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Sensor-array-based evaluation and grading of beef taste quality

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ABSTRACT

A sensor array composed of ion electrodes including 2 glass electrodes, 3 liquid-membrane electrodes and 7 insoluble salt electrodes was built. Before detection, the working electrodes were activated as required in activate fluids, and the stability states of sensors were analyzed in deionized water. Beef samples were evaluated after all working electrodes stabilized. The response signals from the samples were recorded by an electrochemical workstation and used as the evaluation results. A beef taste sensory evaluation criterion was built and used into sensory evaluation of beef samples. The samples were scored with quality grades according to this criterion, and the results were compared with the results of the sensor array in evaluation of beef broth samples. The evaluation results were processed by principal component analysis and used to build a beef taste quality evaluation model based on artificial neural networks. Tests show this model has an accuracy of 90% in classification of beef taste quality grades.

1. Introduction

As a rich source of protein and other nutrients, beef products are both nutritious and delicious. Thus it comes as no surprise that beef protein is in high demand as an ingredient and as a whole meat product by the world's most discerning consumers. In the process of purchase, the major factor that decides the market price and purchase intention is beef quality (Banović, Grunert, Barreira, & Fontes, 2009). Flavor, juiciness and tenderness are the key factors deciding meat quality and highly influence the consumers' decision-making on repeated purchase (Hocquette et al., 2012; Neely et al., 1998). Various methods including shear force measurement, near infrared spectral analysis, and computer image processing techniques have been successively applied to beef quality evaluation (Konda Naganathan et al., 2015; Van Wezemael, De Smet, Ueland, & Verbeke, 2014).

Beef flavor is a combination of taste and odor. Odor is generally sensed by the nose and contains many complex volatile compounds, such as aldehydes, sulfur- containing compounds, ketones, and heterocyclic compounds (Cerny & Grosch, 1992; Farmer & Patterson, 1991; Mottram, 1991, 1998). On the contrary, taste is generally detected by the tongue as sweet, sour, salty, bitter or other sensations. So far, much research is focused on the odor of beef, but rarely on taste quality.

The traditional method to detect the beef taste quality is sensory evaluation. However, organizing and operating a sensory evaluation program is very complicated and the results of sensory evaluation may be affected by physiological and psychological factors (Stone & Sidel, 2004). So far, the sensor array is widely applied in food detection, such as classification of teas from different types or habitations (He et al., 2009), juice level evaluation of non-alcoholic beverages (Peres, Dias, Barcelos, Sá Morais, & Machado, 2009); identification of goat milk adulteration with bovine milk (Dias et al., 2009) and identification of honey (Tiwari, Tudu, Bandyopadhyay, & Chatterjee, 2013). According to the principle of Beidler on taste, the taste will emerge in the brain when taste compounds stimulate the taste receptor and achieve a balance of thermodynamic equilibrium (Liu, Sun, & Xie, 2012). The different soluble taste compounds will generate the change of the pulse number because of the form of removing charge of the different taste compounds on the taste receptors, and the differences of time to stimulate the taste nerve fibers of removing charge, which generates the human taste in the brain. Similarly, different working electrodes with different compositions and structural mechanisms will get different response signals from samples. These signals cover absorption differences of different anions and cations for charge, which is consistent with the principle of Beidler on taste.

This paper used the sensor array to simulate the human's taste receptor to collect the different signals from samples to detect the beef taste quality, and construct a mathematical model that can be used to grade on beef taste quality and implement the prediction of unknown samples.

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Table 1
Sensory evaluation table of beef taste quality[a].

Item	Scoring criterion	Score[b]					
		Grade 1	Grade 2	Grade 3	Grade 4	Grade 5	Total
Fresh meaty aroma	Strong and intense feeling of freshness, beef-specific freshness	33–40	25–32	17–24	9–16	1–8	
Salty taste	Slightly salty taste and freshness, without other irritating odor	17–20	13–16	9–12	5–8	1–4	
Sour and sweet taste	Beef-specific slight sweet taste, without irritating sour or stale taste	9–10	7–8	5–6	3–4	1–2	
Initial impression	Tenderness, delicious, moderate taste	25–30	19–24	13–18	7–12	1–6	

[a] Base on Criterion for Sensory Evaluation of Meat and Meat Products (GB/T22210-22210).
[b] Samples were scored and divided into grade 1, grade 2, grade 3, grade 4, grade 5 by panellists. For example, for item "freshness", "grade 1" is scored between 33 and 40, "grade 2" is scored between 25 and 32 and so on.

2. Materials and methods

2.1. Sample preparation

All the beef samples selected for inclusion in the experiment were Longissimus thoracis (Changchun Haoyue Group Co., Jilin Province, China) which were selected from 30-to 36-month-old oxen (weight 400–550 kg) and fattened for >6 months. After electrical stimulation, the carcasses were chilled at 4 °C for 24 h, then divided, weighted, and transported to the laboratory with vacuum packing at 4 °C. The steaks were cut into cubes ($10 \times 10 \times 5$ mm^3) after the intermuscular fat and connective tissue were removed. Samples (500 g each) were sealed in plastic bags individually and then heated in a 75–80 °C water bath. After the internal temperature in the beef reached 70 °C, the samples were heated for another 15 min (Wang et al., 2015). After that, two cubes ($10 \times 10 \times 5$ mm^3 cooked steaks) were selected to be used for sensory evaluation, and the meat juice which was expelled from the meat structure during cooking, was extruded out from the remaining pieces, filtered by double medical absorbent gauze, and left to cool down to room temperature (20 °C). Approximately 150 ml filtrate from each 500 g sample was collected in a 250 ml graded cylinder and the filtrates were numbered from 1 to 80. 80 samples came from 80 different cattle and each sample was tested in triplicate.

2.2. Sensory evaluation of beef taste quality

Based on a screening test, ten panellists (7 females and 3 males, aged 20-to 25-year-old) were selected from graduate students at the Department of Food Science and Engineering at Jilin University, China to participate in the sensory evaluation (Phat, Moon, & Lee, 2016). According to Criterion for Sensory Evaluation of Meat and Meat Products (GB/T22210-22210) and expert opinions, our scoring criterion covered four aspects of beef taste: fresh meaty aroma, salty taste, sour and sweet taste, and initial impression, and four weights were set: 0.4, 0.2, 0.1, 0.3. The specific criterion is showed in Table 1. All participants were familiar with the specific criterion and had previous experience with sensory evaluation. Each panelist was arranged in a separated room and provided with two cubes ($10 \times 10 \times 5$ mm^3 cooked steaks). Each sample was evaluated in triplicate. The ten panellists were qualified with clean teeth, good health, strong verbal ability, punctuality to attendance, objective attitude to samples, and without thirst or hunger during the evaluations (Wang et al., 2015).

Table 2
Types of sensors and activation parameters[a].

Sensor number	Response ion	Activate fluid[b]	Activation concentration (mol/L)	Activating time (h)
A	Na^+, Ag^+, H^+, K^+, NH_4^+	NaCl	1×10^{-4}	8
B	H^+	H_2O	–	2
C	Ca^{2+}	$CaCl_2$	1×10^{-3}	6
D	K^+	KCl	1×10^{-3}	2
E	NO_3^-	$NaNO_3$	1×10^{-3}	6
F	I^-, CN^-, S^{2-}	KI	1×10^{-3}	12
G	F^-	H_2O	–	6
H	Cl^-, Br^-, S^{2-}, I^-, NH_4^+, CN^+	KCl	1×10^{-3}	2
I	Pb^{2+}, Hg^{2+}, Ag^+, Cu^{2+}	$Pb(NO_3)_2$	1×10^{-3}	8
G	Cu^{2+}, S^{2-}, Fe^{3+}, Pb^{2+}	$CuSO_4$	1×10^{-3}	6
K	Br^-	KBr	1×10^{-3}	2
L	Ag^+, S^{2-}	$AgNO_3$	1×10^{-3}	2

[a] All information is come from production instruction brand of Leici from Shanghai Instrument Scientific Instrument Co., Ltd.
[b] The solvent of all activate fluids are deionized water.

2.3. Examination based on sensor array

2.3.1. Construction of sensor array

The taste sensor array has 12 working electrodes and 1 reference electrode. The reference electrode, a saturated calomel electrode, provides standard potential during the evaluations. The 12 working electrodes in this paper were divided by structures and working principles into 2 glass electrodes, 7 insoluble salt electrodes, and 3 liquid-membrane electrodes (Yang & Yuzo, 2000; Liu, 2000; Yin, 1973). And the 12 working electrodes were numbered from A to L.

2.3.2. Activation of sensors

The sensitive membranes on the working electrodes are slightly different in composition and structural mechanism, and thus the electrodes have different response ions. Under normal conditions, sensors are reserved in dry conditions and can work only after activation. Thus, the working electrodes should be activated before use. Table 2 shows the numbers of these sensor electrodes, the response ions of their sensitive membranes, the activation fluid, and the concentration and activated time of the activation solution (Liu et al., 2012). After activation, the working electrodes, during continuous work time, should be stored in relevant activation fluid, so as to protect the electrodes and prolong their service life.

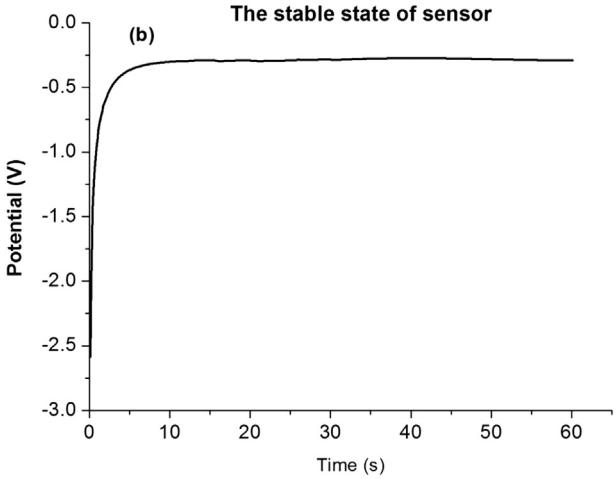

Fig. 1. The stable state of sensor.