

Sensory determinants of stated liking for vegetable names and actual liking for canned vegetables: a cross-country study among European adolescents

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Highlights

- A cross-cultural study using a *between* and *within* vegetable comparison approach
- Positive relationships were found between familiarity with and hedonic responses to different vegetables
- Stated liking for different vegetables is partially shaped by innate taste preferences
- Sensory properties distinctive of the type of vegetable positively affect actual liking for the same vegetable with varied sensory properties
- The hedonic valence of taste and texture descriptors depends on the type of vegetable

Abstract

Sensory properties are reported as one of the main factors hindering an appropriate vegetable intake by the young. In the present work the sensory determinants of likings for vegetables were explored in adolescents of four European countries (Denmark, n=88; France, n=206; Italy, n=110 and United Kingdom, n=93). A questionnaire was designed to study cross country differences in stated liking for and familiarity with a list of vegetables popular among European markets (between-vegetable approach). A within-vegetable comparison approach with actual tasting was used to analyze differences and similarities in liking for canned pea and sweet corn samples across the countries. A close positive relationship between stated liking and familiarity was found. Irrespective of the country, one group of highly liked vegetables (carrots, tomatoes, green salad) was identified, characterized by innately liked tastes (sweet, umami), delicate flavour and bright appealing colour. A second group of highly disliked vegetables consists of cauliflowers and broccoli, characterized by disliked sensations such as bitter taste and objectionable flavour. Internal

Preference Maps from actual liking scores indicate that the generally disliked tastes (bitter, sour), are clearly correlated with a negative hedonic response for both peas and sweet corn. The hedonic valence of a generally well accepted taste such as salty and texture descriptors depends on the type of vegetable. Internal preference maps from actual liking data indicate that flavour and appearance descriptors of the distinct sensory properties of each type of vegetable positively affect liking, while the intensity of unusual flavours is related to sample disliking.

Key words: liking, familiarity, descriptive analysis, preference map, peas, sweet corn

1. Introduction.

Adequate vegetable consumption is fundamental to a healthy balanced diet and high fruit and vegetable intakes are well recognised as beneficial for health (Appleton, Hemingway, Saulais, et al, 2016; Atkins & Mitchie, 2013; Edwards, Engstrom and Hartwell, 2006; Quest & Needham, 2008). High intakes of non-starchy vegetables, fruits and grains in adolescence have been reported as beneficial to prevent cardiovascular risk (Moore, Singer, Bradlee and Daniels, 2015), and to prevent the onset of overweight (Quick, Wall, Larson, Haines and Neumark-Sztainer, 2013), which is in itself a risk factor for chronic disease.

From a more general perspective, vegetable intake can contribute to a diversified and balanced diet due to the huge variety of food items in this product category. Vegetables are characterized by a large variation in appearance, flavour and texture, which is further increased by the many possible methods of preparation and presentation. Vegetable variety has been suggested as a potential factor for improving meal composition in adults and school children (Bucher, van der Horst and Siegrist, 2011; Bucher, van der Horst and Siegrist, 2013). Furthermore, vegetables represent a food category that is suitable for widening the range of sensory experiences in young people. Since flavour variety is associated with variety also in nutritive content, it has been suggested that preferences for a variety of flavours might contribute to the achievement of a well balanced diet (Mennella, Nicklaus, Jagolino and Yourshaw, 2008; Nicklaus, Boggio, Chabanet and Issanchou, 2005).

Vegetable intakes in Europe, the US, and across the world remain, however, below World Health Organization recommendations (European Food Safety Authority, 2008; United States Department of Agriculture, 2010). Consumption data from 22 EU member states detail consumption of 119-182 g vegetables/day, compared to WHO guidelines of 160-240g, and in the US, current reports demonstrate average intakes of 1-1.5 cups of vegetables per day, while recommendations suggest 2.5-3 cups/day for all those over the age of 13 years. In Europe, furthermore, vegetable consumption in adolescents is particularly low (European Food Safety Authority, 2008). Data from adolescents in 33 countries revealed that the prevalence of daily vegetable intake in 2010 ranged from 20% in Estonia to 54% in Flemish Belgium. The proportion of adolescents eating vegetables daily were 45% in France, 42% in Denmark, 38% in England and only 25% in Italy (Vereecken, Pedersen, Ojala, Krølner, Dzielska, Ahluwalia, Giacchi and Kelly, 2015).

The overall trend between 2002 and 2010 is positive, largely attributed to the policy efforts in the surveyed countries, yet consumption remains insufficient to reach daily recommendations for vegetables and fruits (Vereecken, Pedersen, Ojala, Krølner, Dzielska, Ahluwalia, Giacchi and Kelly; 2015).

Adolescence is a period where dietary habits consolidate. Dietary habits then tend to track into adulthood (Mikkilä, Räsänen, Raitakari, Pietinen and Viikari, 2005; Li & Wang, 2008) and are influenced by gender, socioeconomic status and locality of residence (Laake, Mathers, Rugg-Gunn and Adamson, 2006). The repertoire of food preferences strongly changes at this stage due to widening social and cognitive domains (Nu, MacLeod and Barthelemy, 1996). Investigation of the determinants of food preferences with the purpose of promoting vegetable intake in adolescents requires special attention to four aspects (Story, Neumark-Sztainer and French, 2002): 1. the need to cover the energy requirements for rapid physical growth; 2. the impact of eating practices on the risk of immediate health problems; 3. the long term health implications of adolescent eating practices; and 4. the tendency of food habits adopted in adolescence to impact those of adulthood.

Food preferences are largely acquired during childhood, via innate preferences for sweet and salt tastes, and innate dislikes for bitter and, to some extent, sour tastes (Köster & Mojet, 2006; Prescott, 2012). The positive impacts of the energy intake associated with sugar-rich and high-fat food consumption further consolidate and expand these early taste preferences. Relatedly, preferences for some vegetables are not easily learned due to the general dislike for their sensory properties and to their low energy density. As reviewed by Krølner and colleagues (Krølner, Rasmussen, Brug, Klepp, Wind and Due, 2011), adolescents report vegetables to be associated with unpleasant and negative taste experiences. Bitter taste is a well recognized sensory barrier for vegetable liking and consumption (Drewnowski 1997; Drewnowski & Gomez-Carneros, 2000) and the perceived intensity of both bitter and sweet tastes have been reported as negative and positive predictors of vegetable acceptance respectively (Dinehart, Hayes, Bartoshuk, Lanier and Duffy, 2006; Cox, Melo, Zabaras and Delahunty, 2012). Genetic variation in sensitivity to bitter taste of thioureas and related compounds (PROP taster status) has been associated with children lower acceptance of bitter-tasting vegetables (Bell & Tepper, 2006). Studies on twin population showed a moderate heritability of fruit and vegetable preference (Pallister et al., 2015) and genes regulating sour taste perception has been hypothesized to be relevant in the acceptability of naturally sour products such as fruits, berries and vegetables (Törnwall, Silventoinen, Hiekkalinna, Perola, Tuorila and Kaprio, 2014).

Other sensory modalities also play an important role in vegetable perception and acceptance.

Retro-nasal olfaction reinforces both positive and negative hedonic responses to vegetables, thus indicating flavour and the complex net of interplaying factors involved in its perception, as key factors in vegetable acceptance (Lim and Padmanabhan, 2013; Poelman and Delahunty, 2011). Furthermore, individual sensitivity to the compounds responsible for the objectionable odours of cruciferous vegetables have been found to be related to their consumption (Engel, Martin and Issanchou, 2006).

Texture properties are also important for vegetable acceptance in young people, but the hedonic value of specific texture descriptors depends on age and vegetable type. Experimental data indicate that slimy, slippery and/or granular vegetables tend to be disliked while hard/crunchy or soft/juicy vegetables can be both highly accepted by children and teens depending on the vegetable type (Szczesniak, 2002; Zeinstra, Koelen, Kok and de Graaf, 2010; Poelman & Delahunty, 2011).

Appearance, colour and shape also influence vegetable acceptance, more for younger than for older children (Zeinstra, Koelen, Kok and de Graaf, 2007). Small, brightly coloured vegetables are preferred to large dark green vegetables (Baxter, Schröder and Bower, 2000; Zeinstra, Koelen, Kok and de Graaf, 2007). Furthermore, in the case of familiar vegetables, atypical bright colours (yellow versus dark green) can positively affect vegetable acceptance by children (Poelman & Delahunty, 2011). The perceived level of visual complexity influences the hedonic responses to vegetable combinations. Due to a general lower exposure to different foods and food combinations, younger participants tend to prefer less complex mixes compared to adults. However, the same optimal level of visual complexity for visual preferences for vegetable mixes have been reported for adolescents and adults (Mielby, Kildegaard, Gabrielsen, Edelenbos and Thybo, 2012).

Familiarity, that is “the level of experience an individual has had with any given object or stimulus”, has a major role in food preference development and expression (Aldridge, Dovey and Halford, 2009). Familiarity with and preference for foods are often related: foods that had been tried less often tended to be less liked (Cooke, 2007). In relation to vegetables, the perception of a familiar and typical vegetable flavour positively influences the hedonic responses of children and young adults to vegetables (Zeinstra, Koelen, Kok and de Graaf, 2010). Positive correlations have been reported in adult populations between familiarity with and stated liking for various food categories, including vegetables, irrespective to their intensity in bitter taste and astringency (Dinnella, Recchia, Tuorila and Monteleone, 2011).

A common approach to gain information on the determinants of vegetable acceptance is based on *between-vegetable* comparisons based on interview and questionnaire data collection. Participants are asked to state their liking for different vegetables presented as names or as pictures (see Jenkins and Horner, 2005; Krølner, Rasmussen, Brug, Klepp, Wind and Due, 2011; Heath, Houston-Price and Kennedy, 2011 for reviews). The findings of these studies depict a complex frame of sensory determinants for vegetable acceptance. Sensory properties described as liked in one vegetable, can be irrelevant or disliked in another. Thus, it appears difficult to understand the role of flavour and texture in vegetable acceptance without collecting liking data from actual tasting of specific vegetable foods. Whereas it has been broadly developed for other food categories, the *within-vegetable* comparison is quite a new approach for investigating the hedonic valence of the sensory properties in vegetables. In this case, participants are asked to express their liking after tasting the same type of vegetable with varied sensory properties. For example, this has been done for vegetables presented in different shapes or cooked in different ways (Blossfeld, Collins, Kieley and Delahunty, 2007; Zeinstra, Koelen, Kok and de Graaf, 2010; Poelman & Delahunty, 2011; Morizet, 2013). Quality and intensity of appearance, texture, taste, odour and flavour descriptors were typically well related

to children's hedonic responses for a specific vegetable, thus allowing the identification of the sensory drivers for likings for a given vegetable.

The present work aimed to explore the sensory determinants of liking for vegetables in adolescents (12-15 years old) of four European countries (Denmark-DK; France-FR; Italy-IT and the United Kingdom-UK). For the purpose, both the *between-* and *within-vegetable* approaches were adopted to investigate similarities and differences among countries. In particular the "*between-vegetable*" approach was used to investigate cross-country differences in stated liking for and familiarity with eleven vegetables that are popular in the countries participating in the study. The *within-vegetable* approach was used to investigate cross country similarities and differences in sensory drivers of actual liking for canned samples of peas and sweetcorn varying widely in their sensory properties.

2. Material and Methods

2.1. Participants

Adolescents were recruited through school personnel in Copenhagen (Denmark - DK), Lille (France - FR), Florence (Italy, IT) and Bournemouth (United Kingdom, UK). Ethical approval was sought and granted through standard University procedures in all countries. Appropriate health and safety considerations, together with a risk assessment protocol, were carried out prior to the commencement of the research. Individual written informed consent was obtained from parents. Confidentiality and anonymity were assured at all times. Demographic characteristics of participants participating in the study in the four counties are reported in Table 1.

2.2 Questionnaire

A questionnaire was designed to study cross country differences in stated liking for and familiarity with vegetables (*between-vegetable* approach). It consisted in three sections: 1. demographic characteristics (age, gender); 2. liking for a list of eleven named vegetables (broccoli, carrots, cauliflower, green beans, green salad, peas, spinach, sweet corn, tomatoes, courgettes, beans) widespread in Europe on a 9 point category scale (1: dislike extremely - 9: extremely like), furthermore referred to as 'stated liking'. 3. familiarity with the same vegetable list on a 5 point category scale (1: "I do not recognize the product", 2: "I recognize the product, but I have not tasted it", 3: "I have tasted, but I do not use the product", 4: "I occasionally eat the product" and 5: "I regularly eat the product) (Bäckström, Pirttila, Backman, and Tuorila, 2004). In this scale, scores increase from lexical/visual knowledge (scores 1 and 2), to a taste experience not associated with consumption (score 3) and to frequency of consumption (scores 4 and 5).

2.3 Samples

Canned pea and sweetcorn were selected for the *within-vegetable* approach based on the following considerations:

1. canned vegetables can contribute significantly to vegetable consumption (Plessz & Gojard, 2012), represent a convenient way to promote vegetable intake as they generally deliver consistent good nutritional quality compared to their fresh counterparts (Kapica & Weiss, 2012) and can address the demand for convenience in healthy food choice given their long shelf-life, cost advantages and ease of use (Krølner, Rasmussen, Brug, Klepp, Wind and Due, 2011).
2. both canned peas and sweetcorn are largely available in the markets of the countries participating in the study
3. the selected vegetables are characterized by different histories and culinary uses in the four different countries. Peas have been consumed for several centuries (Pelt, 1993) and represent the main component of several dishes in the culinary traditions of the countries participating in the study. Sweetcorn, by comparison, was introduced into Europe in the second part of the 20th century, and its use tends to be less varied and mainly as a secondary ingredient in some countries (e.g. sweetcorn is mainly used as salad topping in FR and IT). Thus, differences in familiarity and liking between these two vegetables are expected, and these differences may influence the hedonic value of their sensory properties.

Ten different canned pea (codes: A,B,D,E,F,J,L,O,P,Q) and eight different canned sweetcorn (codes: H,R,S,T,U,V,W,Z) samples from different labels were considered. These samples were selected in order to cover as many of the sensory spaces of peas and sweetcorn as possible (i.e. diversity of size, texture, colour, flavour). The amount of each sample needed for the whole study was purchased from the producer companies from the same production batch and then delivered to the institutions participating in the study.

Sensory differences among both pea and sweetcorn samples to be used in the *within-vegetable* approach were measured using Descriptive Analysis (Lawless & Heymann, 2010). For this purpose, two panels were trained at the Sensory Lab of Florence University composed with twelve and eleven assessors for pea and sweetcorn samples, respectively. Each panel independently participated in the training procedure that ended with the list of attributes reported in Table 2.

After completing the training, each panel participated in three sessions for sample evaluation. In each session, ten samples of peas or eight samples of sweetcorn were evaluated. Each sample was evaluated three times. Samples (25 gr) were presented in a 100cc plastic cup identified by a 3-digit code. Sample presentation was balanced across participants within each session. After each sample, participants rinsed their mouths with water and ate some plain crackers. Sample evaluations were performed in conditions similar to their standard use modalities (warm and cold dish for peas and sweetcorn, respectively). Thus, peas were presented at 54-56 °C and sweetcorn samples were presented at room temperature. Data were collected with the software Fizz (ver.2.47.B, Biosystemes, Couternon, France).

Results from the ANOVA model on the descriptive data showed a significant sample effect for 23 of the 26 attributes for pea samples and for 15 of the 19 attributes for sweetcorn samples (Table 2). No significant effects of replicate, replicate x sample and sample x assessor interactions were found, thus the panel performance was validated. Non-significant attributes were not included in further data analyses.

2.4 Experimental procedure

The experiment took place in school (canteen or common room set to accommodate waves of 25-30 subjects). The number of subjects in each wave was chosen in order to let the adolescents to complete the test in a quiet environment, facilitate the sample sets preparation/presentation and limit product waste. All tests were conducted individually, and social interaction was not permitted. Pea and sweetcorn samples were evaluated in independent sessions in two different days. No time limits were given, and on average one session lasted 40 min. Depending to their availability, participants evaluated both pea and sweetcorn samples or only one product (only pea or sweetcorn samples). Thus, a part of subjects participated in two evaluation sessions and a part only in one evaluation session. All the participants completed the questionnaire. The number of respondents per product, in each country is reported in Table 1.

The experimental procedure consisted of two subsequent steps:

1. *Within-vegetable* approach: actual liking for pea and sweetcorn sample

Participants were provided with individual trays with 11 or nine three-digit coded pea or sweetcorn samples (10 pea samples plus a replicate, sample O; eight sweetcorn samples plus a replicate, sample H). Sample presentation was the same described above (2.2.Sample). Participants were asked to look at the appearance, and to smell and taste a teaspoon of each sample, then they were asked to rate their liking (actual liking) on a 9-point category scale (1: dislike extremely- 9: extremely like). Participants were asked to rinse their mouth with water before starting the evaluation and after each sample.

2. *Between-vegetable* approach: stated liking for and familiarity with named vegetables

After 15 min break, subjects were presented with the questionnaire and were given instructions about scale use for rating stated liking for and familiarity with the eleven vegetables in the list. Then, they were requested to fill in the questionnaire and encouraged to individually ask for eventual further clarifications.

2.5. Data analysis

2.5.1 Questionnaire data

Familiarity and stated liking data from each country were independently submitted to a Friedman test and to a two way (product and participant) ANOVA, respectively. Pearson coefficients were computed to study the correlation between familiarity rank sums and mean stated liking scores in each country. In order to identify differences across country in liking for vegetable names considering individual differences, Internal preference maps (IPMs) were created by Principal Component Analysis (PCA) using Unscrambler version 10.3 (Camo). IPMs are largely used in consumer studies and may be viewed as Principal Component Analyses (Greenhoff and MacFie, 1994) that reduce the full dimensionality of the sample (rows) x respondents (columns) matrix to a small number of salient dimensions explaining the maximum amount of variance in the consumer scores. The output from an IPM consists of pairs of product scores and consumer loadings for each of the preference dimensions. These may be plotted against each other in separate scatter plots or a single biplot and are known as preference maps. In other words, IPM can extract from complex liking data (a matrix with many samples and respondents) the most important information (how different the samples are from each other and how much each respondent contributes to the differences between samples)

and presents the results in a simplified picture or map in two or three dimensions that can be easily understood. A description of the interpretation of the internal preference map is given in the result section.

2.5.2 Actual Liking data

Both pea and sweetcorn actual liking data from each country were independently submitted to a two way (product and participant) ANOVA.

In order to identify the sensory determinants of actual liking across countries considering individual differences, IPMs were computed on both pea and sweetcorn data. When an IPM is computed, additional data characterizing samples (e.g. descriptive sensory data) can be projected onto the preference dimensions by linear regression. This way of relating sensory properties to a preference space represents a common approach to explore sensory drivers of liking.

In the present study, in order to identify sensory drivers of actual liking for both pea and sweetcorn samples a Principal Component Regression (PCR) was computed (Torri, Dinnella, Recchia, Naes, Tuorila and Monteleone, 2013). This is a method for relating the variance in a response variable (Y-variable) to the variance of several predictors (X-variables), with explanatory or predictive purposes (Naes, Brockhoff and Tomic 2010). In our case, PCR can be viewed as a two-step IPM procedure which first decomposes the liking data matrix (X-matrix) by a PCA (to create an IPM), then fits a Multiple Linear Regression (MLR) model, using the Principal Components instead of the original X-variables as predictors of the sensory descriptive data (Y matrix). In computing the PCR model (Unscrambler version 10.3, Camo), samples were included as dummy variables (down-weighted in the X data matrix) to improve the visual interpretation of the results (Martens and Martens, 2001). The output of the analysis is summarized in a map (correlation loading plot), in which samples, consumers and sensory properties are shown. Moreover, the correlation plot allows the possibility of drawing circles in the plot corresponding to 100% and 50% explained variance for each variable for the two components.

3. Results

3.1. *Between-vegetable approach: Familiarity with and Stated liking for named vegetable*

Mean stated liking scores and familiarity rank sums with vegetables names are reported in Table 3. In all countries, the two variables were highly correlated ($r_{IT} = 0.97$; $p \leq 0.0001$; $r_{FR} = 0.98$; $p \leq 0.0001$; $r_{UK} = 0.97$; $p \leq 0.0001$; $r_{DK} = 0.98$; $p \leq 0.0001$). Although some similarities are evident, stated liking and familiarity patterns vary across countries. Carrots are among the most familiar and preferred vegetables in all countries. DK, FR and IT respondents also show high familiarity with and stated liking for green salad and tomatoes, UK and DK respondents for sweetcorn. Country-specific familiarity and stated liking mean scores can be observed for peas (DK) courgettes (IT), green beans (FR) and broccoli (UK). **French and Italian adolescents reported familiarity with and stated liking for peas higher than sweet corn.** Danish teens do not show differences in either familiarity with or stated liking for peas and sweetcorn. British respondents do not show

differences in familiarity with peas and sweetcorn. Their stated liking was higher for sweetcorn than for peas.

Univariate analysis of preference data assumes that all participants in each country exhibit the same behaviour and mean values are representative of the participants. In order to better explore country and individual differences in stated liking for vegetables, an Internal Preference Map was computed (Fig.1). Individual respondents (geometric forms) are represented on the map by points, which can be considered as end-points of vectors from the origin. The direction of the vector represents the direction of increasing personal 'preference' for a consumer; and the length (from the origin to the end-point) indicates how well that individual is represented by the dimensions that are being plotted (i.e. how much variance is explained). If a participant's point is a long way from the origin, the scores of that person are explained well by one or two 'preference' dimensions (Monteleone, Frewer, Wakeling, and Mela, 1998). Along the first dimension (from the right to the left), the opposition carrots/tomatoes versus broccoli/cauliflower is represented. The former pair includes the most preferred vegetables. In fact, the majority of respondents are located on the left of the first dimension. To the contrary, broccoli and cauliflower are the least preferred products. Green salad, peas and green beans fall to the left side of the first dimension indicating that, in all countries, these vegetables tend to be more preferred than the ones falling on the right side of the map. Respondents are widely spread along the second dimension in which sweetcorn is separated from the rest of the vegetables in opposition to courgettes and spinach. The majority of respondents from Denmark and the UK fall in the upper part of the map. They consistently expressed a higher preference for sweetcorn than for the other vegetables. French respondents are equally distributed at the top and the bottom left side of the map. Those in the top left of the plot, similar to the UK and Danish respondents, prefer carrots and sweetcorn and show little preference for spinach and courgettes. The participants in the bottom left of the plot, mainly composed of Italian and French respondents, show a preference for all kind of vegetables with the exception of sweetcorn, broccoli and cauliflower.

3.2 Within-vegetable approach: Actual Liking data for pea and sweetcorn samples

Mean liking data and F values associated with each country for sweetcorn samples indicate that Danish adolescents (mean= 4.59; F=50.55; p<0.001) discriminate between samples using liking much more than UK (mean= 4.80; F=14.99; p<0.001), French (mean= 5.15; F=12.07; p<0.001) and Italian (mean= 4.46; F=21.67; p<0.001) teens. The picture is different when liking scores for pea samples are considered. According to F values, the greatest differences in mean liking scores among samples were found in France (mean= 5.46; F=38.47; p<0.001) and in Italy (mean= 4.24; F=41.42; p<0.001). Mean liking and F-values were very low both in Denmark (mean= 2.56; F=38.47; p=0.0022) and in the UK (mean= 3.62; F=5.48; p<0.001). It seems that these adolescents expressed a generalised disliking for all pea samples. French and Italian teens expressed similar liking ratings for pea and sweetcorn samples while Danish and British respondents reported greater liking for the sweetcorn than the pea samples.

In order to investigate liking patterns considering individual differences and to identify the sensory determinants of actual liking across countries, a PCR was computed from descriptive sensory data and actual

liking data, for peas and sweetcorn independently (Figure 2 a-b). The IMP maps clearly indicate that adolescents share a common pattern of liking for both pea and sweetcorn samples. Most respondents are located on the right of the first component of the pea sample map (Figure 2a), and their liking is mainly driven by “sweet taste”, “salty taste”, “softness”, “umami taste”, “green colour”, “cooked peas”, “cooked vegetables” and “onion flavour” attributes, “melt-in-the-mouth” and “soft” texture. “Bitter” and “sour” tastes, “skin hardness”, “metallic” and “acid” flavour mainly drove respondent disliking. It can be noted that in general there are no areas of the map in which participants from a specific country are concentrated. This means that differences in liking are driven by the same sensory properties in all countries and that further segmentations for liking are independent of a country effect. Respondents are widely spread along the second dimension. Using the first dimension as a cut-off and considering only the participants on the right side of the map, two segments can be identified. Liking of participants falling on the bottom right is driven, in addition to the attributes correlated with the first dimension listed above, also by “onion”, “cooked peas” and “cooked vegetable” odour notes and “swollen” appearance. At same time, they dislike “bitterness”, “sourness”, “metallic” odour and flavour, and “acid” flavour. Liking and disliking for pea samples of respondents on the top right tend to differ from the rest of the teens mainly due to the influence on their responses of appearance attributes. In fact their liking is positively related to the attribute “size of seeds” and “damaged” appearance and negatively driven by the appearance attributes “size uniformity” and “swollen”. The IMP map of figure 2b shows individual responses across countries for the sweetcorn samples. Similar to that observed in the pea map, the large majority of respondents are located on the right side of the first component indicating a shared general trend in liking patterns among adolescents across countries. Teenagers’ liking for sweetcorn is mainly driven by “sweetness”, “crunchiness”, “yellow colour”, “seed size” and “thickness” as opposed to “acid” flavour, “sour”, “bitter” and “salty” tastes, “astringency”, and “soft” texture attributes. Respondents are spread along the second dimension. However, two segments are identified in the right part of the map using the first dimension as a cut-off. Participants in the bottom right particularly dislike “skin hardness” while teens in the top right relate their negative hedonic response to “saltiness”. Thus the differences between segments are more based on disliking rather than liking for sweetcorn.

The main sensory drivers of adolescent liking for pea and sweetcorn samples, as a result of the two cross-country IMP maps are summarised in Table 4. “Sweetness” as opposed to “sourness” and “bitterness” affects liking for both peas and sweetcorn. “Saltiness” is positively correlated with liking in peas and negatively with liking in sweetcorn as well as with softness. Colour intensity is positively correlated with liking in both products. Specific drivers of liking for canned peas are “cooked” flavour notes such as “peas”, “vegetables” and “onion”. “Crunchiness”, “thickness” and “size of seeds” drive liking for sweetcorn.

4. Discussion

4.1. Between-vegetable approach: Familiarity with and Stated liking for named vegetables

Vegetable names included in the questionnaire represent a selection of the most popular vegetables in the European market. Mean stated liking and familiarity scores expressed by European adolescents varied widely amongst the vegetables and a strong positive correlation was found between these scores in each country confirming an association between familiarity and liking (Morizet, Depezay, Masse, Combris, and Giboreau, 2011). It is worth noting that any vegetable that is familiar and well liked in one country may be unfamiliar and disliked in another. This is, for example, the case of green beans which are very popular among FR respondents but less familiar and not liked by DK and UK respondents. In the same way, broccoli was relatively familiar and liked by UK and DK respondents but was not acceptable to FR and IT respondents. Adolescents experience specific vegetables according to the food habit and culinary tradition of their country. Early exposure to and repeated experience of a given vegetable may allow the initial dislike to be changed to liking through the mechanism of “learned safety” (Kalat and Rozin, 1973) and a food initially avoided could become familiar and potentially preferred (Aldridge, Dovey and Halford, 2009).

Irrespective of country, the Internal Preference Map clearly shows the comparison between one group of highly liked vegetables (carrots, tomatoes, green salad) and one group of highly disliked vegetables (cauliflowers and broccoli). *Sensory descriptions from already published papers indicate that the* first group includes vegetables characterized by innately liked taste (sweet, umami), delicate flavour and bright appealing colour (Varming, Jensen, Moller, Brockhoff, Christiansen, Edelenbos, Bjorn and Poll, 2004; Salles, Nicklaus and Septier, 2003; Dinnella, Torri, Caporale and Monteleone, 2014). Further reasons for liking may be related to their widespread use as raw preparations (Poelman, Delahunty and de Graaf, 2015), to their high use as an ingredient of popular recipes (tomatoes) and to their common use as side dishes, such as raw salad. It is also worth noting that carrot has been reported as one of the most popular vegetables among young people elsewhere (Morizet, Depezay, Masse, Combris, and Giboreau, 2011; Edwards & Hartwell, 2002). The *Brassicaceae* family of vegetables are frequently reported as unacceptable by young people mainly due to an innate disliking of bitter taste and their objectionable flavour (Engel, Martin, Issanchou, 2006). This is confirmed by the preference pattern expressed by European adolescents for cauliflower and broccoli here. Peas appear well accepted by adolescents of all countries while only some respondents prefer sweetcorn. The sweet taste of peas (Malcolmson et al., 2014) together with their long and well established culinary tradition in Europe may be the main reasons for their general high appreciation by adolescents. Despite its sweet taste and bright appealing colour (Gere et al., 2014), sweetcorn is mainly preferred by respondents more familiar with the product (UK and DK adolescents).

In general, it appears that when adolescents are asked to state their liking for relatively familiar vegetables, the response is mainly related to their actual tasting experience, but innate preferences still concur to shape vegetable appreciation.

4.2 Within vegetable approach: Actual liking for pea and sweetcorn samples

Mean actual liking scores display a different pattern from that expected from stated liking for peas and sweetcorn as named vegetables. In general, stated liking scores are higher than actual liking scores. Liking

for well liked product names has been reported to be higher than liking for the tasted preparation of that food. Food names create a vivid emotional response and recall quintessential memories of the food (Cardello, Meiselman, Schutz, Craig, Given, Leshner and Eicher, 2012). Thus, stated liking reflects the memories of the best preparation of that food. On the other hand, the particular preparation of that food, its sensory properties, as well as context effects (such as preceding appetitive context) are responsible for actual liking ratings (Cardello & Maller, 1982; Cardello et al., 2012).

Furthermore, based on stated liking, both products are well accepted in all countries but UK and DK respondents rated actual liking for peas definitively lower than actual liking for sweetcorn. It is worth noting that canned peas are clearly disliked by UK and DK respondents while they are liked by IT and FR respondents. Peas are mainly marketed as a frozen product in both DK and the UK. The evident sensory differences induced by the type of processing may have resulted in a situation where the tasted canned peas were considered an unfamiliar product. Furthermore the discrepancy between the experienced and the expected sensory properties may contribute to the rejection of canned peas by UK and DK adolescents due to the disconfirmation effect (Deliza & McFie, 1996; Cardello, 2007). These differences in likings for pea samples strongly reflect the capacity of respondents from different countries to discriminate among samples as a function of their sensory properties. FR and IT respondents discriminate among pea samples much more than UK and DK respondents did.

Thus, it appears that clear differences in the sensory properties of a product can influence the hedonic response only in the case of liked products, while sensory differences are less important for determining the hedonic response to disliked products. Based on the impact of the sensory properties of pea and sweetcorn samples on actual liking, a strategy for promoting vegetable acceptance based on the manipulation of sensory properties may be more effective for already known and accepted products, but is unlikely to result in appreciable improvement in the case of vegetables not liked by the target population.

The IMP maps, computed by regressing individual actual liking ratings on data from descriptive analysis of pea and sweetcorn samples, allow some general conclusions to be drawn on the hedonic valence of the sensory descriptors of peas and sweetcorn, applicable to all the countries participating in the study. The innately disliked tastes (bitter, sour) are clearly correlated with a negative hedonic response in both the considered vegetable products. On the other hand, the hedonic valence of a generally well accepted taste such as salty can be dependent on the type of vegetable, e.g. a salty taste assumed a positive valence in peas and a negative valence in sweet corn.

A number of flavour descriptors account for pea and sweetcorn preference patterns thus confirming the role of retro-nasal olfaction in vegetable acceptance (Lim and Padmanabhan, 2010; Poelman and Delahunty, 2011). Flavours describing the sensory properties distinctive of the type of vegetable (peas, cooked peas, sweetcorn) as well as those of an ingredient usually used for their culinary preparation (e.g. onions in the case of peas) have a positive effect on liking. On the other hand, the intensity of unusual flavours, described

by the trained panel with words not strictly related to food (e.g. acrid, metallic), is related to sample disliking both in the case of peas and sweetcorn.

Appearance is reported to influence liking for vegetables more in younger (4-5 years old) than older children (10-12 years old) (Zeinstra, Koelen, Kok and de Graaf, 2007) and colour in particular appeared to play a major role. In the present study actual liking for peas and sweetcorn was positively related to the intensity of their typical colour (green and yellow for peas and sweet corn, respectively).

In general, both flavour and appearance descriptors suggest that the compliance with sensory expectations is an important driver of adolescents' actual liking for familiar vegetables – i.e. the more the sensations are typical for the type of vegetable, the more the vegetable is liked. The relationships between the sensory descriptors of the samples and the relevant preference patterns of European adolescents indicate that strategies aimed to promote vegetable intakes of familiar and accepted vegetables could take advantage of presentation modalities and culinary preparations that respect or enhance the distinctive sensory properties for each vegetable type.

Texture is important for vegetable liking and the hedonic value of the texture descriptors used depends on the vegetable type (Szczeniak, 2002; Zeinstra, Koelen, Kok and de Graaf, 2010; Poelman & Delahunty, 2011). In fact, easy to chew texture (soft) is positively related to liking for peas while this texture is related to disliking for sweetcorn. Preferences for complex textures have been found for older children (6-12 years old) (Szczeniak, 1972) and is confirmed here, where adolescents were found to like “crunchy” sweetcorn samples. The texture descriptor “skin hardness” was possibly perceived as a contrast to the soft inner part, and was related to disliking both for pea and sweetcorn samples.

5. Conclusions

A cross-country comparison was performed to identify the sensory drivers of acceptability of certain vegetables among European adolescents. The between-vegetable approach reveals the strong positive connection between familiarity and self-reported liking. The most familiar and most liked vegetables across countries are characterized by innately liked sensations, such as sweet and umami taste, delicate flavour and bright appealing colour. Country specific preference patterns, possibly related to specific gastronomic traditions, further underline the importance of familiarity for vegetable acceptance. Thus, strategies that aim to increase familiarity, e.g. through repeated exposure, could provide an effective way for increasing vegetable acceptance, while taking advantage of both innately liked vegetable sensory properties and country specific gastronomic traditions.

The differences found between stated and actual liking for peas expressed by DK and UK respondents highlight the importance of expectations in adolescents' hedonic responses to vegetables. Furthermore, the preference patterns of European adolescents for pea and sweet corn with varied sensory properties indicate the positive hedonic valence of specific sensory properties for any given vegetable, such as typical aroma and flavour. This suggests that culinary preparations that respect or enhance the typical vegetable aroma and flavour would easily meet expectations for sensory properties and could positively affect vegetable

acceptance by adolescents. On the other hand, the hedonic valence of some tastes, such as saltiness, and texture descriptors is dependent on the context and cannot be considered to be reliable predictors of vegetable liking or disliking *per se*.

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Figure captions

Figure 1: Internal Preference Map: Correlation loading plot from PCA computed on stated liking data for vegetables from DK, FR, IT and UK teenagers. Outer and inner circles on the map represent 100% and 50% explained variance, respectively.

Geometric forms represent respondents from different countries (\triangle = FR; \blacktriangle = IT; \square = UK; \blacksquare = DK).

Figure 2 (a-b): Internal Preference Map: Correlation loading plot from PCR computed on actual liking data for peas (a) and sweetcorn (b) from DK, FR, IT and UK teenagers and on descriptive data from the trained panels. Outer and inner circles on the map represent 100% and 50% explained variance respectively.

Geometric forms represent respondents from different countries (\triangle = FR; \blacktriangle = IT; \square = UK; \blacksquare = DK).

Table 1: Characteristics of the adolescent respondents: country, total number of respondents per country, number of respondents per product in each country, age, gender.

| Country | Respondents total number | Peas | | Sweetcorn | |
|---------|--------------------------|-------------|--------------|-------------|--------------|
| | | Respondents | Age (*) | Respondents | Age (*) |
| DK | 88 | 68 | 15.07 (1.33) | 86 | 15.21 (1.31) |
| FR | 206 | 105 | 12.90 (1.04) | 101 | 13.32 (1.02) |
| IT | 110 | 108 | 15.00 (1.43) | 103 | 14.98 (1.42) |
| UK | 93 | 76 | 13.41 (1.69) | 80 | 13.43 (1.70) |

(*) = mean and standard deviation

Table 2. Sensory attributes of canned pea and sweetcorn samples. Significant attributes ($p < 0.05$) are emboldened.

| | Peas | Sweetcorn |
|-------------------|--|---|
| Appearance | Green Colour uniformity Seed size Size uniformity Swollen Damaged | Yellow Seed size Size uniformity Swollen Damaged |
| Aroma | o-Raw peas o-Cooked peas o-Cooked vegetables o-Acrid o-Metallic o-Onion | o-Cooked vegetables o-Acrid |
| Flavour | f-Raw peas f-Cooked peas f-Cooked vegetables f-Acrid f-Metallic f-Onion Sweet Bitter Sour Umami Salty | f-Sweet corn f-Cooked vegetables f-Acrid Sweet Salty Sour Bitter Astringent |
| Texture | Skin hardness Softness Melt-in-the-mouth | Skin hardness Softness Crunchiness Thickness |

o-: odour; f-: flavour

Table 3. Comparison between familiarity with and stated liking for vegetables in each country, independently.

| Product | Denmark (n=88) | | France (n=206) | | Italy (n=110) | | UK (n=93) | |
|-------------|-------------------------|-------------------|-------------------------|-------------------|-------------------------|---------------------|-------------------------|--------------------|
| | Familiarity rank sum | Liking mean | Familiarity rank sum | Liking mean | Familiarity rank sum | Liking mean | Familiarity rank sum | Liking mean |
| Broccoli | 532 ^{bc} | 6.14 ^b | 763 ^g | 4.06 ^d | 407 ^f | 3.9 ^f | 661 ^b | 5.9 ^{cd} |
| Carrots | 731 ^a | 7.44 ^a | 1583 ^{ab} | 7.39 ^a | 747 ^{bc} | 7.12 ^{ab} | 767 ^a | 6.85 ^{ab} |
| Cauliflower | 383 ^e | 4.91 ^c | 806 ^{fg} | 4.31 ^d | 359 ^f | 3.69 ^f | 462 ^f | 4.6 ^e |
| Green beans | 396 ^{de} | 5.02 ^c | 1634 ^a | 7.55 ^a | 733 ^{cd} | 6.26 ^{cd} | 468 ^{ef} | 4.66 ^e |
| Green salad | 775 ^a | 7.33 ^a | 1547 ^{ab} | 7.37 ^a | 836 ^{ab} | 6.81 ^{bc} | 551 ^{de} | 5.34 ^d |
| Peas | 613 ^b | 6.14 ^b | 1480 ^b | 7.43 ^a | 672 ^{cd} | 6.31 ^{cd} | 658 ^{bc} | 5.47 ^d |
| Spinach | 477 ^{cd} | 5.94 ^b | 927 ^{ef} | 5.28 ^c | 662 ^{cd} | 6.03 ^{de} | 336 ^g | 3.48 ^f |
| Sweetcorn | 613 ^b | 6.5 ^b | 1092 ^{cd} | 6.24 ^b | 554 ^e | 5.45 ^e | 698 ^{ab} | 6.91 ^a |
| Tomatoes | 595 ^b | 6.08 ^b | 1574 ^{ab} | 7.65 ^a | 893 ^a | 7.64 ^a | 571 ^{cd} | 5.36 ^d |
| Courgettes | 334 ^e | 4.44 ^c | 1002 ^{de} | 5.09 ^c | 758 ^{bc} | 6.54 ^{bcd} | 307 ^g | 3.22 ^f |
| Beans | 360 ^e | 4.76 ^c | 1190 ^c | 6.09 ^b | 642 ^{de} | 6.06 ^d | 662 ^b | 6.22 ^{bc} |

Values followed by different letters are significantly different **by column** ($p < 0.05$)

Table 4: Main Sensory drivers of liking for pea and sweetcorn samples

| Canned Product | Sensory Input | Main Sensory Drivers | |
|----------------|---------------|--|---|
| | | Liking | Disliking |
| Peas | Appearance | Green intensity | |
| | Flavour | Sweetness Saltiness Cooked peas Cooked vegetables Cooked onion | Sourness Bitterness Metallic Acrid |
| | Texture | Softness | Skin Hardness |
| Sweet corn | Appearance | Yellow intensity Seed size | |
| | Flavour | Sweetness | Saltiness Sourness Bitterness Acrid Astringency |
| | Texture | Crunchiness Thickness | Softness |