Electronic Nose and Tongue for Pet Food Classification

Viktória ÉLES [1] (✉)
István HULLÁR [2]
Róbert ROMVÁRI [1]

Summary

Commercial canned dog and cat foods (four type of each) were classified by electronic nose (EN) and tongue (ET) methods. The classification was performed by canonical discriminant analysis (DA) followed by cross-validation, using the ET and EN sensory values separately (7 and 18 sensors) and also jointly. The number of entered variables corresponding to the total number of sensors (n=25) were decreased by using a stepwise procedure during DA. First the dog and cat samples were classified than the discrimination were performed on the canned foods (eight type). Thereafter two groups were formed depending on the compositional characteristics of the foods (pure animal vs animal and plant origin), and finally these groups were divided into four subgroups according to the concerning species (dog vs cat). In general, the lowest discriminating results were achieved by the single application of ET method (58.3-81.7 %). The highest classification power (85–98.3%, CV% 83.3–95.8) derived from the joint application of the two sensory methods. According to the results achieved, the common application of EN and ET technology seems to be a promising tool for the aroma classification of pet foods.

Key words

electronic nose, electronic tongue, classification, pet food, cat, dog

[1] University of Kaposvár, Faculty of Animal Science, Department of Agricultural Product Processing and Qualification, Guba S. str. 40, H7400 Kaposvár, Hungary
✉ e-mail: eles.viktoria@ke.hu
[2] Szent István University, Faculty of Veterinary Medicine, Department of Animal Breeding, Nutrition and Laboratory Animal Science, Istvan str. 2, H1400 Budapest, Hungary

Received: March 30, 2013 | Accepted: June 17, 2013

ACKNOWLEDGEMENTS
The financial support of TÁMOP 4.2.2.B research grant is highly acknowledged.

Background and aim

Traditionally in the pet food industry physicochemical measurements have been used for product qualification, without flavor (composed of taste and aroma) component characterization. The identification and quantification of these components is now mostly based on gas cromatography methods such as GC-MS and GC-FID following separation steps. It has to be mentioned that the relationship between the chromatographic data and the perception of the global aroma of a product is not easily described.

Olfaction has an outstanding importance for animals like dogs and cats, as they observe and interpret their environment mainly by sensing odours. Basic differences exist between the above mentioned species. The sense of taste and meal patterning of domestic dogs and cats can be interpreted in terms of their descent from members of the order *Carnivora*. The preference of many dogs for large and infrequent meals reflects the competitive feeding behavior of its pack-hunting ancestor, the wolf *Canis lupus* (Bradshaw 2006). Domestic cats are more specialized. Their preference for several small meals each day reflects a daily pattern of multiple kills of small prey items in their ancestor, the solitary territorial predator *Felis silvestris*. Pet care nutritionists and scientists endeavor to ensure that their products have superior palatability and acceptance. To allow a better understanding of dogs' and cats' feeding behavior, a number of evaluation methods have been developed. The most frequently used is the so-called *preference test* which takes into consideration the immediate choice of the animal, the rate of ingestion or the quantity ingested during a standard time period (reference needed).

The exact setting up of an animal taste preference test is performed under laboratory conditions. This costly and time consuming process needs convenient experimental conditions and well trained staff. It is surprising that human taste panel was also used to optimize the sensory characteristics of canned cat feeds (Pickering 2009). Another possibility is the owner rating of pet preferences. It is remarkable that large differences exist among laboratory and home kept pet animals, as the latter live in much more diverse environment and have had more complex past histories than laboratory dogs which may influence food preferences (Houpt & Smith 1981). However, it is often difficult to make generally applicable statements to the sensory quality of feeds because animals may react individually (Bradshaw et al. 2000). According to Bradshaw (2006), the "monotony effect" reduces the perceived palatability of feeds which has to be taken also into consideration.

Nowadays a new tendency is invented in measurement technology. It becomes more desirable to get information on attributes like quality, condition or state of process instead of measuring single parameters. Due to this trend there is a growing interest towards electronic sensor based techniques as electronic nose (EN) and electronic tongue (ET). From the end of the 1990s the EN instruments have been routinely used in the food and beverage industry to replicate the human olfactory system (Peris & Escuder-Gilabert 2009). Basically the EN consists of an array of chemical sensors, each with partial specificity to a wide range of odorant molecules. The signs of sensory arrays produce the so-called fingerprints of the given flavor which are evaluated with chemometric methods. In food research, beside the EN technique, the ET was developed in the last decade to describe the taste of liquid media. The common principle of the different ET technologies is the application of an array of non-specific chemical sensors with high cross-sensitivity. The pattern recognition techniques are similar for both the EN and ET technologies. An early example of the joint application of EN and ET technologies was described by Winquist *et al.* (1999).

Interestingly, no relevant literature is available concerning the use of EN and ET in pet food qualification, except for one conference proceeding from Oladipupo *et al.* (2011). Most probably data are kept confidentially by the product developers. In pet food manufacturing, edible fat is included in the formulation as an energy supplement, as well as a palatability enhancer. However, during the processing and storage, the added fat may be susceptible to oxidation (Lin et al. 1998). Oxidation of lipids is one common and frequently undesirable chemical change that can impact the flavor, aroma and nutritional quality of the pet food.

The aim of the present work was a methodological development of EN and ET techniques to evaluate the possibility of classificating canned petfoods according to their aroma.

Material and methods

Pet food samples

Eight medium priced commercial canned dog and cat food samples (four type of each) were used. All petfoods were manufactured by the same company and the main ingredients composing each feed are here reported: cat food: 1 – poultry-venison animal origin-carrot, 2 – beef-liver-peas, 3 – veal-poultry and 4 – turkey-rabbit; dog food: 5 – liver-rabbit-carrot, 6 – meat mix, 7 – lamb-rice and 8 – poultry. The samples (100 g of each) were homogenized for EN measurement. For ET analysis, the homogenized samples were first mixed with equal quantity of distilled water and then centrifuged for 10 minutes at 900 g (2700 rpm, Sigma 4-04C) to obtain the supernatant.

Electronic nose measurement

An αFox 4000 (ALPHA MOS, Toulouse, France) type EN with 18 metal oxide sensors (MOS) was used. The adsorption of volatile compounds onto the MOS surface generates a change in the electrical resistance which varies with the type of compound and its concentration in the headspace (HS). According to the applied static headspace (HS) technique, samples were placed in hermetically sealed vials of 20 ml. After the equilibrium has been established between the matrix and the gaseous phase, an ALPHA MOS HS 100 auto sampler was used for sampling the HS. Synthetic air was used as a premanent air-flow. The acquisition time and time between subsequent analyses were 120 and 1200 s, respectively. Five parallel measurements were performed on each sample ($n = 8 \times 5$). During the EN method development the use of the following parameters resulted in values of acceptable signal intensity: sample quantity 1 g, sample temperature 80 °C, equilibration time 120 s, injection volume 1000 μl and the flow rate 150 ml/min.

Electronic tongue measurement

An αAstree II (Alpha-MOS, Toulouse, France) type ET with an LS 48 auto sampler unit was applied to measure the taste characteristics of the liquid samples. The equipment consists of an array of seven cross selective "chemical modified field effect transistor" (CHEMFET) based on potentiometric chemical sensors. In the presence of dissolved compounds, a potentiometric difference is measured between each of the seven sensors and the Ag/AgCl reference electrode. The samples were placed in glass holders of 25 ml into which the measuring unit, namely the chemical sensors, the reference electrode and a stirrer were positioned. For each sample three parallel measurements were performed in nine repetitions (n = 8 × 3 × 9). The first element of the sample series served as sensor conditioning. The measurement and the sensor cleaning times were 120 and 20 s, respectively. Millipore grade water was used for sensor cleaning.

Data analysis

The multisensor arrays of EN and ET (25 sensors totally, corresponding to the 25 variables considered) are interfaced with computers which collect the sensor signals via RS-232 ports. The raw EN sensor values were saved in the form of relative resistance changes ($\Delta R \times R_0^{-1}$). The basic ET parameters were formed by averaging the intensity values when the sensors were in equilibrium. The classification of pet food samples was done by MGLH stepwise procedure and canonical discriminant analysis (DA) using the SPSS 12.0 software. The results were given in the percentage of the correctly classified samples. Results were verified by cross-validation (CV) procedure and percentage of correctly classified samples were presented (CV%).

Results and discussion

As a first step, the classification of dog and cat food samples was performed separately, based on the above mentioned $\Delta R \times R_0^{-1}$ and intensity values that were applied as input variables during DA. The discrimination of samples based on ET measurement were 81.7 and 58.3% (CV% 61.7 and 48.3) in case of cat and dog food, respectively. Using EN method, the concerning results were 85 and 95 % (CV% 75 and 95) for cat and dog food. Further on, both ET and EN data were dragged into a unique model generating discrimination values of 85 and 98.3% (CV% 83.3 and 93.3), respectively.

As a second approximation, the DA was performed simultaneously on the whole database including the 2 species (i.e. dog and cat) and the number of feeds (i.e. n=8). The achieved classification results were 72.5, 87.5 and 95.8% in case of ET, EN and the joint application of the two methods (CV% 55, 80 and 93.3). The results are similar to the previous evaluation, indicating the efficiency of the common application of these techniques. Finally, a stepwise procedure was performed to decrease the entered number of variables of the classification model. According to the applied method 14 variables of the total 25 were selected as an input for the canonical discriminant analysis. Figure 1 represents the samples in a two-dimensional space of the first two functions describing the total variance of 52.4 and 23.7%, respectively. According to the results achieved in this second approximation, 98.3% of the original grouped cases were correctly classified. All the misclassified samples belonged to the group 6.

In the followings two groups were formed according to the compositional characteristics of the feeds. The pure "Animal Origin – AO" group included sample 3, 4, 6 and 8 whereas the "Animal and Plant Origin – APO" group included sample 1, 2, 5 and 7. The achieved classification results were 64.2, 92.5 and 90.8 in case of ET, EN and the common application (CV% 54.2, 92.5 and 90). Similarly to the first two approximations, the weakest result was achieved by the single use of ET method. On the other hand, both EN and the joint application seem to be effective in discriminating feed samples of different composition.

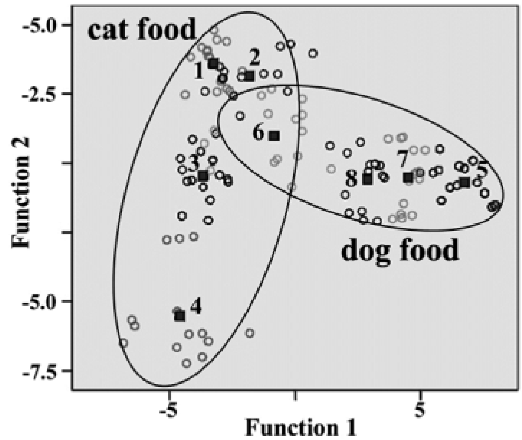

Figure 1. Discriminant factor analysis map of the cat and dog food samples (where: 1, 2, 3, 4 refer to cat food; 5, 6, 7, 8 refer to dog food)

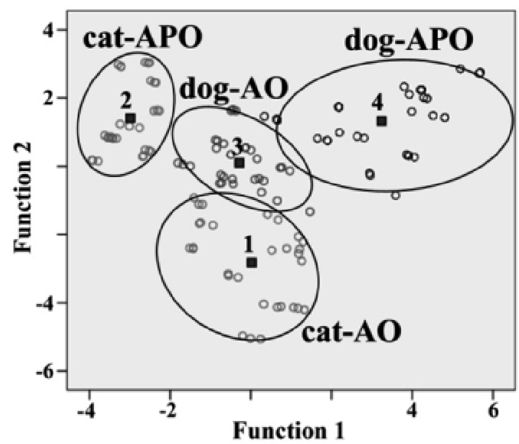

Figure 2. Discriminant factor analysis map of pet food samples of different composition (where: 1: cat-Animal Origin, 2: cat-Animal Plant Origin, 3: dog- Animal Origin, 4: dog-Animal Plant Origin)

Further on, the previous two groups were divided into four sub-groups by the concerning species (cat-AO, cat-APO, dog-AO, dog-APO). The discrimination results of the four subgroups of samples based on ET, EN and the joint measurement were 70.8, 90 and 97.5 (CV% 61.7, 85 and 89.2). Thereafter, a stepwise procedure was performed decreasing the total 25 sensory parameters (ET and EN) to 8.

Figure 2 represents the samples in a two-dimensional space of the first two functions, describing the total variance of 52.8 and 31.8%, respectively. Finally three canonical distribution functions were developed resulting in the best discrimination level of 97.5 (CV% 95.8).

The classification results of dog and cat foods show large variation. The very low (58.3%) correctly predicted group membership of dog foods by ET was presumably caused by the similar taste characteristics of the samples. The 95% classification result of the dog foods by single EN measurement is remarkable. It seems that the manufacturers pay particular attention to the olfactory features of the dog food products. Generally, the use of EN method showed better discrimination results compared with those provided by the ET techniques. A higher accuracy in group membership prediction was achieved when the EN and ET variables were used together to classify the feed types.

According to the DA performed on the whole dataset, a cross validation result of 95.8% was attained proven the efficiency of the applied stepwise method collecting the most effective variables for the model. Some samples from the group 6 (dog, AO) fell into the intersection of the two sets (cat and dog foods). This phenomenon could be explained by the fact that this type of dog food is a mixture of five different types of meat.

Taking the compositional characteristic into consideration, firstly two groups (AO or APO), secondly four groups (composition × species) were formed. In both evaluations the weakest discrimination results were achieved by means of the single application of the ET method. However, although the joint application of ET and EN produced the best discrimination model (CV% 95.8), one misclassification occurred within the cat food group and three occurred within the dog samples. The lowest predicted group membership (90%) was found in the dog food group produced from meat mix (sample 6) and poultry (sample 8).

Conclusions

According to our results and the literature reviewed, interesting possibilities of joint application of EN and ET techniques are connected to the evaluation of flavor types, to the prediction of flavor shelf life or to ensure the correct level of flavor added to different pet foods. This methodology could be applicable in evaluating palatability of complete feeds when ingredients or additives with low acceptability are incorporated.

The complexity of pet food aromas make them difficult to be characterized with conventional flavor analysis techniques. On the other hand, sensory analysis by animal preference test is a costly and difficult process since it requires special circumstances. A comparison between the results obtained from the ET and EN techniques and those from the in vivo preference test on a significant number of individuals should be promoted. However, in the light of the achieved results, the joint application of EN and ET technology seems to be a promising tool to classify different commercial canned dog and cat food products. The described procedure can be applied in the manufacturing process of pet foods, assisting the producers to obtain a better market position by using sophisticated electronic sensory methods. Furthermore, these technologies can be used for fast screening prior to conventional animal preference tests, saving time and money by speeding up the product development.

References

Bradshaw J. W .S., Healey L. M., Thorne C. J. (2000). Differences in food preferences between individuals and populations of domestic cats Felis silvestris catus. Appl Anim Behav Sci 68 (3): 257-268

Bradshaw J. W. S. (2006). The Evolutionary Basis for the Fooding Behavior of Domestic Dogs (*Canis familiaris*) and Cats (*Felis catus*). J Nutr 136: 1927S-1931S

Houpt K. A., Smith S.L. (1981). Taste preferences and their relation to obesity in dogs and cats. Can. Vet. J., 22 (4): 77-81

Lin S., Hsieh F., Huff H.E. (1998). Effects of lipids and processing conditions on lipid oxidation of extruded dry pet food during storage. Anim Food Sci Tech 71 (3-4): 283-294

Oladipupo B., Stough J., Guthrie N. (2011). Application of Combined Electronic Nose and Tongue Technology in Petfood Flavor Development and Quality Control. AIP Conf Proc 1362 pp 75-76

Peris M., Escuder-Gilabert L. (2009). A 21st century technique for food control: Electronic noses. Anal Chim Acta 638: 1-15

Pickering G. J. (2009). Optimizing the sensory characteristics and acceptance of canned cat food: use of a human taste panel. J Anim Phys Nutr 93 (1): 52-60

Winquist F., Lundstrom I., Wide P. (1999). The combination of an electronic tongue and an electronic nose. Sensor. Actuat B-chem. 58 (1-3): 512-517

acs78_37