

## Research Article

### Study on Odor Detection of Shellfish Based on PEN3 Type Electronic Nose Sensor

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**Abstract:** In order to detect the odor of shellfish effectively, the application of PEN3 type electronic nose on it is studied in depth. Firstly, the basic characteristic of PEN3 sensor is discussed. Secondly, the river crabs are used as detecting samples to carry out corresponding experiment, the materials and method are given and the volatile constituents of river crab sample, the output signal of river crabs detected by electronic nose and sensory score with time are obtained, results show that the electronic nose is an effective means for detecting the odor of shellfish.

**Keywords:** Detection, electronic nose, odor, PEN3 sensor, volatile constituent

#### INTRODUCTION

The shellfish often originates along the coast and the shellfish distributes widely and it has a great variety. People often use the outer shape and living habit of shellfish as the basis of classification, however when these types are used to classify the shellfish the individual differences and habitat deterioration and other factors can generate the interference. In addition, the same kind of shellfish has difference because the origin and breeding way are different, especially in the aspect of flavor and taste. For example, the *sinonovacula constricta* in strip of Ninghai is most fresh in Zhejiang area and the price is most expensive, therefore the fact or fiction of *sinonovacula constricta* in strip is often not identified, therefore it is necessary construct a quick and correct identification method for detecting the odor of shellfish. The electronic nose sensor opens up a new stage of food detection and the quick odor detection of shellfish can be possible (Ding *et al.*, 2014).

The electronic nose sensor is a kind of intelligent sensory analysis instrument that can represent the whole feature information of odor materials and it has some advantages, such as short detecting time, strong objectivity and high repeatability. The electronic nose sensor mainly concludes gas sensor array signal processing sub system and mode identification sub system, the gas molecule is absorbed by gas sensor array, the signal produced and generated is sent to the signal processing sub system to be processed and finally the results are judged by mode identification sub system (Crego-Calama *et al.*, 2012). The electronic nose sensor carry out data procession according to the physical changes of sample and sensor and the basic detection system is made up of many same type sensors, which is named as "sensor array". In recent

years, there are many brands of electronic noses, PEN3 electronic nose is one of them. PEN3 electronic nose is developed by German AIRSENSEPEN3 company. PEN3 electronic nose applies building in sample technology, the background gas deduction can be carried out in the outdoor operation and the judgment function, principal component analysis, linear discriminant analysis, euclidean distance and correlation analysis is used to carry out analysis.

**Basic characteristic of PEN3 sensor:** PEN3 electronic nose is a kind of detection system that can detect the gas and vapor with small size, shortcut and high efficiency, it can identify quickly single chemical compound and mixed gas through training. The application range of electronic nose can expand through different identifying computing system. The application range and processing control of German PEN3 electronic nose are listed as follows: dosage of additives in food production, control of industrial clearing procession, control of fermentation process, artificial gas amount of natural gas, manufacturing controls of packing materials in food industry, control of oil squeezed or grilled procession. Quality control of German PEN3 electronic nose concludes stench of grease, fresh degree of food, outer gas of package, polymer solvent residues, drug gas, resin characteristics, aroma of drinks. The environmental safety control of German PEN3 concludes odor of purification process, Smell of fertilizer, filtration process management, organic solvent in air of studio, leakage control, combustion control and bacterial identification (Wang *et al.*, 2014).

So far the PEN3 electronic nose has been applied in many fields successfully, the electronic nose is used to identify the order of different freshness of *Penaeus vannamei* and the relationship between output voltage

of each sensor and acquisition time was discussed and the feature value of each sensor was obtained, results showed that the model accuracy was 96% (Dong *et al.*, 2015). The electronic nose was also used to identify the flavor finger-printing changing of Chinese fermented sausage in the procession of fermentation and the relevance between chemometry quality indicator and flavor finger-printing was analyzed by means of principal component analysis, linear discriminant analysis and model analysis which based on partial least squares method. The sensor array of PEN3 electronic nose showed that the most outstanding capability distinguishing the flavor changing during the sausage fermentation under different conditions and finally the new PLS prediction model for sensitive and precise detection of chemometry indexes of Chinese fermented sausage by flavor finger-printing identification. The electronic nose was used to detect the volatile flavor components from four different parts of both male and female mangrove crabs and results showed that the flavor odor from these four parts of male and female mangrove crabs could be distinguished well. During the procession of storage, transportation and processing of shellfish, they will be affected by outer environment, microorganism and enzyme, then the freshness of shellfish will reduce and the rancidness of them will exist. So far the application of electronic nose on the detection of shellfish has not been concerned and the electronic nose is an effective method for detecting the freshness of shellfish (Miyazawa *et al.*, 2011).

## MATERIALS AND METHODS

**Materials:** Eight river crabs are used in the experiment and there are four river male and female macrabs respectively, all river crabs are bought from panjin city, the river crabs are put in the bubble chamber and brought to laboratory. The specifications of river crabs are shown in Table 1.

**Methods:** The testing samples are processed by the following means, the dirt on the surface should be cleared and the shell is open, then the crab meat, clamp meat, foot meat and sexual gland are taken out, which is stirred to be processed (Kabir and Kim, 2011).

**Electronic nose detection and corresponding detecting system:** The volume optimization is carried out, 20 fresh meat sampled to be detected are chosen, which are divided into five groups according to the injection needle sample volume and every group concludes three parallels, the corresponding number is listed as follows: 250, 500, 1250, 1500, 1750  $\mu\text{L}$ . After every group reaches the equilibrium at 55°C, the clear dry air is used as carrier gas, the velocity of flow is 185 mL/min, the sampling is carried out based on number of every group, the sampling time is taken as 1s and the injection temperature is taken as 65°C and the data collection time is taken as 145s and the lag time is

Table 1: Specifications of river crabs

	Male river crab	Female river crab
Weight	330.43±16.44	292.18±14.32
Carapace length	12.28±0.27	10.62±0.69
Carapace width	9.76±0.15	7.08±0.145

taken as 14 min, the optimal sampling volume is taken as 1750  $\mu\text{L}$ .

The sample size optimization is also carried out, before application of sample three fresh meat samplings are prepared respectively with the weight of (0.80±0.02) g, (1.60±0.02) g, (2.40±0.02) g, (3.20±0.02) g, which give the number of 0.8, 1.6, 2.4 and 3.2 g, respectively. And the optimal sample size is taken as 3.2 g (Gao *et al.*, 2014).

In order to improve the effectiveness of detection, the electronic nose detection system are developed independently, the system is made up of sensor array, data collection system and computer data processing system. The sensor array locates in the detection chamber and the fan is fixed in the detection chamber. The sensor array is made up of six metal oxide semiconductor gas sensors and the number of six sensors is 1, 2, 3, 4, 5, 6 respectively. Number 1 sensor is TGS2600 type air sensor, which is sensitive to the gaseous pollution, number 2 sensor is TGS4161 type sensor, number 3 sensor is TGS2620 type alcohol sensor, which can be used to detect the alcohol and organic solvent, number 4 sensor is TGS825 type vulcanized substance sensor, number 5 is TGS813 type inflammable gas sensor, number 6 sensor is TGS826 ammonia and amines sensor. During the procession of detection, the current source is opened and the electronic nose system is preheated for about 25 min. The detecting sample is put in the sampling bottle and the fan is opened, the volatile constituent distributed by samples enters the detection cabinet, which contacts with sensor array and the corresponding response is produced, the response signal is collected by the data collection system, which is transferred into computer to be processed. The electronic nose system should be cleaned after detection, when the outputting signal curve is smooth the next sample detection is carried out (Liu *et al.*, 2015).

**Data analysis:** The SPSS software is applied in the data analysis, the difference obvious inspection and correlation analysis. The outputting signal data of electronic nose is taken average value±standard deviation of three times repetition, when the difference inspection is carried out for every sensor of electronic nose, when the obvious level  $P \leq 0.05$ , then it is considered as difference obvious. The relational analysis is carried out for outputting signal and TVBN results, when the obvious level  $P \leq 0.05$ , then obvious difference exists, when  $P \leq 0.01$ , it is easy to have obvious difference.

**RESULTS AND DISCUSSION**

**Sensory evaluation:** The sensory evaluation has strong intuition, according to the sensory evaluation index the sensory evaluation is carried out for river crab and linear regression analysis is carried out based on least square method for data obtained from detection, the trending curve of sensory evaluation results is obtained and the standard deviation of residuals is taken as 0.72 and the corresponding result is shown in Fig. 1.

From Fig. 1, with prolongs of storage time, the sensory score will reduce accordingly. The body surface of fresh rive crab has sheen and the musculature is inseparable and has good elastic and has the natural smell, the sensory score is 17, the river crabs losses sheen and the odor of the river crab lightens after the river crabs stores 10 h, the sensory score is 15, the sensory score decreases constantly from 20 to 80 h, the river crabs can not be eaten because they have gone bad.

**Testing results of electronic nose:** When the electronic nose is used to detect the odor of river crabs, data collection time of every sample is taken as 10 min

and a data is collected every 10s, there are 60 data. Because the output signal of electronic nose changes with prolong of collection time. The signal of electronic nose have stabilized when the data collection is carried out for 1 min, therefore the average value of stable value after the sensor collection time is 1.5 min during the procession of data processing and characteristic value choosing. The original value every time detection of every sensor is different, which can be caused by the environment. In order to eliminate the effect of environment, after all collection data detract the average value±standard deviation of three times detections can be used as the final results.

The odor changing situation when the freshness of river crabs detected by electronic nose is obtained, this is shown in Table 2.

From Table 2, for the river crabs sample every sensor shows different changing rules. The output signal of number 1 sensor has decreasing trends with prolong of storage time. The output signal of number 2 sensor has no obvious changes and there is no rules obtained. The output of number 3 sensor decreases

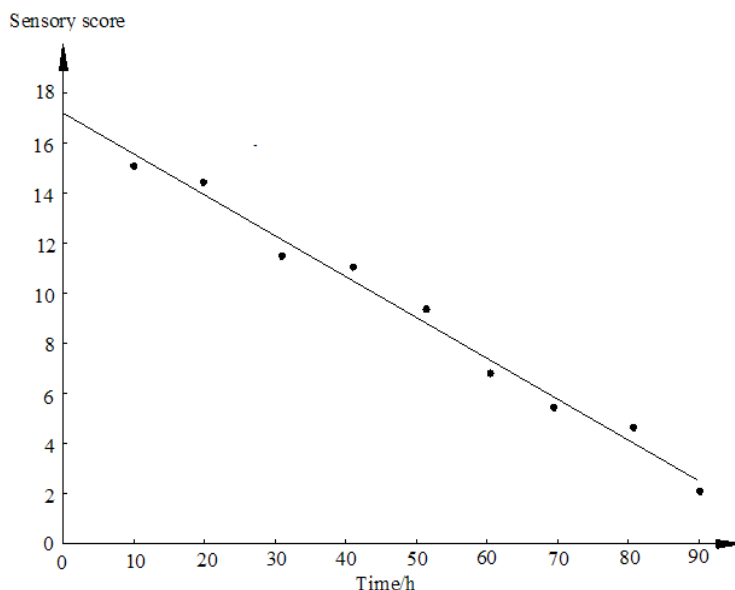


Fig. 1: Changing curve of sensory score with time

Table 2: Detection results of output signal of river crabs detected by electronic nose

Storage time/h	Number of sensor					
	1	2	3	4	5	6
0	5.4e-6±3.2e-7 ab	-4.2e-5±2.9e-6 -5a	-2.5±0.01a	-4.8e-6±2.7e -6a	-2.5±0.01a	-4.8±0.03a
10	1.7e-5±5.9e-7a	7.9e-6±1.8e-6a	-0.6±0.03a	-2.5e-5±3.2e -7a	-2.6±0.02a	-2.5±0.23a
20	1.2e-5±5.9e-7a	7.9e-6±1.8e-6a	-0.6±0.03a	-2.5e-5±3.2e -7a	-2.6±0.02a	-2.5±0.23a
30	-6.7e-7±3.6e-7ab	-2.5e-5±7.5e-6a	-0.4±0.02a	-2.1e-5±2.6e -7a	-3.1±0.06a	-3.2±0.85a
40	-2.4e-5±3.2e-7ab	8.1e-6±2.6e-5a	-0.47±0.02a	1.3e-5±5.8e -6a	-0.82±0.04a	-3.7±0.93a
50	4.6e-6±4.6e-7a	3.1e-6±1.7e-7a	-0.43±0.01a	3.7e-6±1.8e -7a	-5.3±0.21a	4.4±0.48a
60	-5.7e-6±2.46e-6a	-4.2e-6±1.48e-7a	-0.54±0.02a	5.29e-6±5.8e -7a	-0.92±0.21a	-4.64±0.51a
70	6.7e-6±3.8e-6a	6.4e-6±4.1e-6a	-0.53±0.03a	-4.7e-6±3.7e -6a	-4.7±0.04a	-2.5±0.48a
80	-5.5e-6±2.7e-6a	-3.8e-6±4.1e-6a	-0.61±0.02a	-6.1e-5±4.7e -6a	-5.8±0.08a	-6.7±0.41a
90	4.7e-6±4.8e-6a	9.3e-7±3.5e-6a	-0.46±0.01a	-3.5e-5±1.9e -6a	-8.1±0.04a	-5.3±0.28a

Table 3: Detection results of volatile constituents of river crab sample

Compound name	Compound peak area/10 <sup>5</sup>							
	Body meat		Clamp meat		Foot meat		Sexual gland	
	Female	Male	Female	Male	Female	Male	Female	Male
Toluene	2.39	0.00	1.73	0.00	1.48	0.84	0.00	0.00
Naphthaene	13.58	25.42	6.81	21.94	8.53	21.99	23.95	11.82
Naphthalene 1-methyl-	0.00	3.26	2.31	1.54	119.03	107.22	91.84	0.00
Pentadecane	0.73	2.18	2.27	1.59	7.43	3.02	2.85	16.93
1-Penten-3-one	0.00	0.00	0.00	0.00	0.72	0.00	1.34	0.00
2-Butanone	1.54	0.85	0.00	0.00	5.93	0.00	1.58	0.00
2-Nonanone	1.53	0.00	0.00	12.48	6.92	10.25	0.00	2.19
2-Undecanone	0.00	0.00	0.00	0.00	6.94	4.93	0.00	0.00
Acetaldehyde	0.00	0.00	0.00	0.00	1.88	0.93	1.03	0.00

Table 4: Correlation analysis between detection results of electronic nose and volatile constituent testing results

Item	Number of electronic nose					
	1	2	3	4	5	6
Correlation factor	-0.753	0.682	-0.954	0.653	-0.896	-0.953
Probability value	0.135	0.328	0.008	0.175	0.001	0.005

constantly with prolong of time. The output of number 4 sensor increases constantly with prolong of time. The output of number 5 sensor decreases constantly with prolong of time and the decreasing trend is obvious. The output of number 6 sensor has the same changing rules with number 5 sensor.

Changes of every sensor output signal can reflect the odor sensitive degree of every sensor, concludes whole information obtained from detection of electronic nose. With decreasing of freshness of river crabs, the volatile constituent emitted by river crab changes accordingly, the output signal of every sensor of electronic nose system can reflect the changes of odor. The strength of output signal for five sensors with regular changes improve relative to fresh of river crabs.

The volatile constituents of body meat, clamp meat, foot meat and sexual gland of river crab are detected and the corresponding testing results are shown in Table 3.

Hydrocarbon and alcohol compounds are main volatile substances of rive crab. The hydrocarbon material main comes from lipid degradation products, lipid oxidation of alkyl radicals and decomposition process of carotenoid, this kind of substance has high threshold, which has no contribution for the odor of river crab, however aromatic hydrocarbons with benzene ring has low threshold, which can affect the odor of river crabs. Alcohol compound generates from decomposition of two stage hydrogen peroxide of aliphatic acid, effect of lipid oxidase to aliphatic acid, oxo-compound reduction. Generally, alcohol compound has high threshold, which has little contribution to odor of river crab. The unsaturated enol form structure has low threshold, which may has big contribution to odor of river crabs. The content of alcohol compound is relative high, which is affected by water environment.

**Comparing analysis between detection results of electronic nose and volatile constituent testing results:** In order to detect the correctness of freshness

of river crabs obtained from electronic nose, the correlation analysis of output signal of electronic nose and the volatile constituent testing results is carried out and the results are shown in Table 4.

From Table 4, the output of number 3, 5, 6 sensors shows the negative correlation with volatile constituent testing value on level 0.01, the number 1, 4 sensors have a certain correlation, the number 2 sensor has poor correlation. Results show that the number 3, 5, 6 sensors can be used to detect the freshness of river crabs effectively.

## CONCLUSION

The electronic nose can be used to detect the freshness of shellfish effectively and the data collected is stable and has good sensitive degree, the odor of river crabs are used as example, the corresponding tests are carried out and the volatile constituent of river crabs are obtained and correlation analysis is carried out, results show that the electronic nose is an effective method for detecting the shellfish.

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