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Discrimination and characterization of different intensities of goaty flavor in goat milk by means of an electronic nose

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ABSTRACT

An electronic nose based on metal oxide sensors was used to measure goaty flavor in goat milk samples. To study the relationships between electronic nose data, sensory data, and levels of free fatty acids (FFA), multivariate partial least square regression (PLS) was carried out. The electronic nose system evaluation correlated well with sensory evaluation. The coefficients of determination (R^2) of the PLS models reached 90.0%. The electronic nose, combined with principal component analysis and linear discriminant analysis, can discern among goat milk samples with different goaty flavor intensities. In addition, Fisher discriminant analysis and back-propagation neural network were carried out to evaluate goaty flavor intensity, and the prediction accuracies were 98.2 and 100.0%, respectively. The electronic nose is a potentially useful tool to evaluate goaty flavor intensity in goat milk samples.

Key words: goaty flavor, goat milk, electronic nose, sensory analysis, multivariate data analysis

INTRODUCTION

Goat milk is a valuable food product and an excellent raw material from which products of highly nutritive value are made. There is increasing research interest in goat milk due to inherent species-specific biochemical properties that contribute to its nutritional quality (Raynal-Ljutovac et al., 2008; Strzałkowska et al., 2012; Jirillo and Magrone, 2014). However, the flavor of goat milk is different from that of cow milk, and the goaty flavor may prove unacceptable to some consumers, which limits market opportunities for goat milk (Haenlein, 2004). The development of goaty flavor is due to straight-chain FFA, mainly C6:0 to C9:0 (Skjevdal, 1979; Chilliard et al., 2003; Eknæs et al., 2006), and some branched-chain C9:0 and C10:0 FFA (Kim Ha and Lindsay, 1993). Goaty flavor is influenced by factors such as goat breed, feeding model, and industrial process (Skjevdal, 1979; Morgan and Gaborit, 2001; Chilliard et al., 2003).

Flavor is a major attribute that influences the selection and consumption of foods. The analysis of characteristic food flavors has commonly been carried out by human assessment and instrumental analysis. For sensory analysis, taste and aroma are assessed by trained sensory panels. The main issues of this method are measurement standardization, stability, and reproducibility. In addition, the high cost of training people and the use of sensory panels limit the applications of this technique (He et al., 2009; Santos et al., 2010; Russo et al., 2013). Instrumental techniques such as GC, GC-MS, and HPLC have high operating costs and are time consuming (Cozzolino et al., 2005; Qin et al., 2013; Tian et al., 2013). Furthermore, instrumental methods usually separate the aroma into its individual components. This situation in the analysis of food flavors indicates the need for a more objective approach.

One approach for sensory analysis is the use of an electronic nose. The device consists of an array of chemical gas sensors with a broad and partly overlapping selectivity for the measurement of volatile compounds within the headspace over a sample combined with computerized multivariate statistical data processing tools (Gardner and Bartlett, 1994). In principle, both the electronic nose and the human nose operate by simultaneously sensing a large number of components, giving rise to a specific response pattern (Haugen and Kvaal, 1998). The electronic nose assesses the mixture of volatiles released from a sample and has the advantage of being nondestructive and portable, with low cost and good reliability (Echeverría et al., 2004; Zhang et al., 2007).

The electronic nose has been used successfully to evaluate dairy products for aging of milk, (Capone et al., 2000b, 2001), shelf-life prediction (Labreche et al., 2005), classification of bacteria cultures in milk (Magan et al., 2001; Ali et al., 2003), classification by geographical origin of a dairy product (Pillonel et al., 2003), and classification of cheese (Jou and Harper, 1998; Capone et al., 2000a). Meanwhile, the electronic nose has been applied successfully to evaluate odors in environmental contamination cases (Persaud et al., 1996; Stuetz et

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Table 1. Sensors used and their main applications in the electronic nose device (PEN 3 Portable Electronic Nose, Airsense Analytics GmbH, Schwerin, Germany)

Sensor number in array	Sensor name	General description	Reference
S1	W1C	Aromatic compounds	Toluene, 10 mg/kg
S2	W5S	Reacts to nitrogen oxide	NO_2, 1 mg/kg
S3	W3C	Ammonia, aromatic compounds	Benzene, 10 mg/kg
S4	W6S	Mainly hydrogen	H_2, 0.1 mg/kg
S5	W5C	Alkanes, aromatic compounds, less polar compounds	Propane, 1 mg/kg
S6	W1S	Methane	CH_3, 100 mg/kg
S7	W1W	Reacts to sulfur compounds, otherwise sensitive to many terpenes and sulfur organic compounds, which are important for smell, limonene, pyrazine	H_2S, 1 mg/kg
S8	W2S	Alcohol, partially aromatic compounds	CO, 100 mg/kg
S9	W2W	Aromatics compounds, sulfur organic compounds	H_2S, 1 mg/kg
S10	W3S	Reacts to high concentrations, selective methane	CH_3, 100 mg/kg

al., 1999; Sohn et al., 2003; Nake et al., 2005) and to quantify off-flavors in meat foods (Annor-Frempong et al., 1998; Grigioni et al., 2000; Vestergaard et al., 2006; Tikk et al., 2008; Song et al., 2013). Nevertheless, a few studies have discriminated the goaty flavor intensity of goat milk by electronic nose coupled with multivariate data analysis. Therefore, the aim of this work was to investigate the potential of the electronic nose as a useful tool to discriminate the intensity of goaty flavor in goat milk.

MATERIALS AND METHODS

Sample Preparation

Raw goat milk was obtained from the Xinong Saanen dairy goat seed farm in Yangling (Shaanxi Province, China). We have found that the addition of FFA to skim milk does not contribute to typical goaty flavor. Thus, samples with different goaty flavor intensities were prepared by adding different percentages of goat milk lipids to skim goat milk. The preparation process was as follows: (1) goat milk lipids were obtained from raw goat milk by centrifugation at 2,795 × g at room temperature for 10 min; (2) the lipids were added back to the skim milk at different concentrations to obtain goat milk samples with different goaty flavor intensities (6 groups of goat milk samples with varying goaty flavor intensities were prepared); and (3) the reconstituted milks were homogenized and sterilized (65°C, 30 min). The samples were stored at −40°C in sealed sterile glass bottles for further analysis.

Bronopol was added (final concentration: 400 mg/L) before analysis to prevent microbial growth (Eriksson et al., 2005). All samples were assessed by sensory panel, FFA analysis, and the electronic nose to generate data.

Electronic Nose Analysis

The electronic nose device (PEN 3 Portable Electronic Nose, Airsense Analytics GmbH, Schwerin, Germany) contains a detector unit with an array of 10 different metal oxide sensors. The main applications of the 10 sensors and a schematic diagram of the electronic nose are shown in Table 1 and Figure 1 (Airsense Analytics GmbH, 2008).

Six groups of samples (which were created by the method described in sample preparation section) were assessed with different goaty flavor intensities, each group was divided into 40 (10.0 mL) samples, and each sample was evaluated in duplicate. To perform the electronic nose assay, 10.0 mL of the sample was put into a 50-mL glass vial with a Teflon/silicon septum in the screw cap. The sample was equilibrated for 30 min at 25°C to allow for the development of headspace before electronic analysis. Thereafter, one Luer-lock needle connected to a Teflon tubing (3 mm) was used to perforate the seal of the vial and to absorb the air accumulated inside it with a flow rate of 400 mL/min during the measurement. The sensor response was defined as the ratio of conductance G_0/G or G/G_0 (where G_0 and G = conductance of the sensor before and after exposure to the gas samples, respectively). Data were recorded every second by a computer, and the experiment lasted for 60 s (long enough for the sensors to stabilize). Recovery time for the sensors was 240 s (flushing with reference air). The set of signals of the sensors during measurement of a sample formed patterns, which were analyzed in random order. The response values were stable and reproducible in repeated measurements. The electronic nose was used at 25°C ± 2 during all experiments.

Sensory Evaluation

The sensory analysis was carried out to detect the intensity of goaty flavor in the samples using the quan-