have been introduced to investigate such heterogeneity.

- The Mixed Logit Model (MIXL)

The Mixed or heterogeneous logit models (MIXL) (also in the literature is referred to as Random Parameter Logit model, RPL) are currently quite popular. They extend the MNL introducing for unobserved heterogeneity by allowing random coefficients on attributes (Ben-Akiva *et al.*, 1997). In MIXL the utility to person *n* from choosing alternative *j* in choice set *t* is given by:

$$U_{njt} = \beta_n \, x_{njt} + \varepsilon_{njt} \big/ \sigma_n \quad n = 1, \ \ldots, \ N \ \ j = 1, \ \ldots, \ J \ \ t = 1, \ \ldots, \ T \qquad (4)$$

Where, $\beta_n = \beta + \eta_n$ and where $(\eta_n)$ is the vector of person *n* specific deviations from the mean value of the $\beta$ s. The $\eta_n$ is described by an underlying continuous distribution for the attributes defined by the researcher. In most applications the multivariate normal distribution is the most used, MVN (0, Σ). In this case, $\sigma_n$ is also assumed to be one for identification.

For the MIXL model, the choice probability is:

$$(P_j \big| X_{nt}) = \frac{\exp[(\beta + \eta_n)x_{njt}]}{\sum_{j=1}^{J} \exp[(\beta + \eta_n)x_{njt}]} \qquad \forall j \in T \qquad (5)$$

Recently Louviere & Mayer (2007), Louviere *et al.* (2008) argued that much of the preference heterogeneity captured by random parameters in MIXL can be better captured by the scale term; and thus known as "scale heterogeneity". Besides, they stated that the normal distributions of the random attributed in the MIXL do not appear to be very close to it, as followed in almost MIXL applications. The MIXL turns to be likely a poor approximation to stated data if scale heterogeneity is not accounted for (Fiebig *et al.*, 2010).

The scale heterogeneity is the variation of the degree of randomness in the decision-making process over respondents and hence is the degree of individuals' certainty. It is based on the differences of the variance of the error term $(\varepsilon)$ across individual. In this context, the analysis of the scale heterogeneity is important, especially for the stated preference studies (i.e. based on questionnaire). In this type of studies, consumers may interpret and process choice tasks and situations differently. They may have varying levels of attention paid to the task they are presented, as well the level of certainty in their choice (Train & Weeks, 2005). Thus, it would be expected that the scale of the error term could be greater for some consumers than for others.

▪ The Generalized Multinomial Logit Model (GMNL)

On the basis of Keane (2006), Feibig *et al*. (2010) developed the Generalized Multinomial Logit model (GMNL). Within this approach, the $\sigma_n$ is no longer set to be one, and a particular specification of this term is assumed. In this case, multiplying equation (4) through by $\sigma_n$, Feibig *et al*. (2010) identified that the utility to person $n$ from choosing alternative $j$ on choice set $t$ is given by: $U_{njt} = [\sigma_n\beta + \gamma\eta_n + (1-\gamma)\sigma_n\eta_n]X_{njt} + \varepsilon_{njt}$ 　　　　(6)

where $\gamma$ is a parameter between 0 and 1. $\sigma_n$ is a scaling factor that proportionately scales the $\beta$ up or down for each individual $n$. To impose that $\gamma \in [0,1]$ in estimation, Fiebeig *et al*., (2010) used a logistic transform $\gamma = \exp(\gamma^*)/[1+\exp(\gamma^*)]$ and estimate $\gamma^*$. Thus $\gamma$ is a mixing parameter, and its value determines the level of mixing or interaction between the scale heterogeneity coefficient $\sigma_n$ and the parameter heterogeneity coefficient $\eta_n$.

Since the scale heterogeneity factor $\sigma_n$ represents the person-specific scale of the idiosyncratic error, it should be positive. Fiebig *et al*. (2010) proposed that $\sigma_n$ follows a log-normal distribution with mean 1 and standard deviation $\tau$, $\sigma_n \sim \text{LN}(1,\tau^2)$, with the estimated $\tau$ capturing the scale heterogeneity across consumers. Thus, to ensure is poditive, Fiebig *et al*. (2010) an exponential transformation of $\sigma_n = \exp(\bar{\sigma} + \tau\upsilon_n)$ where $\upsilon_n \sim \text{N}(0,1)$.

Because $\sigma_n$ only enters the model as a product of $\sigma_n\beta$ (equation 6), some normalization on $\sigma_n$ is required to identify $\beta$. Fiebig *et al*. (2010) recommend setting the mean of $\sigma_n$ to 1 so $\beta$ is the mean of the utility weights. Because the mean of the log-normally distributed $\sigma_n$ is $\sigma_n = \exp(\bar{\sigma} + \tau\upsilon_n)$ and the $\text{E}(\sigma_n) = \exp(\bar{\sigma} + \tau^2/2)$, thus to ensure $\text{E}(\sigma_n) = 1$, we need to set $\bar{\sigma} = -(\tau^2/2)$.

Let $y_{njt}$ be '1' if respondent $n$ choose alternative $j$ in choice set $t$, and '0' otherwise. The probability that consumer $n$ choose alternative $j$ in choice set $t$ is:

$$(P_j|X_{nt}) = \frac{\exp([\sigma_n\beta + \gamma\eta_n + (1-\gamma)\sigma_n\eta_n]X_{njt})}{\sum_{j=1}^{J}\exp([\sigma_n\beta + \gamma\eta_n + (1-\gamma)\sigma_n\eta_n]X_{njt})} \qquad \forall j \in T \qquad (7)$$

Finally, regarding the Alternative Specific constant (ASC) which usually measure intangible aspects (not gathered by the attributes' utilities) that some consumers like and others dislike. Fiebig *et al*. (2010) indicated that including it within the general GMNL specification may produce special estimation problems. Greene & Hensher (2010) proposed three possible strategies to deal with ASC:

1. Consider the ASC $(\beta_{0j})$ as fixed parameters, assuming homogenous preference for ASCs. In this case the equation (6) is specified as follows:

$$U_{njt} = (\beta_{0j}) + [\sigma_n \beta + \gamma \eta_n + (1-\gamma)\sigma_n \eta_n] X_{njt} + \varepsilon_{njt}$$

2. Make them a part of the general specification of the GMNL model (i.e. to behave like the attributes), then the utility of the ASCs $(\beta_{0j})$ is scaled and considered to be random. The ASCs are considered as the $\beta$s components. In this case equation (6) is specified as follows:

$$U_{njt} = [\sigma_n(\beta_{0j} + \beta) + \gamma(\eta_{0nj} + \eta_n) + (1-\gamma)\sigma_n(\eta_{0nj} + \eta_n)] X_{njt} + \varepsilon_{njt}$$

It is worth mentioning that Feibig *et al*. (2010) observed that this may cause estimator to fail.

3. Consider the ASC only as random parameter and force no special scaling for this variable, so the scaling parameter $\sigma_n = 1$ and $\gamma = 0$. In this case, equation (6) is:

$$U_{njt} = (\beta_{0j} + \eta_{0nj}) + [\sigma_n \beta + \gamma \eta_n + (1-\gamma)\sigma_n \eta_n] X_{njt} + \varepsilon_{njt}$$

where $(\beta_{0j} + \eta_{0nj})$ are the heterogeneous intercepts (which do not have scale heterogeneity), with $\beta_0$ being the mean vector and the $\eta_{0n}$ being the stochastic component.

The GMNL model is specified by default to consider the $\eta_n$ as uncorrelated. That is mean the covariance matrix of $\eta_n$ is constrained to be a diagonal matrix (a matrix in which all values above and to the right of the diagonal are equal to zero), thus, there are only variances estimated, no covariances. However, the GMNL can be specified to allow for correlated parameters. The presence of multiple observations on stated-choice responses for each sampled individual means that the potential for correlated responses across observations can be the product of many sources including the sequencing of offered choice situations that results in mixtures of learning and inertia effects, among other possible influences on choice response (Hensher *et al*., 2005). Thus, discrete choice data with repeated choice situations containing the same attributes and levels may have unobserved effects that are correlated among alternatives in a given choice situation. One way to recognize this

is to permit correlation of random parameters of attributes that are common across alternatives observation (Hensher *et al*., 2005).

In the case of correlated random parameters, the set of random parameters has a full covariance matrix with estimated variances and covariances. Thus, when we have more than one random parameter the estimated standard deviation $\eta_n$ are no longer independent. To assess this, we have to decompose the estimated standard deviation parameters into their attribute specific and attributes-correlations standard deviations. The decomposition procedure is done following the Cholesky decomposition method. This method decouples the contribution to each standard deviation parameter made through correlation with other random parameter estimates and the actual contribution made solely through heterogeneity around the mean of each random parameter estimate (Hensher *et al*., 2005). The correlated parameters GMNL model reports both the "confounding" standard deviation and its Cholesky decomposing matrix. The diagonal value of the Cholesky matrix represent the true standard deviation for each random parameter once the cross-correlated parameter terms have been unconfounded. The below–diagonal elements in Cholesky decomposition matrix are the covariances (cross-correlation) among the random parameter estimates.

From the abovementioned aspects of the GMNL model, in this case study, we used a GMNL model with correlated random parameters $\eta_n$ and considering the ASC $(\beta_{0j})$ as fixed parameters. This decision is because it showed to have the best goodness of fit compared to other specification in terms of Pseudo-R$^2$, AIC and improvement in the Likelihood functions. We used the GMXLOGIT procedure in NLOGIT 5 with

Once parameters are estimated, they represent the marginal utility of attributes and its contribution to the total utility function. Thus, the Marginal Rate of Substitution (MRS) between attributes can be obtained. As one of the attributes is expressed in monetary term (i.e. the price), it is possible to determine its "implicit price" (IP) or part-worth as follows:

$$IP_{\text{Product\_attribute}} = -\left( \frac{\beta_{\text{Product\_attribute}}}{\beta_{\text{monetary\_attribute}}} \right) \tag{8}$$

As the attributes are codified with coding effect in order to avoid the base level to be confounded with the Alternative specific constant of the no–option, the implicit price to move from the base level of each attribute to the analysed level should be multiplied by 2.

## Results and discussion

### Hedonic scores for the different meat tasted

Before analysing the impact of the sensory experience on expected preferences, results of consumers' acceptability for the different sausage types are first reported. Sensory parameters scores for sausages with and without the masking strategy from castrated pigs and boars are shown in Table 1.

Table 1. Least squares means and standard error (SE) of sensory parameters evaluated in frankfurter sausages from castrated pigs and boars.

| Type of pork meat | Odour | Flavour | Overall acceptability |
|---|---|---|---|
| Original sausage from boar meat | 5.40[c] (1.43) | 5.62[c] (1.56) | 5.46[c] (1.61) |
| Flavoured[1] sausage from boar meat | 6.51[a] (1.27) | 6.36[b] (1.26) | 6.42[a] (1.18) |
| Original sausage from castrated meat | 5.69[b] (1.19) | 6.20[b] (1.33) | 5.91[b] (1.30) |
| Flavoured[1] sausage from castrated meat | 6.62[a] (1.16) | 6.69[a] (1.18) | 6.62[a] (1.29) |

[a, b, c] Statistical differences among types of frankfurter sausage for all consumers at 95 %.
[1] with spices and naturally smoked.

Comparing the overall acceptability of the four types of sausage, results showed significant differences. The flavoured sausage obtained from castrated and boar meat had the highest acceptability scores than the remaining type of sausage. This confirms that the applied masking strategy had a positive effect on frankfurter sausage acceptance (Lunde *et al*., 2008; Stolzenbach *et al*., 2009). In this context, the original sausage from boar meat had received the lowest valuation in all the attributes analysed which is clearly showing the negative impact of boar taint on acceptance (Bañon *et al*., 2003). Focusing on the flavour attribute, flavoured sausage obtained from boar meat exhibit a similar acceptance with the original sausage obtained from castrated meat. Finally, regarding the odour attribute, the masking strategy clearly show the non-significant difference between sausages obtained from boar and castrated meat which confirm the positive impact of the proposed ingredients. These results may represent the starting point of the processed pork meat for masking boar taint especially in sausages.

**Impact of sensory evaluation on expected preferences**

Table 2 reports the marginal utilities of the attributes resulting from the G-MNL models with correlated random parameters for the pre and post sensory experiment. Both models showed the highest improvement in the likelihood and the best information criteria (AIC, BIC) over the MNL and MIXL models in line of the results of Fiebig *et al*. (2010), Greene & Hensher (2010) and Pancras & Dey (2011). As can be seen, at a 99% confidence level, we can reject the null hypothesis that all coefficients are jointly equal to zero with a Log-Likelihood ratio test highly significant. The goodness of fit is assessed through the McFadden's pseudo-$R^2$ (0.20 and 0.26 for pre and post sensory respectively) which is within the acceptable range for the discrete choice models.

Table 2: Results from model estimations for consumer data with and without information.

| | Pre sensory | Post sensory |
|---|---|---|
| **Random Parameters in utility functions (β)** | | |
| Boar animal | 0.28**[a] | -0.01[b] |
| Private Brand | -0.21***[a] | -0.26***[a] |
| Flavoured[1] | -0.47**[b] | 0.50**[a] |
| **Non-Random Parameters in utility functions (β)** | | |
| Price | -1.69***[a] | -1.51***[b] |
| Opt-Out | -0.40***[b] | 0.02[a] |
| **Diagonal values in Cholesky matrix** | | |
| Non-castrated animal | 1.20*** | 1.04*** |
| Private brand | 0.04 | 0.46** |
| Flavoured | 0.28 | 0.70*** |
| **Covariances of the Random parameters** | | |
| Private Brand : Non-castrated animal | -0.11 | -0.01 |
| Flavoured : Non-castrated animal | -0.20 | -0.07 |
| Flavoured : Private brand | 0.07 | -0.48* |
| **scale parameters** | | |
| Variance parameter tau in scale parameter | 1.10*** | 0.01 |
| Weighting parameter Gamma | 0.41*** | 0.72*** |
| **Standard deviations of parameters distribution** | | |
| Std. Dev. Non-castrated animal | 1.20*** | 1.04*** |
| Std. Dev. Private brand | 0.10 | 0.47*** |
| Std. Dev. Other Spanish origin | 1.19*** | 1.25*** |
| Log-Likelihood (θ) | -1,529.54 | -1,418.39 |
| Log-Likelihood (0) | -1,931.32 | -1,931.32 |
| LL ratio test | 803.55 (0.000) | 1,025.87 (0.000) |
| Pseudo $R^2$ | 0.208 | 0.265 |
| AIC/N | 2.576 | 2.391 |

*Si*gnificance levels: *** p<0.01; **p<0.05; * p< 0.10.
Attributes with different superscript letters in columns (a, b) differ (P < 0.05).
[1] with spices and naturally smoked.

The positive/negative sign of the coefficient implies higher/lower levels of utility associated with these attributes' levels. In this context, the model estimates showed that all attribute coefficients are statistically significant except the boar animal level in the post sensory. This result revealed that before the hedonic valuation experience, consumers exhibit a preference for meat obtained from pigs reared in natural condition of life without any modification (i.e. castration) as a potential preference for a positive pig welfare. Previous studies have shown that Spanish consumers are not aware if castration is related to meat quality (Kallas *et al.*, 2013). However, after testing the different sausage products, consumers were aware of the importance of castration on meat quality mainly on the odour off the product. Thus, the utility of meat obtained from boars pigs decreased significantly from 0.28 to -0.01.

For the brand attribute preference, consumers showed a rejection of private brands with non-significant differences before and after the hedonic test. This result is confirmed by the descriptive results obtained from participants regarding their consumption behaviours of sausage. Almost a 70% of participants usually purchase manufacturers brand over the private one. Focusing on the flavour attribute, results showed an interesting pattern. While consumers before testing the products showed a negative expected preference for the flavoured sausage with spices and naturally smoked, after testing the product their utility become positive with highly significant difference. A fact that commented by Bredahl *et al.* (1998) who affirmed that the quality expectations and quality experience diverge widely. These results are in accordance to what commented also by Flores (1997) and Leistner (1995) that smoked meat products are not appealing to consumers in the Mediterranean. In addition, the results highlight the appropriateness of this masking strategy against boar taint as an effective masking strategy.

In this line, as expected, the negative sign of the price implies that an increase in the levels of the price attribute, will decrease the utility of the alternatives presented to consumers. Comparing values before and after the experiments results showed slight significant differences. The utility of the price slightly decreased, showing that after eating experience some consumer shifted their election towards alternatives with higher prices that contains specific patterns of the other preferred levels such as flavoured, non-castrated and manufacturers' brands. In this line, there is a clear indication against the no-choice option in both experiments, with highly significance and negative value in the pre sensory test. On average, consumers have a clear preference for the offered products.

Interpreting the tau parameter ($\tau$) which is the key parameter that captures the scale heterogeneity, results showed a substantial scale heterogeneity in the data with a highly significant value of 1.10 in the pre sensory test and a non-significant value of 0.01 in the post experiment. As the parameter tau increases, the degree of scale heterogeneity increases. This result shows that when consumers taste the different sausage

products accompanied by a posterior information about what they eat, the variation of the degree of randomness in their final decision and hence their degree of uncertainty decreased significantly.

Regarding the unobserved taste (preference) heterogeneity (usually captured by the diagonal values in Cholesky matrix, but no more valid in the case of correlated parameters) is captured by the standard deviation of the random parameters (bottom of table 1) as detailed in the methodology section. The estimated models showed statistically significant results with the exception of the private brand in the pre sensory. Thus, as mentioned by Lenk (2011), when the estimated standard deviation of parameters distribution are close to zero, then the unobserved heterogeneity is mostly due to heterogeneity in the scale parameter and not taste. In our results the values are far from zero (i. e. 1.20 and 1.19 in the pre experiment and 0.47, 1.04 and 1.25 in the post experiment) and thus there is a mixture between both sources of heterogeneities. This can be verified analysing the gamma estimate.

The main motivation of the G-MNL model is to separate the estimation of scale heterogeneity from taste heterogeneity (Lenk, 2011) which might be identified by the gamma parameter. The estimate of the gamma in both model are relatively far from zero. Which implies that preference heterogeneity is invariant to scale heterogeneity and thus both heterogeneity are independent. This independence is emphasized in the post experiment. Gamma parameter increased from 0.41 to 0.72 and thus both types of heterogeneity becomes more independently identified.

Finally, the estimates of the covariance matrix of the random parameters showed non-significant values between attributes in both the pre and post experiment with the exception of the flavoured and private brand levels in the post experiment with a highly negative correlation (-0.82)[3]. In this context, consumers seem to negatively associate the new and well accepted flavour of sausage with spices and naturally smoked with the private label.

For the economic interpretation, the implicit price of the attributes levels was calculated following equation 8. Since these estimates are stochastic, it is usual to calculate their confidence intervals. In this study we employ the method proposed by Krinsky & Robb (1986) through 1,000 random repetitions. Analysing preferences before and after the sensory test, results show significant modifications in the implicit prices of the levels as shown in Table 3. The obtained results, confirms the previously explained results about levels utilities in Table 2. To avoid any misinterpretation, results must be considered as the willingness to pay (€/product) to shift preference from the base level of the attribute to the evaluated one. In this line, in contrast to the castrated animal claim, consumers in the pre sensory were willingness to pay for the non-castrated animal (0.340€/product) while after the sensory experience this aspect was not statistically significant.

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[3] The correlation matrix estimated in both models was not reported in the paper due to their non-statistical significance (except the flavoured and private brand in the post experiment).

Moreover, compared to the manufacturer brand, the private brands were not valued with a negative implicit prices in the pre and post sensory experience. This results showed that consumers ask for a price discount to accept the private brand of about 0.252€/product and 0.342€/product in the pre and post sensory test respectively. Finally, the willingness to pay for the proposed flavour was negatively valuated before testing asking for about 0.558 discount by product and showing a significant change of preferences after testing the product, revealing a willingness to pay of 0.66€ for the masking strategy.

Table 3: The willingness to pay from the GMNL Model.

| | *Pre Sensory* | *Post sensory* |
|---|---|---|
| Non-castrated animal | 0.340[**a] (0.06; 0.62) | -0.022[b] (-0.12; 0.08) |
| Private Brand | -0.252[***a] (-0.38; -0.1) | -0.342[**a] (-0.62; -0.060) |
| Flavoured[1] | -0.558[**b] (-0.99; -0.12) | 0.660[**a] (0.12; 1.18) |

Significance levels: *** $p<0.01$; **$p<0.05$; * $p< 0.10$.
[a,b]: Differences between preferences (pre sensory and post sensory) within each group at 95%.
[1] with spices and naturally smoked.

**Conclusion**

Our evidence suggests the appropriateness of the proposed mixture of spices and smoking as a valid masking strategy of boar tainted meat to be used as a raw material for the production of frankfurter sausages. The results proves that this strategy was able to masking boar taint odour and flavour and does not diminish the consumer acceptability in these type of products. In addition, consumers showed their willingness to pay a premium for this type of flavours. In this context, this strategy may represent the starting point for the processed meat industry to adapt their receipt that allows to include the boar tainted meat for the production of frankfurter sausages. However, more research is needed to study other meat products and new cooking strategies.

The sensory experience for the different frankfurter sausages with the main identified strategy of masking boar taint, have had impact on both the scale and preference heterogeneity by affecting the tau and the gamma mixing parameter. The hedonic test, decreased the degree of randomness and uncertainty of consumers in their final election and the source of unobserved heterogeneity obtained from the scale become more independent than the taste preference. These results may highlight the importance of the direct promotion of these types of product in the retail

point by giving potential consumers the opportunity to test the product. These advertising activities in the point of sales may represent a valid way to promote consumers to purchase the product by decreasing their level of uncertainty. In this context, more studies are needed to be done, especially to analyse the impact of sensory experience on the attributes non-attendance and on the internal and external validity of choices. These topics are proposed for future research.

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