МАТЕМАТИКА И МАТЕМАТИЧЕСКО ОБРАЗОВАНИЕ, 2018
MATHEMATICS AND EDUCATION IN MATHEMATICS, 2018
Proceedings of the Forty-seventh Spring Conference
of the Union of Bulgarian Mathematicians
Borovets, April 2–6, 2018

A STUDY ON THE ASSOCIATIONS BETWEEN THE QUALITY ATTRIBUTES OF A FOOD PRODUCT*

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Qualitative characteristics of food products are studied. The aim stems from the need of an adequate model for complex sensations to be built. In this case examining consumers' preferences carries the meaning of finding associations between characteristics of food products by stepwise application of two models of correspondence analysis.

1. Introduction. Sensory evaluation of a food product is carried out through our senses of taste, smell, touch and hearing while we consume food. These complex sensations are used to determine the quality of food when quality control is required or when a new product has been created.

The sensory assessments characterize the quality of food and beverages and are an important factor for the consumer behavior. Whether a product is enjoyed and consumed with pleasure depends exclusively on its organoleptic properties: appearance, smell, texture and taste. For this reason, the sensory evaluation can be very subjective, which has been led to the development of a number of standardized methods of analysis. According to the International Standards Organization (ISO 5492), sensory analysis means an assessment of the organoleptic properties of a product through sensory organs.

The purpose of this paper is to examine associations between quality categories of sensory attributes of a new food product (rose-flavored topping) by consumers, and to establish the directions of the consumers' likes or dislikes. As a result, a general association model will be presented.

2. Experimental design. Consumers (most of them students from the University of Food Technology) were selected according to demographic requirements: 50 % of them females and 50 % of them males, aged between 18 and 30 years, regular confectionary products eaters, as they consumed confectionary goods more than once a week. They were instructed prior to the evaluation to ensure the reliability of the results.

Eighty selected and instructed consumers taste a sample of rose flavored confectionary topping in 8 sessions. The assessors rate the "overall liking" of the product using 5-point hedonic scale with descriptors L1 (dislike very much), L2 (dislike slightly), L3 (neither

*2010 Mathematics Subject Classification: 62-07, 62-09, 62P30.
Key words: correspondence analysis, supplementary points, sensory evaluation .
The research outlined in the current article was partially funded by the Scientific Research Fund of the Plovdiv University "Paisii Hilendarski" as part of project: FP17-FMI-008.

like nor dislike), L4 (like slightly), and L5 (like it very much) by filling out their answers in the questionnaire. Next just-about-right (JAR) questions on six sensory attributes follow: color, aroma, flavor, sweetness, texture and mouthfeel using 3-point JAR scale with descriptors marked with 1 (too weak), 2 (just-about-right), and 3 (too strong).

2.1. Relationship between human senses and sensory properties. Sensory evaluation is the scientific discipline through which the sensory analyst evokes, measures, analysis and interprets human reactions to characteristics of foods and materials as perceived through the senses of sight, smell, taste, touch and hearing.

The relationship between human perceptions and sensory properties is shown on Fig. 1.

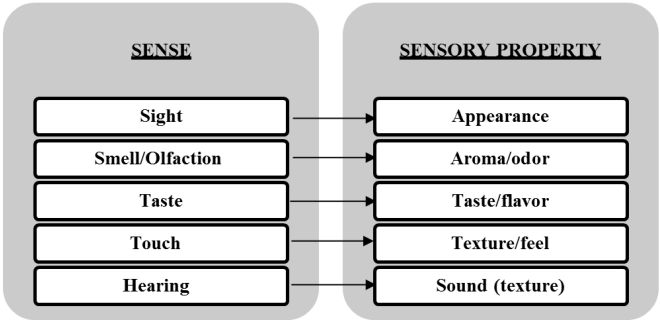

Fig. 1. Relationship between sense and sensory property

Based on the above given definition a few groups (each comprised of a number of sensory properties) were selected to present the sensor attribute path through the perceptual space:

- Sight – "overall liking" and "color"
- Smell/Olfaction – "overall liking", "aroma" and "flavor"
- Taste – "overall liking", "sweetness" and "flavor"
- Touch – "overall liking", "texture" and "mouthfeel"
- Flavor sense – "overall liking", "aroma" and "sweetness".

2.2. Sight. The first impression we get about a product is formed through the sight. Visual sensations are the first basic element in determining the quality of a product. In some cases, the changes of the surface coloring are indicative for the start of the deterioration.

The color of products depends on their ability to absorb, reflect or pass light beams of different wavelengths through. In the visual evaluation, certain color-related associations based on human memory take place, and any deviations from these concepts provoke uncertainty and prejudice.

Therefore, the visual evaluation is an extremely important element of the overall sensory evaluation. In many cases it precedes other impressions.

2.3. Smell/Olfaction. The smell gives the most critical sensory information on the quality of foods and beverages. The smell and taste sensations are closely related to each other physiologically and the pleasure of eating is due to them. Research studies have shown that pleasantly smelling products get a higher score during the evaluation

of the quality of products. On the other hand, the spoilage of all foods and beverages is associated with an unpleasant odor.

The aroma of a product is the characteristic, the typical odor originating from the odor of the raw material.

2.4. Taste. Taste is the sensation that delivers the least information. It allows the identification of only four basic stimuli, the receptors of which are mainly located on the tongue. In sensory analysis, the concept of taste refers only to sweet, salty, sour and bitter. All other hints of tastes we experience appear to be complex combinations of the four basic tastes. Only diluted solutions of substances specifically affect taste receptors, while more concentrated ones can even cause oral pain. The reference for sweet taste is sucrose in the sensory analysis.

2.5. Touch. The common notion of touch includes different in kind and quality sensations. It is a cumulative sensation, including a touch to explore the shape and condition of the product's characteristics. The sensation of "touch" is comprised of the sensory properties "texture" and "consistency".

Texture is a property of substances, a combination of physical and sensory characteristics defined by touch, sight, and hearing. It is the sensation in the mouth when chewing, biting and sucking. The texture feels like the density, juiciness, dryness, hardness, softness, resistance to the movement of the tongue, and the feeling while swallowing food.

Consistency is the condition of the product in the oral cavity that changes with the texture of the product.

2.6. Flavor. The flavor is the sensation shaped by taste and smell at once while eating. The flavor depends on the chemical composition and especially on the presence of volatile compounds associated with the aromatic properties of the product. The character of the flavor can be expressed in words that describe the flavor profile of the product. In the description of the flavor, the following notation given in ISO 5492 should be used: atypical flavor, aftertaste, lingering taste.

3. Expert data sample. In most situations data description, interpretation and modeling work together. But there are situations in which the data description and interpretation assume supreme importance. Such a case is when the data sample is the whole population of interest.

4. Basic concepts in correspondence analysis. Most of statistical methodology concentrates on problems in which a theoretical model is fitted to data. The correspondence analysis (CA) describes data, interprets them and generates a hypothesis that can be tested in a subsequent stage of research.

When data are categorical we can use CA to understand them better. To do it we build contingency tables. In this way we transform the original data into frequencies. The new data are the frequencies of the levels of the categorical data.

The correspondence analysis displays frequency data table as points in a spatial map and interprets the similarities and differences between rows, the similarities and differences between columns and the association between rows and columns. The inertia is used to measure the scaterness of the points.

The correspondence analysis is a data science technique. It identifies the main relationships between the rows and columns on a frequency table and plots them on

a two-dimensional map. The further points are from the origin, the more discriminating they are. The closer points are to origin, the less distinct they probably are.

We are able to gauge the similarity of row points based on their distance on the map (i.e., their proximity). Proximity between row labels probably indicates similarity. Proximity between column points also indicates similarity.

If there is a small angle connecting a row and column point to the origin, they are probably associated. A row and column label are probably not associated if their angle to the origin is 90 degrees. A row and column label are probably negatively associated if they are on opposite sides of the origin. The further a point from the origin, the stronger their positive or negative association.

The rows and columns of a contingency table analyzed by CA determine the orientation of the axes of low-dimensional maps. They are called "active points". All active points are projected onto the map. Supplementary points are additional rows or columns of a table which bring additional meaningful information. They can also be projected onto a low-dimensional map in order to analyse their positions relative to the active points.

Sensory scientists have started to focus their attention on the use of correspondence analysis to analyze sensory evaluation data. McEwen, Schlich have used simple Correspondence Analysis (CA) and Multivariate Correspondence Analysis (MCA) as techniques to assess the quality characteristics of strawberry jam [3]. They summarize the data in a matrix of 288 rows (12 assessors $\times$ 8 samples $\times$ 3 replicates) by 18 columns (attributes). Statistical software SAS was used to perform CA and MCA. The objective was to illustrate the application of CA and MCA to sensory profile data, how the results should be interpreted and how they could be compared to those obtained before. The idea of tracing an attribute path through a perceptual space has its attractions for the interpretation of data, and sensor analysts are encouraged to make use of this approach as complementary to the more traditional methods.

Pagès, Berthelo, Brossier, Gourret examined sensory evaluation data, collected from eight 100% orange juices [5]. They used a combination of three criteria having each one two categories: the brand (Tropicana/Jafaden), the mode of store shelf (shelf at room temperature/refrigerated shelf) and the presence of pulp (with/without). There were six JAR variables: shade of colour, odour intensity, sweet, sour, bitter and pulpy. Initially, these variables had five categories: really not enough, not enough, just about right, too much, really too much (for colour, extreme categories are "really too yellow" and "really too orange"). The questionnaire ended with an overall liking ranging from 0 (I really dislike it) to 10 (I like it very much). The correspondence analysis and multiple correspondence analysis were performed using the R package FactoMineR [2]. The result of MCA was a visualization of the relationships between the variables and it was necessary to get an idea of the causes of these relationships. Were they due to the products? Were they due to the consumers? The authors of the article presented graphs of correspondence analysis for the introduction of the so called: "penalty analysis", used in sensory evaluation. It is pointed out that the visualization, via the CA and MCA, of the relationships between JAR variables help to choose those to be considered together in the context of improving a product.

The aim of our paper is to identify associations between levels of categorical variables tracing the attribute path through the perceptual space and to build a model for sensory

evaluation of food features. We are going to reach it through stepwise application of two models of correspondence analysis.

The main aim is to present the authors approach in interpretation of complicated tables of sensory data. The approach is based on development of association model for each group of sensory characteristics. In each model the categorical variable *overall liking* is included and it is rated using hedonic rating with levels L1 (dislike very much), L2 (dislike slightly), L3 (neither like nor dislike), L4 (like slightly), and L5 (like it very much). The descriptors are rated using 3-point JAR scale: 1 (too weak), 2 (just-about-right), and 3 (too strong).

It is possible and convenient, to represent sensory data in two-dimensional space [4]. The CA plots are asymmetric because the liking row profiles are plotted simultaneously with the apexes of the columns representing sensory descriptors. There were 3 columns and the perfect data representation is achieved in two dimensions.

One of the most flexible aspects of the correspondence analysis is the opinion of representing supplementary data points in the same CA plot. The supplementary points have no influence in determining the axes. The supplementary points plotted in the correspondence analysis plot enrich the interpretation of the data even further [1].

If the total inertia is close to 0, the points in CA plot tend to be tightly clustered around 0 point of the plot (their centroid) and thus an association discovery would be very difficult.

The ***R*** statistical software package ***ca*** is used to perform CA [6].

5. Association model of sight. We deal with two categorical variables: overall liking and color with three dimensions c1 (too light), c2 (JAR) and c3 (too dark). A simple correspondence analysis is used to visualize the sensory data. The asymmetric plot that is produced on the base of correspondence analysis for the sight is illustrated in Fig. 2.

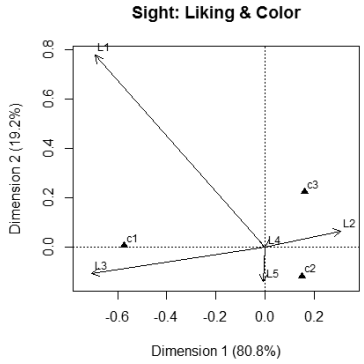

Fig. 2. CA plot of Liking row points and Color Column Vertices

Interpretation in the light of the sensory analysis: Sensory descriptor for color "Too dark" is associated with the hedonic rating "Dislike slightly". Sensory descriptor for color "Too light" is associated with the hedonic rating ,,Neither like nor dislike". Sensory descriptor for color "just-about-right" is associated with the hedonic rating "Like it very much".

Statistical inferences: The interpretation of the graphics, generated through the model of a correspondence analysis, follows the rules: if the length of the line connecting the row label ("*Overall liking"*) to the origin is longer, it indicates that the row label is highly associated with some of the column labels (*sensory attributes – color, aroma, flavor, sweetness, texture and mouthfeel*). If the length of the label connecting the column label to the origin is longer, it again indicates a high association between the column label and one or more row labels. If the angle formed between these two lines is a small enough it indicates association. It is a general rule that 90° angles indicate no relationship and angles near 180° indicate negative associations. Also it is applicable that the further points are from the origin, the more discriminating they are and the closer they are to origin, the less distinct they probably are. Finally the proximity between column labels indicates similarity. On the base of Figure 2 the following conclusion could be outlined: the fact that row-point L1 is positioned relatively far away from row-points L5, L4, L3 and L2 indicates that L1 has very different liking profile from others. L1 is negatively associated with c2. There is a *small* angle connecting row point L3 and column point c1 to the origin. Both points are further from the origin and, therefore, their association is strong. L2 is associated with c3. There is a weak association between L5 and c2. Row point L5 and column point c1 are not associated because their angle to the origin is 90°. The category L4 of the variable *Overall Liking* is at the beginning of the coordinate system (weighted average). It is typical for the consumers to like the appearance of the product slightly. The total inertia is 0.11.

6. Association model of smell. One of the most flexible aspects of the correspondence analysis is the possibility of representing supplementary data points on the same correspondence analysis plot. The supplementary data have the columns in common with the original data. These supplementary columns presenting flavor enrich the interpretation of the data even further.

In the sensory model the smell sense is represented with three categorical variables: overall liking, aroma (1-too weak; 2-JAR; 3-too strong) and flavor (taste along with the olfaction) (1-too weak; 2-JAR; 3-too strong). Hence we use the correspondence analysis with supplementary points. In the model row variable is *Overall liking* and the column variable is the one, where the total inertia of the data is a small number, bigger than 0.1. The third variable flavor is presented by supplementary points. The asymmetric

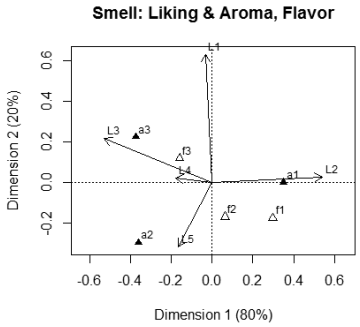

Fig. 3. Map of feeling for smell

plot representing liking row profiles, aroma apexes and supplementary points flavor is presented in Fig. 3.

Statistical inferences: L3 is strongly positively associated with a3, because the lines connecting the row label to the origin and the connecting the column label to the origin are longer and the angle between the lines is less than 90° and L3 is probably also associated with f3. L2 is strongly positively associated with a1 and probably with f1. Again the conclusion comes on the base of the length of the lines, connecting the points and the angle between them. L5 is positively associated with a2 and probably with f2. There is weak or no association between L4 and f3, because the points are close to the origin, which means that less distinct they probably are. L1 is poorly described by any of the aroma descriptors. The total inertia is 0.16.

Interpretation in the light of the sensory analysis: Sensory descriptors for aroma and flavor "Too strong" is associated with the hedonic rating, "Neither like nor dislike". Sensory descriptors for aroma and flavor "Too weak" is associated with the hedonic rating "Dislike slightly". Sensory descriptors for aroma and flavor "Just-about-right" is associated with the hedonic rating "Like very much".

7. Association model of feeling for taste. In the sensory model the taste sense is represented by "overall liking", "sweetness" and "flavor" (see Fig. 4).

Statistical inferences: The category L3 of the variable *Overall liking* is situated near the origin (the weighted average), which means that L1 is less distinct. Hence, it is typical for the consumers to "neither like nor dislike" the product if it concerns the taste of the product. L5 is positively associated with f2, because the length of the lines, connecting the two lines are big enough and the angle formed is less than 90°. On the base of the same reason it is concluded that L4 is positively associated with f3. L2 is strongly positively associated with f1. L1 is poorly described by any of the flavor descriptors. The total inertia is 0.198.

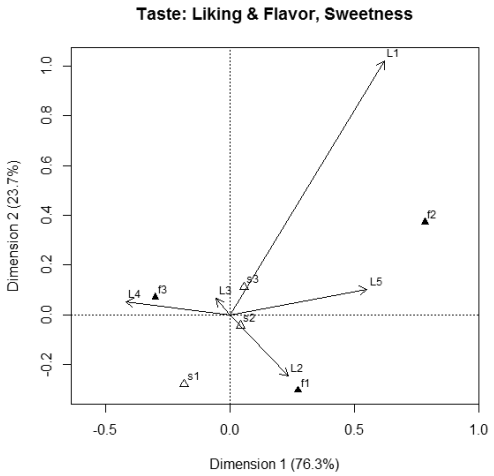

Fig. 4. Map of feeling for taste

Interpretation in the light of the sensory analysis: Sensory descriptor for flavor "Just-about-right" is associated with the hedonic rating "Like very much". Sensory descriptor for flavor "Too strong" is associated with the hedonic rating "Like slightly". Sensory descriptor for flavor "Too weak" is associated with the hedonic rating "Dislike slightly".

Association model of touch: In the sensory model the touch sense is modeled through "overall liking", "texture" and "mouthfeel" (see Fig. 5).

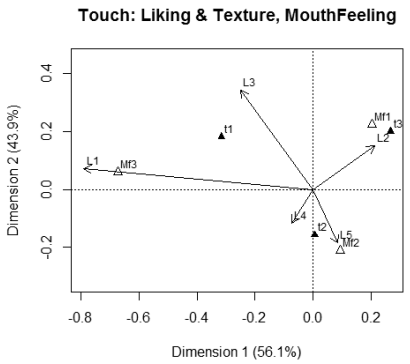

Fig. 5. Map of feeling for touch

Statistical inferences: Probably L1 is strongly positively associated with Mf3, due to the fact that the further a point from the origin, the stronger is the association available. L2 is strongly positively associated with t3, because the *small* angle connecting a row and column label to the origin means probably association. Probably L2 is also positively associated with Mf1. L3 is positively associated with t1. L5 is positively associated with t2. Probably L5 (*Like very much*) is positively associated also with Mf2 (*JAR*). The total inertia is 0.07.

Interpretation in the light of the sensory analysis: The sensory descriptor for the mouthfeel "Too rough" is associated with the hedonic rating "Dislike very much". The sensory descriptor for the texture "Too dense" and the sensory descriptor for the mouthfeel "Too smooth" are associated with the hedonic rating "Dislike slightly". The sensory descriptor for the texture "Too liquid" is associated with the hedonic rating "neither like nor dislike". The sensory descriptors for the texture and the mouthfeel "Just-about-right" are associated with the hedonic rating "Like it very much".

8. Association model of flavor sense. In the sensory model the flavor sense is modeled through "overall liking", "aroma" and "sweetness" (see Fig. 6).

Statistical inferences: L5 is strongly positively associated with a2 and probably with s2. The conclusion is made due to the *long* length of the lines and the small angle (less than 90°) formed between them. For the same reason we conclude that L3 is strongly positive associated with a3. L2 is strongly positively associated with a1. Probably L2 is also associated with s1 (the angle between the lines of L2 and s1 is less than 90°). L4 and s3 are closer to origin. Therefore we can conclude that they probably are less distinct. Probably L1 is negatively associated with s2, because angles near 180° indicate negative associations. The total inertia is 0.16.

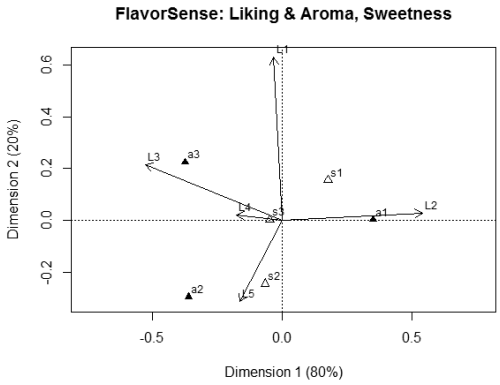

Fig. 6. Map of flavor sense

Interpretation in the light of the sensory analysis: The sensory descriptors for aroma and sweetness "Just-about-right" are associated with the hedonic rating "Like very much". The sensory descriptors for aroma and sweetness "Too weak" and "Too little" are associated with the hedonic rating "Dislike slightly".

In summary, the interpretation of the results in the light of sensory analysis showed that the sensory descriptors for flavor "Just-about-right" and "Too strong" are positively associated with the hedonic rating "Like very much" and "Like slightly", respectively. Exploring Fig. 4, it is noticeable that the hedonic rating "neither like nor dislike" is well centered close to the origin meaning that it is typical for the consumers to neither like nor dislike the taste of the product. Hence the product developers should look for a stronger flavor of their product to meet the needs of the consumers.

Sensory descriptor for sweetness "Just-about-right" is associated with the hedonic rating "Like very much". Now looking at Fig. 6 it is noticeable that the descriptor for sweetness "Too much" is centered right to the origin meaning that it is typical for the consumers to like the product more if it is sweeter.

9. Conclusion. Multiple Correspondence Analysis summarizes the data. The more data, the greater the chance that any good summary will miss out important details. In our approach for examining the associations between the quality attributes of a food product the general sensor model is expressed as a decomposition of simpler association models presenting the sensor attribute path through the perceptual space. In this way, the correspondence analysis with supplementary points greatly simplified the story in the data and added value to the data understanding through obtaining some more detailed information.

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ОТКРИВАНЕ НА ВРЪЗКИ МЕЖДУ КАЧЕСТВЕНИ ХАРАКТЕРИСТИКИ НА ХРАНИТЕЛНИ ПРОДУКТИ

Веска Нончева, Дида Исерлийска, Василка Събева

Възприемането на храната на физиологично равнище може да се представи чрез зрително усещане, обонятелно усещане, осезателно усещане, вкусово усещане и усещане за вкусност. Моделът M на пътя на тези възприятия е редица от асоциативни модели, т.е. M=(M_1, M_2, M_3, M_4, M_5), където M_1 е модел на зрително усещане, M_2 е модел на обонятелно усещане, M_3 е модел на осезателно усещане, M_4 е модел на вкусово усещане и M_5 е модел на усещането за вкусност. Сведохме задачата за изследване на органолептичното възприемане на определен хранителен продукт от консуматора, до задача за откриване на връзки между равнища на категорийни променливи, моделиращи характеристики на хранителни продукти, и я решихме, като използвахме обикновен кореспондентен анализ и кореспондентен анализ с пасивни точки.