Acta Scientific COMPUTER SCIENCES

Volume 4 Issue 2 February 2022

Research Article

# Applications of Nutritional Freshness Inspection Analysis by Electronic Nose (Machine Olfaction Technology)

**Dewanand Atmaram Meshram[1] and Dipti D. Patil[2]***

*[1]Department of Information Technology, RMD Sinhgad School of Engineering Warje/SPPU, Pune, India*

*[2]Department of Information Technology, MKSSS's Cummins College of Engineering for Women, SPPU, Pune, India*

***Corresponding Author:** Dipti D. Patil, Department of Information Technology, MKSSS's Cummins College of Engineering for Women, SPPU, Pune, India.

**Received:** October20, 2021

**Published:** January 31, 2022



## Abstract

This literature aims to investigate the applications of the freshness of food products. Food product contains microorganism that can degrade the quality of the product. Good quality of food product has higher nutritional (protein) level will be beneficial to psychosocial human health status in current and future generations. Fresh foods with good smell and taste and high nutritional value are most important. Such new food products play an essential role in diet selection and metabolism. Literature suggests different methods distinguish well know samples with additional storage time and temperatures. Statistical analysis techniques describe envisaging quality control, process monitoring, freshness evaluation with shelf-life investigation, and authenticity assessment.

**Keywords:** Chemosensory; Electronic Nose (E-nose); Nutrition; Odors; Protein

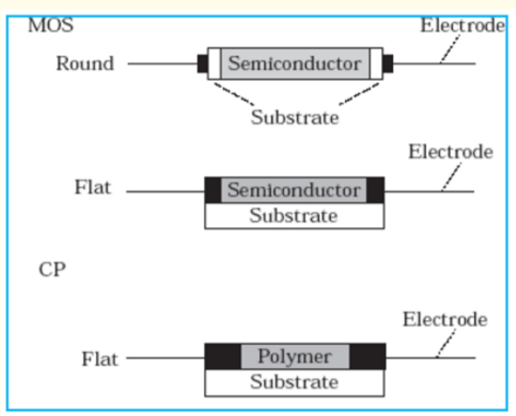
## Introduction

Easy and fast life may affect the human lifestyle. The living community can adjust their life in a critical situation. In the world, 85% of the pupil may lead the human disease when they eat contaminated food. Contamination food sources may vary from place to place as per lifestyle community. The harmful bacteria, toxins, and viruses are responsible for causing human diseases like gastrointestinal infection. The origins of contaminated food could be animals, the environment, or the food processing unit [1]. Meat contamination is the primary source during meat processing at the animal slaughterhouse. After slaughtering, several types of equipment are to be utilized during the food process, which might all factors potentially contribute to maximum acceptable bacterial level, odor, or other appearances for food consumptions [2-3]. Common characteristics of food contain pleasant aroma and good nutritional status. The spoilage food has an excellent bacterial level, unacceptable odor, or appearance for food consumption. High water content and nutrition are considered the most perishable foods [3].

Perishable foods with a good test and high nutritional value are essential in humans' daily lives. The meat's high healthy concentration is highly vulnerable to spoilage and contamination [4-9]. At the animal slaughterhouse, the freshness of meat degrades because of biochemical reactions and higher bacteria and viruses induced during the storage. Bacteria and enzymes decompose carbohydrates, protein, and fat into acetaldehyde, hydrogen sulfide, and ammonia. Therefore, meat/food with different freshness status will generate other gases [9].

Traditionally human sensory system is used to detect and evaluate the freshness of food/meat. Due to the traditional design, the quality of food directly and the reliability of food freshness with disadvantages such as error caused by assessor fatigue and the fact to measure expensive and time consumption reality. Because of it, essential sensory technology development, such as electronic noses and tongues, has good applicability in detection [9]. Electronic noses check for rapid and nondestructive food evaluation; beverages win discrimination, fruit quality detection, and meat evaluation [2,7,8,10-17,18-25]. Therefore, we believe that the E-nose can detect the different kinds of gases produced by food/meat with other freshness statuses [3].

Machine Olfaction Technology is nothing but digital scent technology which is the part of engineering and science discipline which deals with digital olfactory representation. Scent, odor, or aroma is continuously feeding in the air stream and machine has to detect the chemical compound structure in the form of digital smell. Therefore, the machine olfaction technology is to sense, transmit and receive scent enabled digital device called as electronic nose. To understanding of an electronic nose is to describe broadly and partly overlapping specificity and selectivity of a volatile organic compound with an array of chemical gas sensors. It works similarly to several aspects of the human nose. An electronic nose is a chemosensory device capable of chemical compound quantity into an electrical signal and responds to the intensity of specific substances such as atoms, molecules, or ions in gases or liquids states. The inquisitive capability demonstrates a chemosensory response for molecules in the gas phase [26]. Ideally, the sensors used in the electronic nose should fulfill high sensitivity in a chemical compound similar to the human nose (10-12 g/mL), low sensitivity, medium selectivity, and reliability; robust and durable in a short and recovery time; easy calibration and processable output data with small dimensions [26]. A sensor designed for commercial and industrial purposes requires high safety and low power consumption with minimum working temperature and valuable advantages with low manufacturing costs. Numerous types of sensors are available, but only four technologies exist in the application of commercialized electronic noses (Figure 1): metal oxide semiconductors (MOS); Metal oxide semiconductor field-effect transistors (MOSFET); conducting organic polymers (CP); piezoelectric crystals (bulk acoustic wave = BAW).



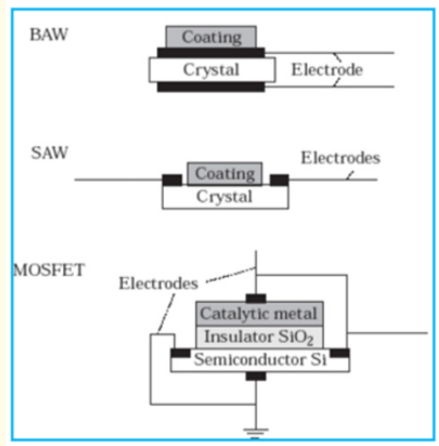




**Figure 1:** Schematic diagrams of 5 different kinds of sensors. Caption: MOS = Metal Oxide Semiconductor; CP = Conducting polymer; BAW = Bulk Acoustic Wave; SAW = Surface Acoustic Wave; MOSFET = Metal Oxide Semiconductor Field Effect Transistor [26].

Several sensors are collected to form an array that detects and recognizes the product based on their odor signature called an electronic nose. The compressive history is of the electronic nose is provided in figure 1 [26]. The device consists of electromechanical sensors and an appropriate pattern classification algorithm to recognize specific odors [27]. An electrochemical device can convert chemical quantity into an electrical signal. However, the sensor technology promises advancements and faster development in a real-time system to ensure the safety of meat quality in products. A review of the current applications and technological progress is shown in table 1.

Nowadays, E-nose is commonly used in various fields, including the food quality/quantity, environmental analysis, medical diagnosis, and narcotics industries [27]. In the food industry, several purposes such as quality control, process monitoring, food freshness evaluation, nutritional life investigation, and authenticity assessment task are performed by an electronic nose in a proven effective manner. A significant volume of work has been done to ensure meat quality yet applying an electronic nose to inspect slaughterer factories remains unknown. A detailed review of meat quality assessment using an electronic nose in different environments is shown in table 1. In the current literature, we advise a tool to inspect a product with an electronic nose to help them while examining slaughter shops.

### e-nose: Applications in product analysis

Reasonably merits of e-nose are determined by specific chemical compounds establishing the aroma profile over the traditional conspicuous method. The product analysis is fast, simple, low cost, and time-consuming for quality control applications. This review paper aims to present a variety of kinds of e-noses used to evaluate products (meat, beef, fish, fruits, and vegetables), future development, methods, and research results discussed for practical e-nose application.

### Product Spoiled monitoring

Monitoring of Product spoilage works by measuring chemical or biological bacterial aroma intensity. The aroma intensity method is traditionally indicated by spoilage indicator. Standard tests include total bacterial count (TBC), thiobarbituric acid reactive substances (TBARS), and total volatile elemental nitrogen (TVBN) measurements [28]. Also, colorimetric sensory evaluation can be helpful in the detection of spoiled samples. The product spoiled monitoring process is strongly connected with aroma changes probability investigation of employment (Table 1). A standard method involves choosing the storage type of packaging and temperature conditions. Different period samples were collected from the storage, typically household, industrial needs, and slaughterhouses for analysis. Metal oxide semiconductors or conducting polymers were used to analyze the product's freshness with particular attention to measuring a nutritional quantity. Few applications using colorimetric sensors to develop statistical data analysis involve multivariate statistics and artificial neuron networks. The successfully attempted samples to employ an E-nose product spoilage monitoring prove the quality of the product. Therefore E-nose is yet to be found in industrial practice. Hence, the methods are proposed to develop a handled device for low cost and good selectivity.

### Differentiation between kindly of products (Meat/fruit/etc.)

From the customer's point of view, the product is an essential issue because of the quality and the customers' health, dietary, and religious aspects [28]. To analyze complex data by a human is a time-consuming process. Therefore, the literature proposed to demonstrate the e-nose to identify total bacterial count (TBC) molecular biology or Spectroscopic measurements. A successful differentiation between product samples (meat, sheep, cattle, and poultry) was performed using e-nose based on odor [29]. Principal component analysis (PCA) could use statistical data analysis from different product samples to identify product freshness. Other types of pieces discriminate by the e-nose to detect product adulteration with proteins from another, cheaper species. Data was obtained with multivariate analysis (PCA, DA, PLS, MLR, and BPNN).

### Production monitoring

In literature, direct use of e-nose simulates the monitoring for the production process. The sensors with tin-oxide semiconductors applied for the tests of the product; few sensors to dope with metal catalysts. For result analysis, PCA with an artificial neural network. The array of sensors can be applied to demonstrate dynamic process monitoring during production. An investigation of process monitoring performed 12 metal-oxide-semiconductor sensors collection to check the freshness of product were subject to manufacture protocols and several even 2,4,6,8,10 days or odd 3,5,7,9,11,13 days. Product adulteration with ochratoxins is very chancy for humans and is considered a cancer-causing agent.

| Sensor Arrays (E-nose) | Type of Product (e.g., meat) | Storage condition | Storage days | Detection methods | Chemosensory classifier | References |
|---|---|---|---|---|---|---|
| Spoilage monitoring | | | | | | |
| 8 QCM coated with metallo-porphyrins | Beef (raw) | 0, 4, 8, 12 or 16 °C | 19 days | Microbiological analysis, sensory analysis | PCA, DFA, SVM | [30] |
| 10 MOS | Beef (raw) | 2 °C | 14 days | TVBN, microbiological analysis, sensory analysis | PCA, LDA, ANN: BPNN, GRNN, LOO, MD | [31] |
| 10 MOS | Beef (raw) | 4, 8 or 16 °C | 12 days | TBA, color evaluation, CO2 determination, microbiological analysis | PCA, CA | [32] |

| | | | | | | |
|---|---|---|---|---|---|---|
| 6 MOS | Beef (raw) | 20 °C | 6 days | --- | The output of each sensor gets expressed in function of time of storage | [33] |
| 6 tin oxide sensors based TGS<br>temperature sensor<br>humidity sensor | Beef, sheep (raw) | 4 °C | 15 days | Microbiological analysis TVC | PCA, PLS, SVM | [34] |
| Colorimetric array of 16 sensing materials | Poultry (boiled marinated turkey) | 0, 3, 10, 17, 24, 31 MAP (30% CO2, 70% N2) | 38 and 45 days; | Microbiological analysis, sensory analysis | HCA, PLS | [35] |
| Colorimetric sensor array | Poultry (raw chicken breast fillet) | 4 °C | 1 to 9 days | Total volatile basic nitrogen | OLDA and adaptive boosting (AdaBoost); LA, BPNN | [36] |
| 11 MOS | Pork (raw) | 4 °C | 11 days | TVBN | PCA, BPNN | [37] |
| Colorimetric gas-sensor array | Pork | 5 °C | 7 days | Biogenic amine, The total viable bacterial count | PCA, PLS | [38] |
| 8 MOS | Pork (raw) | 5, 10 or 15 °C | 7 days | TVBN, microbiological analysis,<br>sensory analysis | PCA | [39] |
| 18 MOS | Pork (raw) | 4 °C | 10 days | Microbiological analysis | PCA, PLS, LOO-CV, SVR | [40] |
| 38 MOS | Pork (raw) | 4 or 25 °C | 8 days | ---- | LDA, LOO | [18] |
| Differentiation between types of meat | | | | | | |
| SAW sensor | Pork, mutton, chicken, beef sausages | −20 °C | --- | GCMS-HS | PCA | [29] |
| 10 MOS | Mutton, pork | −18 °C | --- | ----- | CDA, BDA, PLS, MLR, NN | [21] |
| Process monitoring in the production | | | | | | |
| 16 semiconductor sensors | Pork, Iberian ham | --- | 5, 10, 13 months | sensory analysis | PCA, ANN | [41] |
| 12 MOS | pork sausages | --- | 5, 7, 10, 14 season days | HS-SPME/GC–MS, HPLC | DFA | [42] |

**Table 1:** Applications of nutritional freshness analysis (e-noses) [28].

Detection methodology were used to identify the nutritional freshness as per the type of food product shown in table 1. The methodology uses to differentiate between the types of meat, process monitoring in the production as well as spoiling of food product. Number of sensors array has to receive the scent of food product which is store odd/even days and different storage conditions. Based on the storage condition the chemosensory classifier differentiate as well as transform the validation of nutritional freshness of product.

## Frequency of olfactory disorders

The frequency of olfactory disorder has been higher and associated with cultural development (smell and test) [43,44]. The common observation that sensory properties influence food choice, evidence supporting an association between taste and smell function and nutritional status is limited [43,45-47]. However, the patients commonly report partial smell and taste for common foods such as meats, fresh fruits, coffee, eggs, and carbonated beverages is not necessarily improved health to their overall nutrient intake [48]. Changes in associated gastronomic practices, such as increased salt, sugar, and heavy use, might obscure hypertension, diabetes, and circulatory disease. Additionally, some entities with chemosensory syndromes increase food intake to compensate for reduced sensory inspiration and gain weight.

In contrast, other patients reduce food consumption due to lesser food appeal, resulting in weight loss [48]. The chemosensory function may have limited data support to maintain physical/mental health. A systematic literature review, olfactory and chemosensory functions may affect smell detection, sensitivity identification, and psychiatric disorder quality, respectively [43]. Due to specific smell and test functions have been proposed food intake strategy.

## Cancer

In a cancer patient, the nutrient product is to maintain adequate energy. The nature of cancer patients has been reported as dyspepsia, dysosmia, and heightened and diminished sensitivity to specific taste qualities or odors [4,6,49,50]. The chemosensory function depends on lower energy intake, BMI, quality of health, and protein intake [5,51-59]. To recover the patients, anti-cancer therapies like radiation therapy reduce the number of tongue taste exposure related to tongue taste impairment.

Patients are suffering from radioactivity therapy exhibit sensitivity in taste relative to pre-treatment levels. Radioactive treatment commonly alters the flavor up to 56 % -76%. As demonstrated, the cyclical effects of radioactive therapy on taste function decrease the taste identification abilities linking. The recent evidence suggests that taste alteration during radioactive treatment may be related to specific protein rather than specific taste.

After the six months post-treatment, changes convinced by radioactive treatment resulted in Olfactory sensitivity reported in patients. Modifications in chemosensory function in cancer patients experiencing radioactive therapy can influence food preferences and real-world social aspects of human life.

## Diabetes

In a diabetic patient, a chemosensory dysfunction has been reported in over 60% sweet taste sensitivity. The disturbances of chemosensors in diabetic patients are associated with comorbidities and complications. Taste and smell function have failed to detect differences in healthy controls and uncomplicated diabetic patients. However, taste and olfactory functions have found the severity of gustatory symptoms and degree of neuropathy. During the diabetic diseases, evidence suggests that reported differences in sweet taste function due to neuropathy rather than defects of glucose reception. Also found acetone in an exhale breath through the chemosensory sensors.

## Hypertension

Quantity of sodium intake may increase in a food product investigate the associate relationship between salt taste, salt intake, and blood pressure. While eating salty food, heartbeat and blood pressure may increase during hypertension. Although some doctors/researchers proposed decreasing the use of high salt taste may reduce the risk of hypertension. Most evidence does not support differences between normotensive and hypertensive patients using sodium chloride sensitivity. Examination of hypertension individually classified has failed to reveal variances of salt taste sensitivity and intensity perception capacity of the body. In such cases, drug treatment should be considered a salty taste.

## Protein and Amino Acids

Protein is essential in a food product when switching from a vegetarian diet to a non-vegetarian diet. In a developed country, higher food demand for high-quality protein occurs to severe nutritional deficiency. A new meat-based diet is associated with high protein and high fatty levels. As a protein diet, crucial amino acids are frequently not synthesized by the human body. Some of the essential amino acids are closely related to mood disorders. An essential role in brain functioning, the deficiency of protein and amino acids may lead to pathologies mood disorders. Amino acids directly provide in a meal to increase the amount of tryptophan that reaches the neurons, i.e., serotonin plays an imperative role in the brain area that is accountable for emotional directive and sleep. Such changes observed in brain function associate's consecutive human behavior due to increased serotonin production in the brain. Another critical factor, amino acid, includes tyrosine, a precursor of dopamine [60]. A critical study can contribute dopamine in a pleasure motivational experience that shows the ingestion of protein food products to increase the level of tyrosine in blood [60]. Increasing the amino acids in a nervous system seems greatly useful while determining the protein quality of different origins in a mixed diet.

## Conclusion

The current literature suggests that an electronic nose can detect contamination of dietary products (meat/foods/etc.) with statistical analysis. The application of product contamination uses different aroma/odors by PCA and DFA methods (classification and identification). Several storage samples were identified by different stages considering odd and even days (i.e., 1 to 45 days). Determination of the nutritional (protein) state, diet manipulation is a long-term process that may impact psychosocial human health status in current and future generations. The particular ingredient cannot take place with different nutritional needs. Such elements may play an important role (smell and test). The literature illustrates that various applications can assist the dietary food market. Hence the electronic nose having different application to monitor quality control, process monitoring as well as the nutritional freshness of eatble food products to secure from olfactory disorder.

## Bibliography


1. Abdallah SA., *et al.* "The detection of foodborne bacteria on beef: The application of the electronic nose". *Springer Plus* 2.1 (2013): 687.
2. Aleixandre M., *et al.* "A wireless and portable electronic nose to differentiate musts of different ripeness degrees and grape varieties". *Sensors* 15.4 (2015): 8429-8443.
3. Benabdellah N., *et al.* "Identification of two types of rotten meat using an electronic nose for food quality control". I*nternational Journal on Smart Sensing and Intelligent Systems* 10.3 (2017): 673-695.
4. Boer CC., *et al.* "Taste disorders and oral evaluation in patients undergoing allogeneic hematopoietic SCT". *Bone Marrow Transplantation* 45.4 (2010): 705-711.
5. Boltong A., *et al.* "A prospective cohort study of adjuvant breast cancer chemotherapy effects on taste function, food liking, appetite, and associated nutritional outcomes". *PLoS ONE* 9.7 (2014): e103512.
6. Bovio G., *et al.* "Upper gastrointestinal symptoms in patients with advanced cancer: Relationship to nutritional and performance status". *Supportive Care in Cancer* 17.10 (2009): 1317-1324.
7. Brezmes J., *et al.* "Correlation between electronic nose signals and fruit quality indicators on shelf-life measurements with pink lady apples". *Sensors and Actuators B: Chemical* 80.1 (2001): 41-50.
8. Brezmes J., *et al.* "Fruit ripeness monitoring using an Electronic Nose". *Sensors and Actuators B: Chemical* 69.3 (2000): 223-229.
9. Chen J., *et al.* "Freshness evaluation of three kinds of meats based on the electronic nose". *Sensors* 19.3 (2019): 605.
10. Chen LY., *et al.* "Develop a dual mos electronic nose/camera system to improve fruit ripeness classification". *Sensors* 18.10 (2018): 3256.
11. Di Natale C., *et al.* "The evaluation of the quality of postharvest oranges and apples using an electronic nose". *Sensors and Actuators B: Chemical* 78.1-3 (2001): 26-31.
12. García M., *et al.* "Electronic nose for wine discrimination". *Sensors and Actuators B: Chemical* 113.2 (2006): 911-916.
13. Gobbi E., *et al.* "Electronic nose and Alicyclobacillus spp. spoilage of fruit juices: An emerging diagnostic tool". *Food Control* 21.10 (2010): 1374-1382.
14. Gruber J., *et al.* "A conductive polymer-based electronic nose for early detection of Penicillium digitatum in postharvest oranges". *Materials Science and Engineering: C* 33.5 (2013): 2766-2769.
15. Haugen JE and Kvaal K. "Electronic nose and artificial neural network". *Meat Science* 49 (1998): S273-S286.

16. López de Lerma., *et al.* "Feasibility of an electronic nose to differentiate commercial Spanish wines elaborated from the same grape variety". *Food Research International* 51.2 (2013): 790-796.

17. Lozano J., *et al.* "Electronic nose for wine aging detection". *Sensors and Actuators B: Chemical* 133.1 (2008): 180-186.

18. Musatov VYu., *et al.* "Assessment of meat freshness with metal oxide sensor microarray electronic nose: A practical approach". *Sensors and Actuators B: Chemical* 144.1 (2010a): 99-103.

19. Prieto N., *et al.* "Application of multi-way analysis to UV-visible spectroscopy, gas chromatography, and electronic nose data for wine aging evaluation". *Analytica Chimica Acta* 719 (2012): 43-51.

20. Song S., *et al.* "Effect of enzymatic hydrolysis with subsequent mild thermal oxidation of tallow on precursor formation and sensory profiles of beef flavors assessed by partial least squares regression". *Meat Science* 96.3 (2014): 1191-1200.

21. Tian X., *et al.* "Analysis of pork adulteration in minced mutton using the electronic nose of metal oxide *Sensors*". *Journal of Food Engineering* 119.4 (2013a): 744-749.

22. Wei Z., *et al.* "Identification of the rice wines with different marked ages by electronic nose coupled with smartphone and cloud storage platform". *Sensors* 17.11 (2017): 2500.

23. Wijaya DR., *et al.* "Development of mobile electronic nose for beef quality monitoring". *Procedia Computer Science* 124 (2017): 728-735.

24. Wojtasik-Kalinowska I., *et al.* "Volatile compounds and fatty acids profile in Longissimus dorsi muscle from pigs fed with feed containing bioactive components". *LWT - Food Science and Technology* 67 (2016): 112-117.

25. Xu S., *et al.* "Detecting and monitoring the flavor of tomato (Solanum Lycopersicum) under the impact of postharvest handlings by physicochemical parameters and electronic nose". *Sensors* 18.6 (2018): 1847.

26. Ghasemi-Varnamkhasti M., *et al.* "Meat quality assessment by the electronic nose (Machine olfaction technology)". *Sensors* 9.8 (2009): 6058-6083.

27. Hasan N., *et al.* "Meat and fish freshness inspection system based on odor sensing". *Sensors* 12.11 (2012): 15542-15557.

28. Górska-Horczyczak E., *et al.* "Applications of electronic noses in meat analysis". *Food Science and Technology* 36.3 (2016): 389-395.

29. Nurjuliana M., *et al.* "Rapid identification of pork for halal authentication using the electronic nose and gas chromatography-mass spectrometer with headspace analyzer". *Meat Science* 88.4 (2011a): 638-644.

30. Dissing BS., *et al.* "Using multispectral imaging for spoilage detection of pork meat". *Food and Bioprocess Technology* 6.9 (2013): 2268-2279.

31. Hong X., *et al.* "Discrimination and prediction of multiple beef freshness indexes based on the electronic nose". *Sensors and Actuators B: Chemical* 161.1 (2012): 381-389.

32. Limbo S., *et al.* "Evaluation and predictive modeling of shelf life of minced beef stored in high-oxygen modified atmosphere packaging at different temperatures". *Meat Science* 84.1 (2010): 129-136.

33. Zhang Z., *et al.* "Electronic nose with an air sensor matrix for detecting beef freshness". *Journal of Bionic Engineering* 5.1 (2008a): 67-73.

34. El Barbri N., *et al.* "Electronic nose based on metal oxide semiconductor *Sensors* as an alternative technique for the spoilage classification of red meat". *Sensors* 8.1 (2008): 142-156.

35. Salinas Y., *et al.* "A chromogenic sensor array for boiled marinated turkey freshness monitoring". *Sensors and Actuators B: Chemical* 190 (2014): 326-333.

36. Chen Q., *et al.* "Evaluation of chicken freshness using a low-cost colorimetric sensor array with AdaBoost-OLDA classification algorithm". *LWT - Food Science and Technology* 57.2 (2014): 502-507.

37. Huang L., *et al.* "Nondestructive measurement of total volatile elemental nitrogen (Tvb-n) in pork meat by integrating near-infrared spectroscopy, computer vision, and electronic nose techniques". *Food Chemistry* 145 (2014): 228-236.

38. Huang X., *et al.* "Determination of pork spoilage by colorimetric gas sensor array based on natural pigments". *Food Chemistry* 145 (2014): 549-554.

39. Tian XY., *et al.* "Rapid classification of hairtail fish and pork freshness using an electronic nose based on the PCA method". *Sensors* 12.1 (2011): 260-277.

40. Wang D., *et al.* "Prediction of total viable counts on chilled pork using an electronic nose combined with a support vector machine". *Meat Science* 90.2 (2012): 373-377.

41. Santos JP., *et al.* "Electronic nose for the identification of pig feeding and ripening time in Iberian hams". *Meat Science* 66.3 (2004): 727-732.

42. Lippolis V., *et al.* "Rapid prediction of ochratoxin A-producing strains of Penicillium on dry-cured meat by MOS-based electronic nose". *International Journal of Food Microbiology* 218 (2016): 71-77.

43. Kershaw JC and Mattes RD. "Nutrition and taste and smell dysfunction". *World Journal of Otorhinolaryngology-Head and Neck Surgery* 4.1 (2018): 3-10.

44. Liu G., *et al.* "Prevalence and risk factors of taste and smell impairment in a nationwide representative sample of the US population: A cross-sectional study". *BMJ Open* 6.11 (2016): e013246.

45. Deems DA., *et al.* "Smell and taste disorders, a study of 750 patients from the University of Pennsylvania, smell and taste center". *Archives of Otolaryngology-Head and Neck Surgery* 117.5 (1991): 519-528.

46. Ferris AM., *et al.* "Anosmia and nutritional status". *Nutrition Research* 5.2 (1985): 149-156.

47. Fischer ME., *et al.* "The intensity of salt taste and prevalence of hypertension are not related in the beaver dam offspring study". *Chemosensory Perception* 5.2 (2012): 139-145.

48. Mattes RD and Cowart BJ. "Dietary assessment of patients with chemosensory disorders". *Journal of the American Dietetic Association* 94.1 (1994): 50-56.

49. Dysgeusia Section, Oral Care Study Group, Multinational Association of Supportive Care in Cancer (MASCC)/International Society of Oral Oncology (ISOO), Hovan AJ., *et al.* "A systematic review of dysgeusia induced by cancer therapies". *Supportive Care in Cancer* 18.8 (2010): 1081-1087.

50. Hutton JL., *et al.* "Chemosensory dysfunction is a primary factor in the evolution of declining nutritional status and quality of life in patients with advanced cancer". *Journal of Pain and Symptom Management* 33.2 (2007): 156-165.

51. De Vries YC., *et al.* "Altered food preferences and chemosensory perception during chemotherapy in breast cancer patients: A longitudinal comparison with healthy controls". *Food Quality and Preference* 63 (2018): 135-143.

52. Epstein JB., *et al.* "Quality of life and oral function in patients treated with radiation therapy for head and neck cancer". *Head and Neck* 23.5 (2001): 389-398.

53. Ponticelli E., *et al.* "Dysgeusia and health-related quality of life of cancer patients receiving chemotherapy: A cross-sectional study". *European Journal of Cancer Care* 26.2 (2017): e12633.

54. Sandow PL., *et al.* "Taste loss and recovery following radiation therapy". *Journal of Dental Research* 85.7 (2006): 608-611.

55. Trant AS., *et al.* "Is taste related to anorexia in cancer patients?" *The American Journal of Clinical Nutrition* 36.1 (1982): 45-58.

56. Walliczek-Dworschak U., *et al.* "Testicular cancer patients undergoing cisplatin-based chemotherapy exhibit temporary olfactory threshold scores changes". *European Archives of Oto-Rhino-Laryngology* 274.7 (2017): 2813-2818.

57. Yamashita H., *et al.* "Relation between acute and late irradiation impairment of four basic tastes and irradiated tongue volume in patients with head-and-neck cancer". *International Journal of Radiation Oncology*Biology*Physics* 66.5 (2006): 1422-1429.

58. Yamashita H., *et al.* "Taste dysfunction in patients receiving radiotherapy". *Head and Neck* 28.6 (2006): 508-516.

59. Zabernigg A., *et al.* "Taste alterations in cancer patients receiving chemotherapy: A neglected side effect?" *The Oncologist* 15.8 (2010): 913-920.

60. Modlinska K and Pisula W. "Selected psychological aspects of meat consumption-A short review". *Nutrients* 10.9 (2018): 1301.